HOOMD-blue Documentation

Release 2.9.3

The Regents of the University of Michigan

Oct 28, 2020

Getting started

HOOMD-blue is a general purpose particle simulation toolkit. It performs hard particle Monte Carlo simulations of a variety of shape classes, and molecular dynamics simulations of particles with a range of pair, bond, angle, and other potentials. **HOOMD-blue** runs fast on NVIDIA GPUs, and can scale across thousands of nodes. For more information, see the HOOMD-blue website.

Resources

- GitHub Repository: Source code and issue tracker.
- *Installation Guide*: Instructions for installing and compiling **HOOMD-blue**.
- hoomd-users Google Group: Ask questions to the **HOOMD-blue** community.
- HOOMD-blue Tutorial: Beginner's guide, code examples, and sample scripts.
- HOOMD-blue website: Additional information, benchmarks, and publications.

Job scripts

HOOMD-blue job scripts are Python scripts. You can control system initialization, run protocols, analyze simulation data, or develop complex workflows all with Python code in your job.

Here is a simple example:

```python
import hoomd
from hoomd import md
hoomd.context.initialize()

# Create a 10x10x10 simple cubic lattice of particles with type name A
hoomd.init.create_lattice(unitcell=hoomd.lattice.sc(a=2.0, type_name='A'), n=10)

# Specify Lennard-Jones interactions between particle pairs
nl = md.nlist.cell()
lj = md.pair.lj(r_cut=3.0, nlist=nl)
lj.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)

# Integrate at constant temperature
md.integrate.mode_standard(dt=0.005)
hoomd.md.integrate.langevin(group=hoomd.group.all(), kT=1.2, seed=4)

# Run for 10,000 time steps
hoomd.run(10e3)
```

Save this script as `lj.py` and run it with `python lj.py` (or `singularity exec software.simg python3 lj.py` if using Singularity containers).

2.1 Installing binaries

HOOMD-blue binaries are available in the glotzerlab-software Docker/Singularity images and for Linux and macOS via the hoomd package on conda-forge.

2.1.1 Singularity / Docker images

See the glotzerlab-software documentation for container usage information and cluster specific instructions.

2.1.2 Conda package

HOOMD-blue is available on conda-forge. To install, first download and install miniconda. Then install `hoomd` from the `conda-forge` channel:

```
$ conda install -c conda-forge hoomd
```

2.2 Compiling from source

2.2.1 Prerequisites

Compiling **HOOMD-blue** requires a number of software packages and libraries.

- Required:
    - Python >= 3.5
    - NumPy >= 1.7
    - CMake >= 2.8.10.1
    - C++11 capable compiler (tested with `gcc` 4.8, 5.4, 5.5, 6.4, 7, 8, 9, `clang` 5, 6, 7, 8)
- Optional:
    - Git >= 1.7.0
    - NVIDIA CUDA Toolkit >= 9.0
    - Intel Threading Building Blocks >= 4.3
    - MPI (tested with OpenMPI, MVAPICH)
    - LLVM >= 5.0
- Useful developer tools
    - Doxygen >= 1.8.5

Software prerequisites on clusters

Most cluster administrators provide versions of Git, Python, NumPy, MPI, and CUDA as modules. You will need to consult the documentation or ask the system administrators for instructions to load the appropriate modules.

Prerequisites on workstations

On a workstation, use the system's package manager to install all of the prerequisites. Some Linux distributions separate `-dev` and normal packages, you need the development packages to build **HOOMD-blue**.

On macOS systems, you can use MacPorts or Homebrew to install prerequisites. You will need to install Xcode (free) through the Mac App Store to supply the C++ compiler.

Installing prerequisites with conda

> **Caution:** *Using conda to provide build prerequisites is not recommended.* Conda is very useful as a delivery platform for stable binaries, but there are many pitfalls when using it to provide development prerequisites.

Despite this warning, many users wish to use conda to provide those development prerequisites. There are a few additional steps required to build **HOOMD-blue** against a conda software stack, as you must ensure that all libraries (MPI, Python, etc.) are linked from the conda environment. First, install miniconda. Then, uninstall the `hoomd` package if it is installed, and install the prerequisite libraries and tools. On Linux or macOS, run:

```
conda install -c conda-forge sphinx git openmpi numpy cmake
```

After configuring, check the CMake configuration to ensure that it finds Python, NumPy, and MPI from within the conda installation. If any of these library or include files reference directories other than your conda environment, you will need to set the appropriate setting for `PYTHON_EXECUTABLE`, etc.

> **Warning:** On macOS, installing gcc with conda is not sufficient to build **HOOMD-blue**. Update Xcode to the latest version using the Mac App Store.

2.2.2 Compile HOOMD-blue

Download source releases directly from the web: https://glotzerlab.engin.umich.edu/Downloads/hoomd

```
$ curl -O https://glotzerlab.engin.umich.edu/Downloads/hoomd/hoomd-v2.9.3.tar.gz
```

Or, clone using Git:

```
$ git clone --recursive https://github.com/glotzerlab/hoomd-blue
```

HOOMD-blue uses Git submodules. Either clone with the `--recursive` option, or execute `git submodule update --init` to fetch the submodules.

> **Note:** When using a shared (read-only) Python installation, such as a module on a cluster, create a virtual environment where you can install **HOOMD-blue**:
>
> ```
> python3 -m venv /path/to/new/virtual/environment --system-site-packages
> ```
>
> Activate the environment before configuring and before executing **HOOMD-blue** scripts:
>
> ```
> source /path/to/new/virtual/environment/bin/activate
> ```

Configure:

```
$ cd hoomd-blue
$ mkdir build
$ cd build
$ cmake ../ -DCMAKE_INSTALL_PREFIX=`python3 -c "import site; print(site.
→getsitepackages()[0])"`
```

By default, **HOOMD-blue** configures a *Release* optimized build type for a generic CPU architecture and with no optional libraries. Specify:

```
-DCMAKE_CXX_FLAGS=-march=native -DCMAKE_C_FLAGS=-march=native
```

(or the appropriate option for your compiler) to enable optimizations specific to your CPU. Specify `-DENABLE_CUDA=ON` to compile code for the GPU (requires CUDA) and `-DENABLE_MPI=ON` to enable parallel simulations with MPI. Configure a performance optimized build:

```
$ cmake ../ -DCMAKE_INSTALL_PREFIX=`python3 -c "import site; print(site.
→getsitepackages()[0])"` -DCMAKE_CXX_FLAGS=-march=native -DCMAKE_C_FLAGS=-
→march=native -DENABLE_CUDA=ON -DENABLE_MPI=ON
```

See the build options section below for a full list of options.

Compile:

```
$ make -j4
```

Test your build (requires a GPU to pass if **HOOMD-blue** was built with CUDA support):

```
$ ctest
```

Attention: On a cluster, run `ctest` within a job on a GPU compute node.

To install **HOOMD-blue** into your Python environment, run:

```
make install
```

Build options

Here is a list of all the build options that can be changed by CMake. To change these settings, navigate to the `build` directory and run:

```
$ ccmake .
```

After changing an option, press `c` to configure, then press `g` to generate. The `Makefile` is now updated with the newly selected options. You can also set these parameters on the command line with `cmake`:

```
cmake $HOME/devel/hoomd -DENABLE_CUDA=ON
```

Options that specify library versions only take effect on a clean invocation of CMake. To set these options, first remove `CMakeCache.txt` and then run CMake and specify these options on the command line:

- `PYTHON_EXECUTABLE` - Specify which `python` to build against. Example: `/usr/bin/python3`.
    - Default: `python3.X` detected on `$PATH`
- `CUDA_TOOLKIT_ROOT_DIR` - Specify the root direction of the CUDA installation.
    - Default: location of `nvcc` detected on `$PATH`
- `MPI_HOME` (env var) - Specify the location where MPI is installed.
    - Default: location of `mpicc` detected on the `$PATH`

Other option changes take effect at any time. These can be set from within `ccmake` or on the command line:

- `CMAKE_INSTALL_PREFIX` - Directory to install the `hoomd` Python module. All files will be under `${CMAKE_INSTALL_PREFIX}/hoomd`.

- `BUILD_CGCMM` - Enables building the `hoomd.cgcmm` module.

- `BUILD_DEPRECATED` - Enables building the `hoomd.deprecated` module.

- `BUILD_HPMC` - Enables building the `hoomd.hpmc` module.

- `BUILD_MD` - Enables building the `hoomd.md` module.

- `BUILD_METAL` - Enables building the `hoomd.metal` module.

- `BUILD_TESTING` - Enables the compilation of unit tests.

- `CMAKE_BUILD_TYPE` - Sets the build type (case sensitive) Options:

  - `Debug` - Compiles debug information into the library and executables. Enables asserts to check for programming mistakes. HOOMD-blue will run slow when compiled in Debug mode, but problems are easier to identify.

  - `RelWithDebInfo` - Compiles with optimizations and debug symbols. Useful for profiling benchmarks.

  - `Release` - (default) All compiler optimizations are enabled and asserts are removed. Recommended for production builds: required for any benchmarking.

- `ENABLE_CUDA` - Enable compiling of the GPU accelerated computations. Default: `OFF`.

- `ENABLE_DOXYGEN` - Enables the generation of developer documentation Default: `OFF`.

- `SINGLE_PRECISION` - Controls precision. Default: `OFF`.

  - When set to `ON`, all calculations are performed in single precision.

  - When set to `OFF`, all calculations are performed in double precision.

- `ENABLE_HPMC_MIXED_PRECISION` - Controls mixed precision in the hpmc component. When on, single precision is forced in expensive shape overlap checks.

- `ENABLE_MPI` - Enable multi-processor/GPU simulations using MPI.

  - When set to `ON`, multi-processor/multi-GPU simulations are supported.

  - When set to `OFF` (the default), always run in single-processor/single-GPU mode.

- `ENABLE_MPI_CUDA` - Enable CUDA-aware MPI library support.

  - Requires a MPI library with CUDA support to be installed.

  - When set to `ON` (default if a CUDA-aware MPI library is detected), **HOOMD-blue** will make use of the capability of the MPI library to accelerate CUDA-buffer transfers.

  - When set to `OFF`, standard MPI calls will be used.

  - *Warning:* Manually setting this feature to `ON` when the MPI library does not support CUDA may cause **HOOMD-blue** to crash.

- `ENABLE_TBB` - Enable support for Intel's Threading Building Blocks (TBB).

  - Requires TBB to be installed.

  - When set to `ON`, HOOMD will use TBB to speed up calculations in some classes on multiple CPU cores.

- `UPDATE_SUBMODULES` - When `ON` (the default), CMake will execute `git submodule update --init` whenever it runs.

- `COPY_HEADERS` - When `ON` (`OFF` is default), copy header files into the build directory to make it a valid plugin build source.

These options control CUDA compilation:

- `CUDA_ARCH_LIST` - A semicolon-separated list of GPU architectures to compile in.

- `NVCC_FLAGS` - Allows additional flags to be passed to `nvcc`.

2.3 Change Log

2.3.1 v2.x

v2.9.3 (2020-08-05)

Bug fixes

- Fix a compile error with CUDA 11

v2.9.2 (2020-06-26)

Bug fixes

- Fix a bug where repeatedly using objects with `period=None` would use significant amounts of memory.
- Support CUDA 11.
- Reccomend citing the 2020 Computational Materials Science paper 10.1016/j.commatsci.2019.109363.

v2.9.1 (2020-05-28)

Bug fixes

- Fixed a minor bug where the variable period timestep would be off by one when the timestep got sufficiently large.
- Updated collections API to hide `DeprecationWarning`.
- Fix scaling of cutoff in Gay-Berne potential to scale the current maximum distance based on the orientations of the particles, ensuring ellipsoidal energy isocontours.
- Misc documentation fixes.

v2.9.0 (2020-02-03)

New features

- General
  - Read and write GSD 2.0 files.
    * HOOMD >=2.9 can read and write GSD files created by HOOMD <= 2.8 or GSD 1.x. HOOMD <= 2.8 cannot read GSD files created by HOOMD >=2.9 or GSD >= 2.0.
    * OVITO >=3.0.0-dev652 reads GSD 2.0 files.
    * A future release of the `gsd-vmd` plugin will read GSD 2.0 files.
- HPMC
  - User-settable parameters in `jit.patch`.
  - 2D system support in muVT updater.
  - Fix bug in HPMC where overlaps were not checked after adding new particle types.

- MD

    - The performance of `nlist.tree` has been drastically improved for a variety of systems.

v2.8.2 (2019-12-20)

Bug fixes

- Fix randomization of barostat and thermostat velocities with `randomize_velocities()` for non-unit temperatures.

- Improve MPCD documentation.

- Fix uninitialized memory in some locations which could have led to unreproducible results with HPMC in MPI, in particular with `ALWAYS_USE_MANAGED_MEMORY=ON`.

- Fix calculation of cell widths in HPMC (GPU) and `nlist.cell()` with MPI.

- Fix potential memory-management issue in MPI for migrating MPCD particles and cell energy.

- Fix bug where exclusions were sometimes ignored when `charge.pppm()` is the only potential using the neighbor list.

- Fix bug where exclusions were not accounted for properly in the `pppm_energy` log quantity.

- Fix a bug where MD simulations with MPI start off without a ghost layer, leading to crashes or dangerous builds shortly after `run()`.

- `hpmc.update.remove_drift` now communicates particle positions after updating them.

v2.8.1 (2019-11-26)

Bug fixes

- Fix a rare divide-by-zero in the `collide.srd` thermostat.

- Improve performance of first frame written by `dump.gsd`.

- Support Python 3.8.

- Fix an error triggering migration of embedded particles for MPCD with MPI + GPU configurations.

v2.8.0 (2019-10-30)

New Features

- MD:

    - `hoomd.md.dihedral.harmonic` now accepts phase offsets, `phi_0`, for CHARMM-style periodic dihedrals.

    - Enable per-type shape information for anisotropic pair potentials that complements the existing pair parameters struct.

- HPMC:

    - Enable the use of an array with adjustable parameters within the user defined pair potential.

    - Add muVT updater for 2D systems.

Bug fixes

- Fix missing header in external plugin builds.

- Enable `couple='none'` option to `md.integrate.npt()` when randomly initializing velocities.

- Documentation improvements.

- Skip gsd shape unit test when required modules are not compiled.

- Fix default particle properties when new particles are added to the system (e.g., via the muVT updater).

- Fix `charge.pppm()` execution on multiple GPUs.

- Enable `with SimulationContext() as c`.

- Fix a bug for `mpcd.collide.at` with embedded particles, which may have given incorrect results or simulation crashes.

v2.7.0 (2019-10-01)

New features

- General:

  - Allow components to use `Logger` at the C++ level.

  - Drop support for python 2.7.

  - User-defined log quantities in `dump.gsd`.

  - Add `hoomd.dump.gsd.dump_shape` to save particle shape information in GSD files.

- HPMC:

  - Add `get_type_shapes` to `ellipsoid`.

- MPCD:

  - `mpcd.stream.slit_pore` allows for simulations through parallel-plate (lamellar) pores.

  - `mpcd.integrate` supports integration of MD (solute) particles with bounce-back rules in MPCD streaming geometries.

Bug fixes

- `hoomd.hdf5.log.query` works with matrix quantities.

- `test_group_rigid.py` is run out of the `md` module.

- Fix a bug in `md.integrate.langevin()` and `md.integrate.bd()` where on the GPU the value of `gamma` would be ignored.

- Fix documentation about interoperability between `md.mode_minimize_fire()` and MPI.

- Clarify `dump.gsd` documentation.

- Improve documentation of `lattice_field` and `frenkel_ladd_energy` classes.

- Clarify singularity image download documentation.

- Correctly document the functional form of the Buckingham pair potential.

- Correct typos in HPMC example snippets.

- Support compilation in WSL.

v2.6.0 (2019-05-28)

New features

- General:

    - Enable `HPMC` plugins.

    - Fix plug-in builds when `ENABLE_TBB` or `ALWAYS_USE_MANAGED_MEMORY` CMake parameters are set.

    - Remove support for compute 3.0 GPUs.

    - Report detailed CUDA errors on initialization.

    - Document upcoming feature removals and API changes.

- MD:

    - Exclude neighbors that belong to the same floppy molecule.

    - Add fourier potential.

- HPMC:

    - New shape class: `hpmc.integrate.faceted_ellipsoid_union()`.

    - Store the *orientable* shape state.

- MPCD:

    - `mpcd.stream.slit` allows for simulations in parallel-plate channels. Users can implement other geometries as a plugin.

    - MPCD supports virtual particle filling in bounded geometries through the `set_filler` method of `mpcd.stream` classes.

    - `mpcd.stream` includes an external `mpcd.force` acting on the MPCD particles. A block force, a constant force, and a sine force are implemented.

Bug fixes

- Fix compile errors with LLVM 8 and `-DBUILD_JIT=on`.

- Allow simulations with 0 bonds to specify bond potentials.

- Fix a problem where HOOMD could not be imported in `mpi4py` jobs.

- Validate snapshot input in `restore_snapshot`.

- Fix a bug where rigid body energy and pressure deviated on the first time step after `run()`.

- Fix a bug which could lead to invalid MPI simulations with `nlist.cell()` and `nlist.stencil()`.

C++ API changes

- Refactor handling of `MPI_Comm` inside library

- Use `random123` for random number generation

- CMake version 2.8.10.1 is now a minimum requirement for compiling from source

v2.5.2 (2019-04-30)

Bug fixes

- Support LLVM 9 in `jit`

- Fix error when importing `jit` before `hpmc`

- HPMC integrators raise errors when `restore_state=True` and state information is missing

- Send messages to replaced `sys.stdout` and `sys.stderr` streams

- Add `hpmc.update.clusters` to documentation index

- Fix a bug in the MPCD Gaussian random number generator that could lead to NaN values

- Fix issue where an initially cubic box can become non-cubic with `integrate.npt()` and `randomize_velocities()`

- Fix illegal memory access in NeighborListGPU with `-DALWAYS_USE_MANAGED_MEMORY=ON` on single GPUs

- Improve `pair.table` performance with multi-GPU execution

- Improve `charge.pppm` performance with multi-GPU execution

- Improve rigid body performance with multi-GPU execution

- Display correct cell list statistics with the `-DALWAYS_USE_MANAGED_MEMORY=ON` compile option

- Fix a sporadic data corruption / bus error issue when data structures are dynamically resized in simulations that use unified memory (multi-GPU, or with -DALWAYS_USE_MANAGED_MEMORY=ON compile time option)

- Improve `integrate.nve` and `integrate.npt` performance with multi-GPU execution

- Improve some angular degrees of freedom integrators with multi-GPU execution

- Improve rigid body pressure calculation performance with multi-GPU execution

v2.5.1 (2019-03-14)

Bug fixes

- fix out-of-range memory access in `hpmc.integrate.convex_polyheron`

- Remove support for clang3.8 and 4.0

- Documentation improvements

- Fix a segfault when using `SLURM_LOCALID`

v2.5.0 (2019-02-05)

New features

- General:

  - Fix BondedGroupData and CommunicatorGPU compile errors in certain build configurations

- MD:

  - Generalize `md.integrate.brownian` and `md.integrate.langevin` to support anisotropic friction coefficients for rotational Brownian motion.

  - Improve NVLINK performance with rigid bodies

  - `randomize_velocities` now chooses random values for the internal integrator thermostat and barostat variables.

  - `get_net_force` returns the net force on a group of particles due to a specific force compute

- HPMC:
    - Fix a bug where external fields were ignored with the HPMC implicit integrator unless a patch potential was also in use.
- JIT:
    - Add `jit.external.user` to specify user-defined external fields in HPMC.
    - Use `-DHOOMD_LLVMJIT_BUILD` now instead of `-DHOOMD_NOPYTHON`

v2.4.2 (2018-12-20)

Bug fixes

- Miscellaneous documentation updates
- Fix compile error with `with -DALWAYS_USE_MANAGED_MEMORY=ON`
- Fix MuellerPlatheFlow, cast input parameter to int to avoid C++ constructor type mismatch
- Improve startup time with multi-GPU simulations
- Correctly assign GPUs to MPI processes on Summit when launching with more than one GPU per resource set
- Optimize multi-GPU performance with NVLINK
- Do not use mapped memory with MPI/GPU anymore
- Fix some cases where a multi-GPU simulation fails with an alignment error
- Eliminate remaining instance of unsafe `__shfl`
- Hide CMake warnings regarding missing CPU math libraries
- Hide CMake warning regarding missing MPI<->CUDA interoperability
- Refactor memory management to fix linker errors with some compilers

C++ API Changes

- May break some plug-ins which rely on `GPUArray` data type being returned from `ParticleData` and other classes (replace by `GlobalArray`)

v2.4.1 (2018-11-27)

Bug fixes

- Install `WarpTools.cuh` for use by plugins
- Fix potential violation of detailed balance with anisotropic particles with `hpmc.update.clusters` in periodic boundary conditions
- Support llvm 7.0

v2.4.0 (2018-11-07)

New features

- General:
    - Misc documentation updates
    - Accept `mpi4py` communicators in `context.initialize`.

- CUDA 10 support and testing

- Sphinx 1.8 support

- Flush message output so that `python -u` is no longer required to obtain output on some batch job systems

- Support multi-GPU execution on dense nodes using CUDA managed memory. Execute with `--gpu=0, 1,..,n-1` command line option to run on the first n GPUs (Pascal and above).

    * Node-local acceleration is implemented for a subset of kernels. Performance improvements may vary.

    * Improvements are only expected with NVLINK hardware. Use MPI when NVLINK is not available.

    * Combine the `--gpu=..` command line option with mpirun to execute on many dense nodes

- Bundle `libgetar` v0.7.0 and remove `sqlite3` dependency

- When building with ENABLE_CUDA=on, CUDA 8.0 is now a minimum requirement

- MD:

    - *no changes*.

- HPMC:

    - Add `convex_spheropolyhedron_union` shape class.

    - Correctly count acceptance rate when maximum particle move is is zero in `hpmc.integrate.*`.

    - Correctly count acceptance rate when maximum box move size is zero in `hpmc.update.boxmc`.

    - Fix a bug that may have led to overlaps between polygon soups with `hpmc.integrate.polyhedron`.

    - Improve performance in sphere trees used in `hpmc.integrate.sphere_union`.

    - Add `test_overlap` method to python API

- API:

    - Allow external callers of HOOMD to set the MPI communicator

    - Removed all custom warp reduction and scan operations. These are now performed by CUB.

    - Separate compilation of pair potentials into multiple files.

    - Removed compute 2.0 workaround implementations. Compute 3.0 is now a hard minimum requirement to run HOOMD.

    - Support and enable compilation for sm70 with CUDA 9 and newer.

- Deprecated:

    - HPMC: The implicit depletant mode `circumsphere` with `ntrial > 0` does not support compute 7.0 (Volta) and newer GPUs and is now disabled by default. To enable this functionality, configure HOOMD with option the `-DENABLE_HPMC_REINSERT=ON`, which will not function properly on compute 7.0 (Volta) and newer GPUs.

    - HPMC: `convex_polyhedron_union` is replaced by `convex_spheropolyhedron_union` (when sweep_radii are 0 for all particles)

v2.3.5 (2018-10-07)

Bug fixes

- Document `--single-mpi` command line option.

- HPMC: Fix a bug where `hpmc.field.lattice_field` did not resize 2D systems properly in combination with `update.box_resize`.

v2.3.4 (2018-07-30)

Bug fixes

- `init.read_gsd` no longer applies the *time_step* override when reading the *restart* file
- HPMC: Add `hpmc_patch_energy` and `hpmc_patch_rcut` loggable quantities to the documentation

v2.3.3 (2018-07-03)

Bug fixes

- Fix `libquickhull.so` not found regression on Mac OS X

v2.3.2 (2018-06-29)

Bug fixes

- Fix a bug where gsd_snapshot would segfault when called without an execution context.
- Compile warning free with gcc8.
- Fix compile error when TBB include files are in non-system directory.
- Fix `libquickhull.so` not found error on additional platforms.
- HOOMD-blue is now available on **conda-forge** and the **docker hub**.
- MPCD: Default value for `kT` parameter is removed for `mpcd.collide.at`. Scripts that are correctly running are not affected by this change.
- MPCD: `mpcd` notifies the user of the appropriate citation.
- MD: Correct force calculation between dipoles and point charge in `pair.dipole`

Deprecated

- The **anaconda** channel **glotzer** will no longer be updated. Use **conda-forge** to upgrade to v2.3.2 and newer versions.

v2.3.1 (2018-05-25)

Bug fixes

- Fix doxygen documentation syntax errors
- Fix libquickhull.so not found error on some platforms
- HPMC: Fix bug that allowed particles to pas through walls
- HPMC: Check spheropolyhedra with 0 vertices against walls correctly
- HPMC: Fix plane wall/spheropolyhedra overlap test
- HPMC: Restore detailed balance in implicit depletant integrator
- HPMC: Correctly choose between volume and lnV moves in `hpmc.update.boxmc`
- HPMC: Fix name of log quantity `hpmc_clusters_pivot_acceptance`

- MD: Fix image list for tree neighbor lists in 2d

v2.3.0 (2018-04-25)

New features

- General:
  - Store `BUILD_*` CMake variables in the hoomd cmake cache for use in external plugins.
  - `init.read_gsd` and `data.gsd_snapshot` now accept negative frame indices to index from the end of the trajectory.
  - Faster reinitialization from snapshots when done frequently.
  - New command line option `--single-mpi` allows non-mpi builds of hoomd to launch within mpirun (i.e. for use with mpi4py managed pools of jobs)
  - For users of the University of Michigan Flux system: A `--mode` option is no longer required to run hoomd.

- MD:
  - Improve performance with `md.constrain.rigid` in multi-GPU simulations.
  - New command `integrator.randomize_velocities()` sets a particle group's linear and angular velocities to random values consistent with a given kinetic temperature.
  - `md.force.constant()` now supports setting the force per particle and inside a callback

- HPMC:
  - Enabled simulations involving spherical walls and convex spheropolyhedral particle shapes.
  - Support patchy energetic interactions between particles (CPU only)
  - New command `hpmc.update.clusters()` supports geometric cluster moves with anisotropic particles and/or depletants and/or patch potentials. Supported move types: pivot and line reflection (geometric), and AB type swap.

- JIT:
  - Add new experimental `jit` module that uses LLVM to compile and execute user provided C++ code at runtime. (CPU only)
  - Add `jit.patch.user`: Compute arbitrary patch energy between particles in HPMC (CPU only)
  - Add `jit.patch.user_union`: Compute arbitrary patch energy between rigid unions of points in HPMC (CPU only)
  - Patch energies operate with implicit depletant and normal HPMC integration modes.
  - `jit.patch.user_union` operates efficiently with additive contributions to the cutoff.

- MPCD:
  - The `mpcd` component adds support for simulating hydrodynamics using the multiparticle collision dynamics method.

Beta feature

- Node local parallelism (optional, build with `ENABLE_TBB=on`):
  - The Intel TBB library is required to enable this feature.

- The command line option `--nthreads` limits the number of threads HOOMD will use. The default is all CPU cores in the system.

- Only the following methods in HOOMD will take advantage of multiple threads:

  * `hpmc.update.clusters()`

  * HPMC integrators with implicit depletants enabled

  * `jit.patch.user_union`

Node local parallelism is still under development. It is not enabled in builds by default and only a few methods utilize multiple threads. In future versions, additional methods in HOOMD may support multiple threads.

To ensure future workflow compatibility as future versions enable threading in more components, explicitly set –nthreads=1.

Bug fixes

- Fixed a problem with periodic boundary conditions and implicit depletants when `depletant_mode=circumsphere`

- Fixed a rare segmentation fault with `hpmc.integrate.*_union()` and `hpmc.integrate.polyhedron`

- `md.force.active` and `md.force.dipole` now record metadata properly.

- Fixed a bug where HPMC restore state did not set ignore flags properly.

- `hpmc_boxmc_ln_volume_acceptance` is now available for logging.

Other changes

- Eigen is now provided as a submodule. Plugins that use Eigen headers need to update include paths.

- HOOMD now builds with pybind 2.2. Minor changes to source and cmake scripts in plugins may be necessary. See the updated example plugin.

- HOOMD now builds without compiler warnings on modern compilers (gcc6, gcc7, clang5, clang6).

- HOOMD now uses pybind11 for numpy arrays instead of `num_util`.

- HOOMD versions v2.3.x will be the last available on the anaconda channel `glotzer`.

v2.2.5 (2018-04-20)

Bug fixes

- Pin cuda compatible version in conda package to resolve `libcu*.so` not found errors in conda installations.

v2.2.4 (2018-03-05)

Bug fixes

- Fix a rare error in `md.nlist.tree` when particles are very close to each other.

- Fix deadlock when `init.read_getar` is given different file names on different ranks.

- Sample from the correct uniform distribution of depletants in a sphere cap with `depletant_mode='overlap_regions'` on the CPU

- Fix a bug where ternary (or higher order) mixtures of small and large particles were not correctly handled with `depletant_mode='overlap_regions'` on the CPU

- Improve acceptance rate in depletant simulations with `depletant_mode='overlap_regions'`

---

v2.2.3 (2018-01-25)

Bug fixes

- Write default values to gsd frames when non-default values are present in frame 0.
- `md.wall.force_shifted_lj` now works.
- Fix a bug in HPMC where `run()` would not start after `restore_state` unless shape parameters were also set from python.
- Fix a bug in HPMC Box MC updater where moves were attempted with zero weight.
- `dump.gsd()` now writes `hpmc` shape state correctly when there are multiple particle types.
- `hpmc.integrate.polyhedron()` now produces correct results on the GPU.
- Fix binary compatibility across python minor versions.

v2.2.2 (2017-12-04)

Bug fixes

- `md.dihedral.table.set_from_file` now works.
- Fix a critical bug where forces in MPI simulations with rigid bodies or anisotropic particles were incorrectly calculated
- Ensure that ghost particles are updated after load balancing.
- `meta.dump_metadata` no longer reports an error when used with `md.constrain.rigid`
- Miscellaneous documentation fixes
- `dump.gsd` can now write GSD files with 0 particles in a frame
- Explicitly report MPI synchronization delays due to load imbalance with `profile=True`
- Correctly compute net torque of rigid bodies with anisotropic constituent particles in MPI execution on multiple ranks
- Fix `PotentialPairDPDThermoGPU.h` for use in external plugins
- Use correct ghost region with `constrain.rigid` in MPI execution on multiple ranks
- `hpmc.update.muvt()` now works with `depletant_mode='overlap_regions'`
- Fix the sampling of configurations with in `hpmc.update.muvt` with depletants
- Fix simulation crash after modifying a snapshot and re-initializing from it
- The pressure in simulations with rigid bodies (`md.constrain.rigid()`) and MPI on multiple ranks is now computed correctly

v2.2.1 (2017-10-04)

Bug fixes

- Add special pair headers to install target
- Fix a bug where `hpmc.integrate.convex_polyhedron`, `hpmc.integrate.convex_spheropolyhedron`, `hpmc.integrate.polyedron`, `hpmc.integrate.faceted_sphere`, `hpmc.integrate.sphere_union` and `hpmc.integrate.convex_polyhedron_union` produced spurious overlaps on the GPU

v2.2.0 (2017-09-08)

New features

- General:

    - Add `hoomd.hdf5.log` to log quantities in hdf5 format. Matrix quantities can be logged.

    - `dump.gsd` can now save internal state to gsd files. Call `dump_state(object)` to save the state for a particular object. The following objects are supported:

        * HPMC integrators save shape and trial move size state.

    - Add *dynamic* argument to `hoomd.dump.gsd` to specify which quantity categories should be written every frame.

    - HOOMD now inter-operates with other python libraries that set the active CUDA device.

    - Add generic capability for bidirectional ghost communication, enabling multi body potentials in MPI simulation.

- MD:

    - Added support for a 3 body potential that is harmonic in the local density.

    - `force.constant` and `force.active` can now apply torques.

    - `quiet` option to `nlist.tune` to quiet the output of the embedded `run()` commands.

    - Add special pairs as exclusions from neighbor lists.

    - Add cosine squared angle potential `md.angle.cosinesq`.

    - Add `md.pair.DLVO()` for evaluation of colloidal dispersion and electrostatic forces.

    - Add Lennard-Jones 12-8 pair potential.

    - Add Buckingham (exp-6) pair potential.

    - Add Coulomb 1-4 special_pair potential.

    - Check that composite body dimensions are consistent with minimum image convention and generate an error if they are not.

    - `md.integrate.mode.minimize_fire()` now supports anisotropic particles (i.e. composite bodies)

    - `md.integrate.mode.minimize_fire()` now supports flexible specification of integration methods

    - `md.integrate.npt()`/`md.integrate.nph()` now accept a friction parameter (gamma) for damping out box fluctuations during minimization runs

    - Add new command `integrate.mode_standard.reset_methods()` to clear NVT and NPT integrator variables

- HPMC:

    - `hpmc.integrate.sphere_union()` takes new capacity parameter to optimize performance for different shape sizes

    - `hpmc.integrate.polyhedron()` takes new capacity parameter to optimize performance for different shape sizes

    - `hpmc.integrate.convex_polyhedron` and `convex_spheropolyhedron` now support arbitrary numbers of vertices, subject only to memory limitations (`max_verts` is now ignored).

- HPMC integrators restore state from a gsd file read by `init.read_gsd` when the option `restore_state` is `True`.

- Deterministic HPMC integration on the GPU (optional): `mc.set_params(deterministic=True)`.

- New `hpmc.update.boxmc.ln_volume()` move allows logarithmic volume moves for fast equilibration.

- New shape: `hpmc.integrate.convex_polyhedron_union` performs simulations of unions of convex polyhedra.

- `hpmc.field.callback()` now enables MC energy evaluation in a python function

- The option `depletant_mode='overlap_regions'` for `hpmc.integrate.*` allows the selection of a new depletion algorithm that restores the diffusivity of dilute colloids in dense depletant baths

Deprecated

- HPMC: `hpmc.integrate.sphere_union()` no longer needs the `max_members` parameter.

- HPMC: `hpmc.integrate.convex_polyhedron` and `convex_spheropolyhedron` no longer needs the `max_verts` parameter.

- The *static* argument to `hoomd.dump.gsd` should no longer be used. Use *dynamic* instead.

Bug fixes

- HPMC:

  - `hpmc.integrate.sphere_union()` and `hpmc.integrate.polyhedron()` missed overlaps.

  - Fix alignment error when running implicit depletants on GPU with ntrial > 0.

  - HPMC integrators now behave correctly when the user provides different RNG seeds on different ranks.

  - Fix a bug where overlapping configurations were produced with `hpmc.integrate.faceted_sphere()`

- MD:

  - `charge.pppm()` with `order=7` now gives correct results

  - The PPPM energy for particles excluded as part of rigid bodies now correctly takes into account the periodic boundary conditions

- EAM:

  - `metal.pair.eam` now produces correct results.

Other changes

- Optimized performance of HPMC sphere union overlap check and polyhedron shape

- Improved performance of rigid bodies in MPI simulations

- Support triclinic boxes with rigid bodies

- Raise an error when an updater is given a period of 0

- Revised compilation instructions

- Misc documentation improvements

- Fully document `constrain.rigid`

- `-march=native` is no longer set by default (this is now a suggestion in the documentation)

- Compiler flags now default to CMake defaults

- `ENABLE_CUDA` and `ENABLE_MPI` CMake options default OFF. User must explicitly choose to enable optional dependencies.

- HOOMD now builds on powerpc+CUDA platforms (tested on summitdev)

- Improve performance of GPU PPPM force calculation

- Use sphere tree to further improve performance of `hpmc.integrate.sphere_union()`

v2.1.9 (2017-08-22)

Bug fixes

- Fix a bug where the log quantity `momentum` was incorrectly reported in MPI simulations.

- Raise an error when the user provides inconsistent `charge` or `diameter` lists to `md.constrain.rigid`.

- Fix a bug where `pair.compute_energy()` did not report correct results in MPI parallel simulations.

- Fix a bug where make rigid bodies with anisotropic constituent particles did not work on the GPU.

- Fix hoomd compilation after the rebase in the cub repository.

- `deprecated.dump.xml()` now writes correct results when particles have been added or deleted from the simulation.

- Fix a critical bug where `charge.pppm()` calculated invalid forces on the GPU

v2.1.8 (2017-07-19)

Bug fixes

- `init.read_getar` now correctly restores static quantities when given a particular frame.

- Fix bug where many short calls to `run()` caused incorrect results when using `md.integrate.langevin`.

- Fix a bug in the Saru pseudo-random number generator that caused some double-precision values to be drawn outside the valid range [0,1) by a small amount. Both floats and doubles are now drawn on [0,1).

- Fix a bug where coefficients for multi-character unicode type names failed to process in Python 2.

Other changes

- The Saru generator has been moved into `hoomd/Saru.h`, and plugins depending on Saru or SaruGPU will need to update their includes. The `SaruGPU` class has been removed. Use `hoomd::detail::Saru` instead for both CPU and GPU plugins.

v2.1.7 (2017-05-11)

Bug fixes

- Fix PPM exclusion handling on the CPU

- Handle `r_cut` for special pairs correctly

- Fix tauP reference in NPH documentation

- Fixed `constrain.rigid` on compute 5.x.

- Fixed random seg faults when using sqlite getar archives with LZ4 compression

- Fixed XZ coupling with `hoomd.md.integrate.npt` integration

- Fixed aspect ratio with non-cubic boxes in `hoomd.hpmc.update.boxmc`

v2.1.6 (2017-04-12)

Bug fixes

- Document `hpmc.util.tune_npt`
- Fix dump.getar.writeJSON usage with MPI execution
- Fix a bug where integrate.langevin and integrate.brownian correlated RNGs between ranks in multiple CPU execution
- Bump CUB to version 1.6.4 for improved performance on Pascal architectures. CUB is now embedded using a git submodule. Users upgrading existing git repositories should reinitialize their git submodules with `git submodule update --init`
- CMake no longer complains when it finds a partial MKL installation.

v2.1.5 (2017-03-09)

Bug fixes

- Fixed a compile error on Mac

v2.1.4 (2017-03-09)

Bug fixes

- Fixed a bug re-enabling disabled integration methods
- Fixed a bug where adding particle types to the system failed for anisotropic pair potentials
- scipy is no longer required to execute DEM component unit tests
- Issue a warning when a subsequent call to context.initialize is given different arguments
- DPD now uses the seed from rank 0 to avoid incorrect simulations when users provide different seeds on different ranks
- Miscellaneous documentation updates
- Defer initialization message until context.initialize
- Fixed a problem where a momentary dip in TPS would cause walltime limited jobs to exit prematurely
- HPMC and DEM components now correctly print citation notices

v2.1.3 (2017-02-07)

Bug fixes

- Fixed a bug where the WalltimeLimitReached was ignored

v2.1.2 (2017-01-11)

Bug fixes

- (HPMC) Implicit depletants with spheres and faceted spheres now produces correct ensembles
- (HPMC) Implicit depletants with ntrial > 0 now produces correct ensembles
- (HPMC) NPT ensemble in HPMC (`hpmc.update.boxmc`) now produces correct ensembles
- Fix a bug where multiple nvt/npt integrators caused warnings from analyze.log.
- update.balance() is properly ignored when only one rank is available
- Add missing headers to plugin install build
- Fix a bug where charge.pppm calculated an incorrect pressure
- Other changes *
- Drop support for compute 2.0 GPU devices
- Support cusolver with CUDA 8.0

v2.1.1 (2016-10-23)

Bug fixes

- Fix `force.active` memory allocation bug
- Quiet Python.h warnigns when building (python 2.7)
- Allow multi-character particle types in HPMC (python 2.7)
- Enable `dump.getar.writeJSON` in MPI
- Allow the flow to change directions in `md.update.mueller_plathe_flow`
- Fix critical bug in MPI communication when using HPMC integrators

v2.1.0 (2016-10-04)

New features

- enable/disable overlap checks between pairs of constituent particles for `hpmc.integrate.sphere_union()`
- Support for non-additive mixtures in HPMC, overlap checks can now be enabled/disabled per type-pair
- Add `md.constrain.oned` to constrain particles to move in one dimension
- `hpmc.integrate.sphere_union()` now takes max_members as an optional argument, allowing to use GPU memory more efficiently
- Add `md.special_pair.lj()` to support scaled 1-4 (or other) exclusions in all-atom force fields
- `md.update.mueller_plathe_flow()`: Method to create shear flows in MD simulations
- `use_charge` option for `md.pair.reaction_field`
- `md.charge.pppm()` takes a Debye screening length as an optional parameter
- `md.charge.pppm()` now computes the rigid body correction to the PPPM energy

Deprecated

- HPMC: the `ignore_overlaps` flag is replaced by `hpmc.integrate.interaction_matrix`

Other changes

- Optimized MPI simulations of mixed systems with rigid and non-rigid bodies

- Removed dependency on all boost libraries. Boost is no longer needed to build hoomd

- Intel compiler builds are no longer supported due to c++11 bugs

- Shorter compile time for HPMC GPU kernels

- Include symlinked external components in the build process

- Add template for external components

- Optimized dense depletant simulations with HPMC on CPU

Bug fixes

- fix invalid mesh energy in non-neutral systems with `md.charge.pppm()`

- Fix invalid forces in simulations with many bond types (on GPU)

- fix rare cases where analyze.log() would report a wrong pressure

- fix possible illegal memory access when using `md.constrain.rigid()` in GPU MPI simulations

- fix a bug where the potential energy is misreported on the first step with `md.constrain.rigid()`

- Fix a bug where the potential energy is misreported in MPI simulations with `md.constrain.rigid()`

- Fix a bug where the potential energy is misreported on the first step with `md.constrain.rigid()`

- `md.charge.pppm()` computed invalid forces

- Fix a bug where PPPM interactions on CPU where not computed correctly

- Match logged quantitites between MPI and non-MPI runs on first time step

- Fix `md.pair.dpd` and `md.pair.dpdlj` set_params

- Fix diameter handling in DEM shifted WCA potential

- Correctly handle particle type names in lattice.unitcell

- Validate `md.group.tag_list` is consistent across MPI ranks

v2.0.3 (2016-08-30)

- hpmc.util.tune now works with particle types as documented

- Fix pressure computation with pair.dpd() on the GPU

- Fix a bug where dump.dcd corrupted files on job restart

- Fix a bug where HPMC walls did not work correctly with MPI

- Fix a bug where stdout/stderr did not appear in MPI execution

- HOOMD will now report an human readable error when users forget context.initialize()

- Fix syntax errors in frenkel ladd field

v2.0.2 (2016-08-09)

- Support CUDA Toolkit 8.0
- group.rigid()/nonrigid() did not work in MPI simulations
- Fix builds with ENABLE_DOXYGEN=on
- Always add -std=c++11 to the compiler command line arguments
- Fix rare infinite loops when using hpmc.integrate.faceted_sphere
- Fix hpmc.util.tune to work with more than one tunable
- Fix a bug where dump.gsd() would write invalid data in simulations with changing number of particles
- replicate() sometimes did not work when restarting a simulation

v2.0.1 (2016-07-15)

Bug fixes

- Fix acceptance criterion in mu-V-T simulations with implicit depletants (HPMC).
- References to disabled analyzers, computes, updaters, etc. are properly freed from the simulation context.
- Fix a bug where `init.read_gsd` ignored the `restart` argument.
- Report an error when HPMC kernels run out of memory.
- Fix ghost layer when using rigid constraints in MPI runs.
- Clarify definition of the dihedral angle.

v2.0.0 (2016-06-22)

HOOMD-blue v2.0 is released under a clean BSD 3-clause license.

New packages

- `dem` - simulate faceted shapes with dynamics
- `hpmc` - hard particle Monte Carlo of a variety of shape classes.

Bug fixes

- Angles, dihedrals, and impropers no longer initialize with one default type.
- Fixed a bug where integrate.brownian gave the same x,y, and z velocity components.
- Data proxies verify input types and vector lengths.
- dump.dcd no longer generates excessive metadata traffic on lustre file systems

New features

- Distance constraints `constrain.distance` - constrain pairs of particles to a fixed separation distance
- Rigid body constraints `constrain.rigid` - rigid bodies now have central particles, and support MPI and replication
- Multi-GPU electrostatics `charge.pppm` - the long range electrostatic forces are now supported in MPI runs
- `context.initialize()` can now be called multiple times - useful in jupyter notebooks
- Manage multiple simulations in a single job script with `SimulationContext` as a python context manager.

- `util.quiet_status()` / `util.unquiet_status()` allow users to control if line status messages are output.

- Support executing hoomd in Jupyter (ipython) notebooks. Notice, warning, and error messages now show up in the notebook output blocks.

- `analyze.log` can now register python callback functions as sources for logged quantities.

- The GSD file format (http://gsd.readthedocs.io) is fully implemented in hoomd

    - `dump.gsd` writes GSD trajectories and restart files (use `truncate=true` for restarts).

    - `init.read_gsd` reads GSD file and initializes the system, and can start the simulation from any frame in the GSD file.

    - `data.gsd_snapshot` reads a GSD file into a snapshot which can be modified before system initialization with `init.read_snapshot`.

    - The GSD file format is capable of storing all particle and topology data fields in hoomd, either static at frame 0, or varying over the course of the trajectory. The number of particles, types, bonds, etc. can also vary over the trajectory.

- `force.active` applies an active force (optionally with rotational diffusion) to a group of particles

- `update.constrain_ellipsoid` constrains particles to an ellipsoid

- `integrate.langevin` and `integrate.brownian` now apply rotational noise and damping to anisotropic particles

- Support dynamically updating groups. `group.force_update()` forces the group to rebuild according to the original selection criteria. For example, this can be used to periodically update a cuboid group to include particles only in the specified region.

- `pair.reaction_field` implements a pair force for a screened electrostatic interaction of a charge pair in a dielectric medium.

- `force.get_energy` allows querying the potential energy of a particle group for a specific force

- `init.create_lattice` initializes particles on a lattice.

    - `lattice.unitcell` provides a generic unit cell definition for `create_lattice`

    - Convenience functions for common lattices: sq, hex, sc, bcc, fcc.

- Dump and initialize commands for the GTAR file format (http://libgetar.readthedocs.io).

    - GTAR can store trajectory data in zip, tar, sqlite, or bare directories

    - The current version stores system properties, later versions will be able to capture log, metadata, and other output to reduce the number of files that a job script produces.

- `integrate.npt` can now apply a constant stress tensor to the simulation box.

- Faceted shapes can now be simulated through the `dem` component.

Changes that require job script modifications

- `context.initialize()` is now required before any other hoomd script command.

- `init.reset()` no longer exists. Use `context.initialize()` or activate a `SimulationContext`.

- Any scripts that relied on undocumented members of the `globals` module will fail. These variables have been moved to the `context` module and members of the currently active `SimulationContext`.

- bonds, angles, dihedrals, and impropers no longer use the `set_coeff` syntax. Use `bond_coeff.set`, `angle_coeff.set`, `dihedral_coeff.set`, and `improper_coeff.set` instead.

- `hoomd_script` no longer exists, python commands are now spread across `hoomd`, `hoomd.md`, and other sub packages.

- `integrate.\*_rigid()` no longer exists. Use a standard integrator on `group.rigid_center()`, and define rigid bodies using `constrain.rigid()`

- All neighbor lists must be explicitly created using `nlist.\*`, and each pair potential must be attached explicitly to a neighbor list. A default global neighbor list is no longer created.

- Moved cgcmm into its own package.

- Moved eam into the metal package.

- Integrators now take `kT` arguments for temperature instead of `T` to avoid confusion on the units of temperature.

- phase defaults to 0 for updaters and analyzers so that restartable jobs are more easily enabled by default.

- `dump.xml` (deprecated) requires a particle group, and can dump subsets of particles.

Other changes

- CMake minimum version is now 2.8

- Convert particle type names to `str` to allow unicode type name input

- `__version__` is now available in the top level package

- `boost::iostreams` is no longer a build dependency

- `boost::filesystem` is no longer a build dependency

- New concepts page explaining the different styles of neighbor lists

- Default neighbor list buffer radius is more clearly shown to be r_buff = 0.4

- Memory usage of `nlist.stencil` is significantly reduced

- A C++11 compliant compiler is now required to build HOOMD-blue

Removed

- Removed `integrate.bdnvt`: use `integrate.langevin`

- Removed `mtk=False` option from `integrate.nvt` - The MTK NVT integrator is now the only implementation.

- Removed `integrate.\*_rigid()`: rigid body functionality is now contained in the standard integration methods

- Removed the global neighbor list, and thin wrappers to the neighbor list in `nlist`.

- Removed PDB and MOL2 dump writers.

- Removed init.create_empty

Deprecated

- Deprecated analyze.msd.

- Deprecated dump.xml.

- Deprecated dump.pos.

- Deprecated init.read_xml.

- Deprecated init.create_random.

- Deprecated init.create_random_polymers.

2.3.2 v1.x

v1.3.3 (2016-03-06)

Bug fixes

- Fix problem including `hoomd.h` in plugins
- Fix random memory errors when using walls

v1.3.2 (2016-02-08)

Bug fixes

- Fix wrong access to system.box
- Fix kinetic energy logging in MPI
- Fix particle out of box error if particles are initialized on the boundary in MPI
- Add integrate.brownian to the documentation index
- Fix misc doc typos
- Fix runtime errors with boost 1.60.0
- Fix corrupt metadata dumps in MPI runs

v1.3.1 (2016-1-14)

Bug fixes

- Fix invalid MPI communicator error with Intel MPI
- Fix python 3.5.1 seg fault

v1.3.0 (2015-12-8)

New features

- Automatically load balanced domain decomposition simulations.
- Anisotropic particle integrators.
- Gay-Berne pair potential.
- Dipole pair potential.
- Brownian dynamics `integrate.brownian`
- Langevin dynamics `integrate.langevin` (formerly `bdnvt`)
- `nlist.stencil` to compute neighbor lists using stencilled cell lists.
- Add single value scale, `min_image`, and `make_fraction` to `data.boxdim`
- `analyze.log` can optionally not write a file and now supports querying current quantity values.
- Rewritten wall potentials.
  - Walls are now sums of planar, cylindrical, and spherical half-spaces.
  - Walls are defined and can be modified in job scripts.

- – Walls execute on the GPU.

- – Walls support per type interaction parameters.

- – Implemented for: lj, gauss, slj, yukawa, morse, force_shifted_lj, and mie potentials.

- External electric field potential: `external.e_field`

Bug fixes

- Fixed a bug where NVT integration hung when there were 0 particles in some domains.

- Check SLURM environment variables for local MPI rank identification

- Fixed a typo in the box math documentation

- Fixed a bug where exceptions weren't properly passed up to the user script

- Fixed a bug in the velocity initialization example

- Fixed an openmpi fork() warning on some systems

- Fixed segfaults in PPPM

- Fixed a bug where compute.thermo failed after reinitializing a system

- Support list and dict-like objects in init.create_random_polymers.

- Fall back to global rank to assign GPUs if local rank is not available

Deprecated commands

- `integrate.bdnvt` is deprecated. Use `integrate.langevin` instead.

- `dump.bin` and `init.bin` are now removed. Use XML files for restartable jobs.

Changes that may break existing scripts

- `boxdim.wrap` now returns the position and image in a tuple, where it used to return just the position.

- `wall.lj` has a new API

- `dump.bin` and `init.bin` have been removed.

v1.2.1 (2015-10-22)

Bug fixes

- Fix a crash when adding or removing particles and reinitializing

- Fix a bug where simulations hung on sm 5.x GPUs with CUDA 7.5

- Fix compile error with long tests enabled

- Issue a warning instead of an error for memory allocations greater than 4 GiB.

- Fix invalid RPATH when building inside `zsh`.

- Fix incorrect simulations with `integrate.npt_rigid`

- Label mie potential correctly in user documentation

v1.2.0 (2015-09-30)

New features

- Performance improvements for systems with large particle size disparity
- Bounding volume hierarchy (tree) neighbor list computation
- Neighbor lists have separate `r_cut` values for each pair of types
- addInfo callback for dump.pos allows user specified information in pos files

Bug fixes

- Fix `test_pair_set_energy` unit test, which failed on numpy < 1.9.0
- Analyze.log now accepts unicode strings.
- Fixed a bug where calling `restore_snapshot()` during a run zeroed potential parameters.
- Fix segfault on exit with python 3.4
- Add `cite.save()` to documentation
- Fix a problem were bond forces are computed incorrectly in some MPI configurations
- Fix bug in pair.zbl
- Add pair.zbl to the documentation
- Use `HOOMD_PYTHON_LIBRARY` to avoid problems with modified CMake builds that preset `PYTHON_LIBRARY`

v1.1.1 (2015-07-21)

Bug fixes

- `dump.xml(restart=True)` now works with MPI execution
- Added missing documentation for `meta.dump_metadata`
- Build all unit tests by default
- Run all script unit tests through `mpirun -n 1`

v1.1.0 (2015-07-14)

New features

- Allow builds with ninja.
- Allow K=0 FENE bonds.
- Allow number of particles types to change after initialization.

```
system.particles.types.add('newtype')
```

- Allow number of particles to change after initialization.

```
system.particles.add('A')
del system.particles[0]
```

- OPLS dihedral

- Add `phase` keyword to analyzers and dumps to make restartable jobs easier.

- `HOOMD_WALLTIME_STOP` environment variable to stop simulation runs before they hit a wall clock limit.

- `init.read_xml()` Now accepts an initialization and restart file.

- `dump.xml()` can now write restart files.

- Added documentation concepts page on writing restartable jobs.

- New citation management infrastructure. `cite.save()` writes `.bib` files with a list of references to features actively used in the current job script.

- Snapshots expose data as numpy arrays for high performance access to particle properties.

- `data.make_snapshot()` makes a new empty snapshot.

- `analyze.callback()` allows multiple python callbacks to operate at different periods.

- `comm.barrier()``and comm.barrier_all()``allow users to insert barriers into their scripts.

- Mie pair potential.

- `meta.dump_metadata()` writes job metadata information out to a json file.

- `context.initialize()` initializes the execution context.

- Restart option for `dump.xml()`

Bug fixes

- Fix slow performance when initializing `pair.slj()` in MPI runs.

- Properly update particle image when setting position from python.

- PYTHON_SITEDIR hoomd shell launcher now calls the python interpreter used at build time.

- Fix compile error on older gcc versions.

- Fix a bug where rigid bodies had 0 velocity when restarting jobs.

- Enable `-march=native` builds in OS X clang builds.

- Fix `group.rigid()` and `group.nonrigid()`.

- Fix image access from the python data access proxies.

- Gracefully exit when launching MPI jobs with mixed execution configurations.

Changes that may require updated job scripts

- `context.initialize()` **must** be called before any `comm` method that queries the MPI rank. Call it as early as possible in your job script (right after importing `hoomd_script`) to avoid problems.

Deprecated

- `init.create_empty()` is deprecated and will be removed in a future version. Use `data.make_snapshot()` and `init.read_snapshot()` instead.

- Job scripts that do not call `context.initialize()` will result in a warning message. A future version of HOOMD will require that you call `context.initialize()`.

Removed

- Several `option` commands for controlling the execution configuration. Replaced with `context.initialize`.

v1.0.5 (2015-05-19)

Bug fixes

- Fix segfault when changing integrators
- Fix system.box to indicate the correct number of dimensions
- Fix syntax error in comm.get_rank with –nrank
- Enable CUDA enabled builds with the intel compiler
- Use CMake builtin FindCUDA on recent versions of CMake
- GCC_ARCH env var sets the -march command line option to gcc at configure time
- Auto-assign GPU-ids on non-compute exclusive systems even with –mode=gpu
- Support python 3.5 alpha
- Fix a bug where particle types were doubled with boost 1.58.0
- Fix a bug where angle_z=true dcd output was inaccurate near 0 angles
- Properly handle lj.wall potentials with epsilon=0.0 and particles on top of the walls

v1.0.4 (2015-04-07)

Bug fixes

- Fix invalid virials computed in rigid body simulations when multi-particle bodies crossed box boundaries
- Fix invalid forces/torques for rigid body simulations caused by race conditions
- Fix compile errors on Mac OS X 10.10
- Fix invalid pair force computations caused by race conditions
- Fix invalid neighbour list computations caused by race conditions on Fermi generation GPUs

Other

- Extremely long running unit tests are now off by default. Enable with -DHOOMD_SKIP_LONG_TESTS=OFF
- Add additional tests to detect race conditions and memory errors in kernels

v1.0.3 (2015-03-18)

Bug fixes

- Enable builds with intel MPI
- Silence warnings coming from boost and python headers

v1.0.2 (2015-01-21)

Bug fixes

- Fixed a bug where `linear_interp` would not take a floating point value for *zero*
- Provide more useful error messages when cuda drivers are not present
- Assume device count is 0 when `cudaGetDeviceCount()` returns an error

- Link to python statically when `ENABLE_STATIC=on`
- Misc documentation updates

v1.0.1 (2014-09-09)

Bug fixes

1. Fixed bug where error messages were truncated and HOOMD exited with a segmentation fault instead (e.g. on Blue Waters)

2. Fixed bug where plug-ins did not load on Blue Waters

3. Fixed compile error with gcc4.4 and cuda5.0

4. Fixed syntax error in `read_snapshot()`

5. Fixed a bug where `init.read_xml throwing` an error (or any other command outside of `run()`) would hang in MPI runs

6. Search the install path for hoomd_script - enable the hoomd executable to be outside of the install tree (useful with cray aprun)

7. Fixed CMake 3.0 warnings

8. Removed dependancy on tr1/random

9. Fixed a bug where `analyze.msd` ignored images in the r0_file

10. Fixed typos in `pair.gauss` documentation

11. Fixed compile errors on Ubuntu 12.10

12. Fix failure of `integrate.nvt` to reach target temperature in analyze.log. The fix is a new symplectic MTK integrate.nvt integrator. Simulation results in hoomd v1.0.0 are correct, just the temperature and velocity outputs are off slightly.

13. Remove MPI from Mac OS X dmg build.

14. Enable `import hoomd_script as ...`

Other changes

1. Added default compile flag -march=native

2. Support CUDA 6.5

3. Binary builds for CentOS/RHEL 6, Fedora 20, Ubuntu 14.04 LTS, and Ubuntu 12.04 LTS.

Version 1.0.0 (2014-05-25)

New features

- Support for python 3
- New NPT integrator capable of flexible coupling schemes
- Triclinic unit cell support
- MPI domain decomposition
- Snapshot save/restore
- Autotune block sizes at run time
- Improve performance in small simulation boxes

- Improve performance with smaller numbers of particles per GPU

- Full double precision computations on the GPU (compile time option must be enabled, binary builds provided on the download page are single precision)

- Tabulated bond potential `bond.table`

- Tabulated angle potential `angle.table`

- Tabulated dihedral potental `dihedral.table`

- `update.box_resize` now accepts `period=None` to trigger an immediate update of the box without creating a periodic updater

- `update.box_resize` now replaces *None* arguments with the current box parameters

- `init.create_random` and `init.create_random_polymers` can now create random configurations in triclinc and 2D boxes

- `init.create_empty` can now create triclinic boxes

- particle, bond, angle, dihedral, and impropers types can now be named in `init.create_empty`

- `system.replicate` command replicates the simulation box

Bug fixes

- Fixed a bug where init.create_random_polymers failed when lx,ly,lz were not equal.

- Fixed a bug in init.create_random_polymers and init.create_random where the separation radius was not accounted for correctly

- Fixed a bug in bond.* where random crashes would occur when more than one bond type was defined

- Fixed a bug where dump.dcd did not write the period to the file

Changes that may require updated job scripts

- `integrate.nph`: A time scale `tau_p` for the relaxation of the barostat is now required instead of the barostat mass *W* of the previous release. The time scale is the relaxation time the barostat would have at an average temperature `T_0 = 1`, and it is related to the internally used (Andersen) Barostat mass *W* via `W = d N T_0 tau_p^2`, where *d* is the dimensionality and *N* the number of particles.

- `sorter` and `nlist` are now modules, not variables in the __main__ namespace.

- Data proxies function correctly in MPI simulations, but are extremely slow. If you use `init.create_empty`, consider separating the generation step out to a single rank short execution that writes an XML file for the main run.

- `update.box_resize(Lx=...)` no longer makes cubic box updates, instead it will keep the current **Ly** and **Lz**. Use the `L=...` shorthand for cubic box updates.

- All `init.*` commands now take `data.boxdim` objects, instead of `hoomd.boxdim` (or *3-tuples*). We strongly encourage the use of explicit argument names for `data.boxdim()`. In particular, if `hoomd.boxdim(123)` was previously used to create a cubic box, it is now required to use `data.boxdim(L=123)` (CORRECT) instead of `data.boxdim(123)` (INCORRECT), otherwise a box with unit dimensions along the y and z axes will be created.

- `system.dimensions` can no longer be set after initialization. System dimensions are now set during initialization via the `data.boxdim` interface. The dimensionality of the system can now be queried through `system.box`.

- `system.box` no longer accepts 3-tuples. It takes `data.boxdim` objects.

- `system.dimensions` no longer exists. Query the dimensionality of the system from `system.box`. Set the dimensionality of the system by passing an appropriate `data.boxdim` to an `init` method.

- `init.create_empty` no longer accepts `n_*_types`. Instead, it now takes a list of strings to name the types.

Deprecated

- Support for G80, G200 GPUs.

- `dump.bin` and `read.bin`. These will be removed in v1.1 and replaced with a new binary format.

Removed

- OpenMP mult-core execution (replaced with MPI domain decomposition)

- `tune.find_optimal_block_size` (replaced by Autotuner)

2.3.3 v0.x

Version 0.11.3 (2013-05-10)

Bug fixes

- Fixed a bug where charge.pppm could not be used after init.reset()

- Data proxies can now set body angular momentum before the first run()

- Fixed a bug where PPPM forces were incorrect on the GPU

Version 0.11.2 (2012-12-19)

New features

- Block sizes tuned for K20

Bug fixes

- Warn user that PPPM ignores rigid body exclusions

- Document that proxy iterators need to be deleted before init.reset()

- Fixed a bug where body angular momentum could not be set

- Fixed a bug where analyze.log would report nan for the pressure tensor in nve and nvt simulations

Version 0.11.1 (2012-11-2)

New features

- Support for CUDA 5.0

- Binary builds for Fedora 16 and OpenSUSE 12.1

- Automatically specify /usr/bin/gcc to nvcc when the configured gcc is not supported

Bug fixes

- Fixed a compile error with gcc 4.7

- Fixed a bug where PPPM forces were incorrect with neighborlist exclusions

- Fixed an issue where boost 1.50 and newer were not detected properly when BOOST_ROOT is set

- Fixed a bug where accessing force data in python prevented init.reset() from working

- Fixed a bug that prevented pair.external from logging energy

- Fixed a unit test that failed randomly

Version 0.11.0 (2012-07-27)

New features

1. Support for Kepler GPUs (GTX 680)

2. NPH integration (*integrate.nph*)

3. Compute full pressure tensor

4. Example plugin for new bond potentials

5. New syntax for bond coefficients: *bond.bond_coeff.set('type', params)*

6. New external potential: *external.periodic* applies a periodic potential along one direction (uses include inducing lamellar phases in copolymer systems)

7. Significant performance increases when running *analyze.log*, *analyze.msd*, *update.box_resize*, *update.rescale_temp*, or *update.zero_momentum* with a small period

8. Command line options may now be overwritten by scripts, ex: *options.set_gpu(2)*

9. Added *–user* command line option to allow user defined options to be passed into job scripts, ex: *–user="-N=5 -phi=0.56"*

10. Added *table.set_from_file* method to enable reading table based pair potentials from a file

11. Added *–notice-level* command line option to control how much extra information is printed during a run. Set to 0 to disable, or any value up to 10. At 10, verbose debugging information is printed.

12. Added *–msg-file* command line option which redirects the message output to a file

13. New pair potential *pair.force_shifted_lj* : Implements http://dx.doi.org/10.1063/1.3558787

Bug fixes

1. Fixed a bug where FENE bonds were sometimes computed incorrectly

2. Fixed a bug where pressure was computed incorrectly when using pair.dpd or pair.dpdlj

3. Fixed a bug where using OpenMP and CUDA at the same time caused invalid memory accesses

4. Fixed a bug where RPM packages did not work on systems where the CUDA toolkit was not installed

5. Fixed a bug where rigid body velocities were not set from python

6. Disabled OpenMP builds on Mac OS X. HOOMD-blue w/ openmp enabled crashes due to bugs in Apple's OpenMP implementation.

7. Fixed a bug that allowed users to provide invalid rigid body data and cause a seg fault.

8. Fixed a bug where using PPPM resulted in error messages on program exit.

API changes

1. Bond potentials rewritten with template evaluators

2. External potentials use template evaluators

3. Complete rewrite of ParticleData - may break existing plugins

4. Bond/Angle/Dihedral data structures rewritten

   - The GPU specific data structures are now generated on the GPU

5. DPDThermo and DPDLJThermo are now processed by the same template class

6. Headers that cannot be included by nvcc now throw an error when they are

7. CUDA 4.0 is the new minimum requirement

8. Rewrote BoxDim to internally handle minimum image conventions

9. HOOMD now only compiles ptx code for the newest architecture, this halves the executable file size

10. New Messenger class for global control of messages printed to the screen / directed to a file.

Testing changes

1. Automated test suite now performs tests on OpenMPI + CUDA builds

2. Valgrind tests added back into automated test suite

3. Added CPU test in bd_ridid_updater_tests

4. ctest -S scripts can now set parallel makes (with cmake > 2.8.2)

Version 0.10.1 (2012-02-10)

1. Add missing entries to credits page

2. Add `dist_check` option to neighbor list. Can be used to force neighbor list builds at a specified frequency (useful in profiling runs with nvvp).

3. Fix typos in ubuntu compile documentation

4. Add missing header files to hoomd.h

5. Add torque to the python particle data access API

6. Support boost::filesystem API v3

7. Expose name of executing gpu, n_cpu, hoomd version, git sha1, cuda version, and compiler version to python

8. Fix a bug where multiple `nvt_rigid` or `npt_rigid` integrators didn't work correctly

9. Fix missing pages in developer documentation

Version 0.10.0 (2011-12-14)

New features

1. Added *pair.dpdlj* which uses the DPD thermostat and the Lennard-Jones potential. In previous versions, this could be accomplished by using two pair commands but at the cost of reduced performance.

2. Additional example scripts are now present in the documentation. The example scripts are cross-linked to the commands that are used in them.

3. Most dump commands now accept the form: *dump.ext(filename="filename.ext")* which immediately writes out filename.ext.

4. Added *vis* parameter to dump.xml which enables output options commonly used in files written for the purposes of visulization. dump.xml also now accepts parameters on the instantiation line. Combined with the previous feature, *dump.xml(filename="file.xml", vis=True)* is now a convenient short hand for what was previously

```
xml = dump.xml()
xml.set_params(position = True, mass = True, diameter = True,
                   type = True, bond = True, angle = True,
                   dihedral = True, improper = True, charge = True)
xml.write(filename="file.xml")
```

5. Specify rigid bodies in XML input files

6. Simulations that contain rigid body constraints applied to groups of particles in BDNVT, NVE, NVT, and NPT ensembles.

   - *integrate.bdnvt_rigid*

   - *integrate.nve_rigid*

   - *integrate.nvt_rigid*

   - *integrate.npt_rigid*

7. Energy minimization of rigid bodies (*integrate.mode_minimize_rigid_fire*)

8. Existing commands are now rigid-body aware

   - update.rescale_temp

   - update.box_resize

   - update.enforce2d

   - update.zero_momentum

9. NVT integration using the Berendsen thermostat (*integrate.berendsen*)

10. Bonds, angles, dihedrals, and impropers can now be created and deleted with the python data access API.

11. Attribution clauses added to the HOOMD-blue license.

Changes that may break existing job scripts

1. The *wrap* option to *dump.dcd* has been changed to *unwrap_full* and its meaning inverted. *dump.dcd* now offers two options for unwrapping particles, *unwrap_full* fully unwraps particles into their box image and *unwrap_rigid* unwraps particles in rigid bodies so that bodies are not broken up across a box boundary.

Bug/fixes small enhancements

1. Fixed a bug where launching hoomd on mac os X 10.5 always resulted in a bus error.

2. Fixed a bug where DCD output restricted to a group saved incorrect data.

3. force.constant may now be applied to a group of particles, not just all particles

4. Added C++ plugin example that demonstrates how to add a pair potential in a plugin

5. Fixed a bug where box.resize would always transfer particle data even in a flat portion of the variant

6. OpenMP builds re-enabled on Mac OS X

7. Initial state of integrate.nvt and integrate.npt changed to decrease oscillations at startup.

8. Fixed a bug where the polymer generator would fail to initialize very long polymers

9. Fixed a bug where images were passed to python as unsigned ints.

10. Fixed a bug where dump.pdb wrote coordinates in the wrong order.

11. Fixed a rare problem where a file written by dump.xml would not be read by init.read_xml due to round-off errors.

12. Increased the number of significant digits written out to dump.xml to make them more useful for ad-hoc restart files.

13. Potential energy and pressure computations that slow performance are now only performed on those steps where the values are actually needed.

14. Fixed a typo in the example C++ plugin

15. Mac build instructions updated to work with the latest version of macports

16. Fixed a bug where set_period on any dump was ineffective.

17. print_status_line now handles multiple lines

18. Fixed a bug where using bdnvt tally with per type gammas resulted in a race condition.

19. Fix an issue where ENABLE_CUDA=off builds gave nonsense errors when –mode=gpu was requested.

20. Fixed a bug where dumpl.xml could produce files that init.xml would not read

21. Fixed a typo in the example plugin

22. Fix example that uses hoomd as a library so that it compiles.

23. Update maintainer lines

24. Added message to nlist exclusions that notifies if diameter or body exclusions are set.

25. HOOMD-blue is now hosted in a git repository

26. Added bibtex bibliography to the user documentation

27. Converted user documentation examples to use doxygen auto cross-referencing \example commands

28. Fix a bug where particle data is not released in dump.binary

29. ENABLE_OPENMP can now be set in the ctest builds

30. Tuned block sizes for CUDA 4.0

31. Removed unsupported GPUS from CUDA_ARCH_LIST

Version 0.9.2 (2011-04-04)

Note: only major changes are listed here.

New features

1. *New exclusion option:* Particles can now be excluded from the neighbor list based on diameter consistent with pair.slj.

2. *New pair coeff syntax:* Coefficients for multiple type pairs can be specified conveniently on a single line.

```
coeff.set(['A', 'B', 'C', 'D'], ['A', 'B', 'C', 'D'], epsilon=1.0)
```

3. *New documentation:* HOOMD-blue's system of units is now fully documented, and every coefficient in the documentation is labeled with the appropriate unit.

4. *Performance improvements:* Performance has been significantly boosted for simulations of medium sized systems (5,000-20,000 particles). Smaller performance boosts were made to larger runs.

5. *CUDA 3.2 support:* HOOMD-blue is now fully tested and performance tuned for use with CUDA 3.2.

6. *CUDA 4.0 support:* HOOMD-blue compiles with CUDA 4.0 and passes initial tests.

7. *New command:* tune.r_buff performs detailed auto-tuning of the r_buff neighborlist parameter.

8. *New installation method:* RPM, DEB, and app bundle packages are now built for easier installation

9. *New command:* charge.pppm computes the full long range electrostatic interaction using the PPPM method

Bug/fixes small enhancements

1. Fixed a bug where the python library was linked statically.

2. Added the PYTHON_SITEDIR setting to allow hoomd builds to install into the native python site directory.

3. FIRE energy minimization convergence criteria changed to require both energy *and* force to converge

4. Clarified that groups are static in the documentation

5. Updated doc comments for compatibility with Doxygen#7.3

6. system.particles.types now lists the particle types in the simulation

7. Creating a group of a non-existant type is no longer an error

8. Mention XML file format for walls in wall.lj documentation

9. Analyzers now profile themselves

10. Use \n for newlines in dump.xml - improves performance when writing many XML files on a NFS file system

11. Fixed a bug where the neighbor list build could take an exceptionally long time (several seconds) to complete the first build.

12. Fixed a bug where certain logged quantities always reported as 0 on the first step of the simulation.

13. system.box can now be used to read and set the simulation box size from python

14. Numerous internal API updates

15. Fixed a bug the resulted in incorrect behavior when using integrate.npt on the GPU.

16. Removed hoomd launcher shell script. In non-sitedir installs, ${HOOMD_ROOT}/bin/hoomd is now the executable itself

17. Creating unions of groups of non-existent types no longer produces a seg fault

18. hoomd now builds on all cuda architectures. Modify CUDA_ARCH_LIST in cmake to add or remove architectures from the build

19. hoomd now builds with boost#46.0

20. Updated hoomd icons to maize/blue color scheme

21. hoomd xml file format bumped to#3, adds support for charge.

22. FENE and harmonic bonds now handle 0 interaction parameters and 0 length bonds more gracefully

23. The packaged plugin template now actually builds and installs into a recent build of hoomd

Version 0.9.1 (2010-10-08)

Note: only major changes are listed here.

New features

1. *New constraint*: constrain.sphere constrains a group of particles to the surface of a sphere

2. *New pair potential/thermostat*: pair.dpd implements the standard DPD conservative, random, and dissipative forces

3. *New pair potential*: pair.dpd_conservative applies just the conservative DPD potential

4. *New pair potential*: pair.eam implements the Embedded Atom Method (EAM) and supports both *alloy* and *FS* type computations.

5. *Faster performance*: Cell list and neighbor list code has been rewritten for performance.

   - In our benchmarks, *performance increases* ranged from *10-50%* over HOOMD-blue 0.9.0. Simulations with shorter cutoffs tend to attain a higher performance boost than those with longer cutoffs.

   - We recommended that you *re-tune r_buff* values for optimal performance with 0.9.1.

   - Due to the nature of the changes, *identical runs* may produce *different trajectories*.

6. *Removed limitation*: The limit on the number of neighbor list exclusions per particle has been removed. Any number of exclusions can now be added per particle. Expect reduced performance when adding excessive numbers of exclusions.

Bug/fixes small enhancements

1. Pressure computation is now correct when constraints are applied.

2. Removed missing files from hoomd.h

3. pair.yukawa is no longer referred to by "gaussian" in the documentation

4. Fermi GPUs are now prioritized over per-Fermi GPUs in systems where both are present

5. HOOMD now compiles against CUDA 3.1

6. Momentum conservation significantly improved on compute#x hardware

7. hoomd plugins can now be installed into user specified directories

8. Setting r_buff=0 no longer triggers exclusion list updates on every step

9. CUDA 2.2 and older are no longer supported

10. Workaround for compiler bug in 3.1 that produces extremely high register usage

11. Disabled OpenMP compile checks on Mac OS X

12. Support for compute 2.1 devices (such as the GTX 460)

Version 0.9.0 (2010-05-18)

Note: only major changes are listed here.

New features

1. *New pair potential*: Shifted LJ potential for particles of varying diameters (pair.slj)

2. *New pair potential*: Tabulated pair potential (pair.table)

3. *New pair potential*: Yukawa potential (pair.yukawa)

4. *Update to pair potentials*: Most pair potentials can now accept different values of r_cut for different type pairs. The r_cut specified in the initial pair.*** command is now treated as the default r_cut, so no changes to scripts are necessary.

5. *Update to pair potentials*: Default pair coeff values are now supported. The parameter alpha for lj now defaults to#0, so there is no longer a need to specify it for a majority of simulations.

6. *Update to pair potentials*: The maximum r_cut needed for the neighbor list is now determined at the start of each run(). In simulations where r_cut may decrease over time, increased performance will result.

7. *Update to pair potentials*: Pair potentials are now specified via template evaluator classes. Adding a new pair potential to hoomd now only requires a small amount of additional code.

8. *Plugin API* : Advanced users/developers can now write, install, and use plugins for hoomd without needing to modify core hoomd source code

9. *Particle data access*: User-level hoomd scripts can now directly access the particle data. For example, one can change all particles in the top half of the box to be type B:

```
top = group.cuboid(name="top", zmin=0)
for p in top:
    p.type = 'B'
```

. *All* particle data including position, velocity, type, ''et cetera'', can be read and written in this manner. Computed forces and energies can also be accessed in a similar way.

10. *New script command*: init.create_empty() can be used in conjunction with the particle data access above to completely initialize a system within the hoomd script.

11. *New script command*: dump.bin() writes full binary restart files with the entire system state, including the internal state of integrators.

    • File output can be gzip compressed (if zlib is available) to save space

    • Output can alternate between two different output files for safe crash recovery

12. *New script command*: init.read_bin() reads restart files written by dump.bin()

13. *New option*: run() now accepts a quiet option. When True, it eliminates the status information printouts that go to stdout.

14. *New example script*: Example 6 demonstrates the use of the particle data access routines to initialize a system. It also demonstrates how to initialize velocities from a gaussian distribution

15. *New example script*: Example 7 plots the pair.lj potential energy and force as evaluated by hoomd. It can trivially be modified to plot any potential in hoomd.

16. *New feature*: Two dimensional simulations can now be run in hoomd: #259

17. *New pair potential*: Morse potential for particles of varying diameters (pair.morse)

18. *New command*: run_upto will run a simulation up to a given time step number (handy for breaking long simulations up into many independent jobs)

19. *New feature*: HOOMD on the CPU is now accelerated with OpenMP.

20. *New feature*: integrate.mode_minimize_fire performs energy minimization using the FIRE algorithm

21. *New feature*: analyze.msd can now accept an xml file specifying the initial particle positions (for restarting jobs)

22. *Improved feature*: analyze.imd now supports all IMD commands that VMD sends (pause, kill, change trate, etc.)

23. *New feature*: Pair potentials can now be given names, allowing multiple potentials of the same type to be logged separately. Additionally, potentials that are disabled and not applied to the system dynamics can be optionally logged.

24. *Performance improvements*: Simulation performance has been increased across the board, but especially when running systems with very low particle number densities.

25. *New hardware support*: 0.9.0 and newer support Fermi GPUs

26. *Deprecated hardware support*: 0.9.x might continue run on compute#1 GPUs but that hardware is no longer officially supported

27. *New script command*: group.tag_list() takes a python list of particle tags and creates a group

28. *New script command*: compute.thermo() computes thermodynamic properties of a group of particles for logging

29. *New feature*: dump.dcd can now optionally write out only those particles that belong to a specified group

Changes that will break jobs scripts written for 0.8.x

1. Integration routines have changed significantly to enable new use cases. Where scripts previously had commands like:

```
integrate.nve(dt=0.005)
```

they now need

```
all = group.all()
integrate.mode_standard(dt=0.005)
integrate.nve(group=all)
```

. Integrating only specific groups of particles enables simulations to fix certain particles in place or integrate different parts of the system at different temperatures, among many other possibilities.

2. sorter.set_params no longer takes the ''bin_width'' argument. It is replaced by a new ''grid'' argument, see the documentation for details.

3. conserved_quantity is no longer a quantity available for logging. Instead log the nvt reservoir energy and compute the total conserved quantity in post processing.

Bug/fixes small enhancements

1. Fixed a bug where boost#38 is not found on some machines

2. dump.xml now has an option to write particle accelerations

3. Fixed a bug where periods like 1e6 were not accepted by updaters

4. Fixed a bug where bond.fene forces were calculated incorrectly between particles of differing diameters

5. Fixed a bug where bond.fene energies were computed incorrectly when running on the GPU

6. Fixed a bug where comments in hoomd xml files were not ignored as they aught to be: #331

7. It is now possible to prevent bond exclusions from ever being added to the neighbor list: #338

8. init.create_random_polymers can now generate extremely dense systems and will warn the user about large memory usage

9. variant.linear_interp now accepts a user-defined zero (handy for breaking long simulations up into many independent jobs)

10. Improved installation and compilation documentation

11. Integration methods now silently ignore when they are given an empty group

12. Fixed a bug where disabling all forces resulted in some forces still being applied

13. Integrators now behave in a reasonable way when given empty groups

14. Analyzers now accept a floating point period

15. run() now aborts immediately if limit_hours=0 is specified.

16. Pair potentials that diverge at r=0 will no longer result in invalid simulations when the leading coefficients are set to zero.

17. integrate.bdnvt can now tally the energy transferred into/out of the "reservoir", allowing energy conservation to be monitored during bd simulation runs.

18. Most potentials now prevent NaN results when computed for overlapping particles

19. Stopping a simulation from a callback or time limit no longer produces invalid simulations when continued

20. run() commands limited with limit_hours can now be set to only stop on given timestep multiples

21. Worked around a compiler bug where pair.morse would crash on Fermi GPUs

22. ULF stability improvements for G200 GPUs.

Version 0.8.2 (2009-09-10)

Note: only major changes are listed here.

New features

1. Quantities that vary over time can now be specified easily in scripts with the variant.linear_interp command.

2. Box resizing updater (update.box_resize) command that uses the time varying quantity command to grow or shrink the simulation box.

3. Individual run() commands can be limited by wall-clock time

4. Angle forces can now be specified

5. Dihedral forces can now be specified

6. Improper forces can now be specified

7. 1-3 and 1-4 exclusions from the cutoff pair force can now be chosen

8. New command line option: –minimize-cpu-usage cuts the CPU usage of HOOMD down to 10% of one CPU core while only decreasing overall performance by 10%

9. Major changes have been made in the way HOOMD chooses the device on which to run (all require CUDA 2.2 or newer)

   • there are now checks that an appropriate NVIDIA drivers is installed

   • running without any command line options will now correctly revert to running on the CPU if no capable GPUs are installed

   • when no gpu is explicitly specified, the default choice is now prioritized to choose the fastest GPU and one that is not attached to a display first

   • new command line option: –ignore-display-gpu will prevent HOOMD from executing on any GPU attached to a display

   • HOOMD now prints out a short description of the GPU(s) it is running on

   • on linux, devices can be set to compute-exclusive mode and HOOMD will then automatically choose the first free GPU (see the documentation for details)

10. nlist.reset_exclusions command to control the particles that are excluded from the neighbor list

Bug/fixes small enhancements

1. Default block size change to improve stability on compute#3 devices

2. ULF workaround on GTX 280 now works with CUDA 2.2

3. Standalone benchmark executables have been removed and replaced by in script benchmarking commands

4. Block size tuning runs can now be performed automatically using the python API and results can be saved on the local machine

5. Fixed a bug where GTX 280 bug workarounds were not properly applied in CUDA 2.2

6. The time step read in from the XML file can now be optionally overwritten with a user-chosen one

7. Added support for CUDA 2.2

8. Fixed a bug where the WCA forces included in bond.fene had an improper cutoff

9. Added support for a python callback to be executed periodically during a run()

10. Removed demos from the hoomd downloads. These will be offered separately on the webpage now to keep the required download size small.

11. documentation improvements

12. Significantly increased performance of dual-GPU runs when build with CUDA 2.2 or newer

13. Numerous stability and performance improvements

14. Temperatures are now calculated based on 3N-3 degrees of freedom. See #283 for a more flexible system that is coming in the future.

15. Emulation mode builds now work on systems without an NVIDIA card (CUDA 2.2 or newer)

16. HOOMD now compiles with CUDA 2.3

17. Fixed a bug where uninitialized memory was written to dcd files

18. Fixed a bug that prevented the neighbor list on the CPU from working properly with non-cubic boxes

19. There is now a compile time hack to allow for more than 4 exclusions per particle

20. Documentation added to aid users in migrating from LAMMPS

21. hoomd_script now has an internal version number useful for third party scripts interfacing with it

22. VMD#8.7 is now found by the live demo scripts

23. live demos now run in vista 64-bit

24. init.create_random_polymers can now create polymers with more than one type of bond

Version 0.8.1 (2009-03-24)

Note: only major changes are listed here.

New features

1. Significant performance enhancements

2. New build option for compiling on UMich CAC clusters: ENABLE_CAC_GPU_ID compiles HOOMD to read in the *$CAC_GPU_ID* environment variable and use it to determine which GPUs to execute on. No –gpu command line required in job scripts any more.

3. Particles can now be assigned a *non-unit mass*

4. *init.reset()* command added to allow for the creation of a looped series of simulations all in python

5. *dump.pdb()* command for writing PDB files

6. pair.lj now comes with an option to *shift* the potential energy to 0 at the cutoff

7. pair.lj now comes with an opiton to *smoothly switch* both the *potential* and *force* to 0 at the cutoff with the XPLOR smoothing function

8. *Gaussian pair potential* computation added (pair.gauss)

9. update and analyze commands can now be given a function to determine a non-linear rate to run at

10. analyze.log, and dump.dcd can now append to existing files

Changes that will break scripts from 0.8.0

1. *dump.mol2()* has been changed to be more consistent with other dump commands. In order to get the same result as the previous behavior, replace

```
dump.mol2(filename="file.mol2")
```

with

```
mol2 = dump.mol2()
mol2.write(filename="file.mol2")
```

2. Grouping commands have been moved to their own package for organizational purposes. *group_all()* must now be called as *group.all()* and similarly for tags and type.

Bug/fixes small enhancements

1. Documentation updates

2. DCD file writing no longer crashes HOOMD in windows

3. !FindBoost.cmake is patched upstream. Use CMake 2.6.3 if you need BOOST_ROOT to work correctly

4. Validation tests now run with –gpu_error_checking

5. ULF bug workarounds are now enabled only on hardware where they are needed. This boosts performance on C1060 and newer GPUs.

6. !FindPythonLibs now always finds the shared python libraries, if they exist

7. "make package" now works fine on mac os x

8. Fixed erroneously reported dangerous neighbor list builds when using –mode=cpu

9. Small tweaks to the XML file format.

10. Numerous performance enhancements

11. Workaround for ULF on compute#1 devices in place

12. dump.xml can now be given the option "all=true" to write all fields

13. total momentum can now be logged by analyze.log

14. HOOMD now compiles with boost#38 (and hopefully future versions)

15. Updaters can now be given floating point periods such as 1e5

16. Additional warnings are now printed when HOOMD is about to allocate a large amount of memory due to the specification of an extremely large box size

17. run() now shows up in the documentation index

18. Default sorter period is now 100 on CPUs to improve performance on chips with small caches

Version 0.8.0 (2008-12-22)

Note: only major changes are listed here.

New features

1. Addition of FENE bond potential

2. Addition of update.zero_momentum command to zero a system's linear momentum

3. Brownian dynamics integration implemented

4. Multi-GPU simulations

5. Particle image flags are now tracked. analyze.msd command added to calculate the mean squared displacement.

Changes that will break scripts from 0.7.x

1. analyze.log quantity names have changed

Bug/fixes small enhancements

1. Performance of the neighbor list has been increased significantly on the GPU (overall performance improvements are approximately 10%)

2. Profile option added to the run() command

3. Warnings are now correctly printed when negative coefficients are given to bond forces

4. Simulations no longer fail on G200 cards

5. Mac OS X binaries will be provided for download: new documentation for installing on Mac OS x has been written

6. Two new demos showcasing large systems

7. Particles leaving the simulation box due to bad initial conditions now generate an error

8. win64 installers will no longer attempt to install on win32 and vice-versa

9. neighborlist check_period now defaults to 1

10. The elapsed time counter in run() now continues counting time over multiple runs.

11. init.create_random_polymers now throws an error if the bond length is too small given the specified separation radii

12. Fixed a bug where a floating point value for the count field in init.create_random_polymers produced an error

13. Additional error checking to test if particles go NaN

14. Much improved status line printing for identifying hoomd_script commands

15. Numerous documentation updates

16. The VS redistributable package no longer needs to be installed to run HOOMD on windows (these files are distributed with HOOMD)

17. Now using new features in doxygen#5.7 to build pdf user documentation for download.

18. Performance enhancements of the Lennard-Jones pair force computation, thanks to David Tarjan

19. A header prefix can be added to log files to make them more gnuplot friendly

20. Log quantities completely revamped. Common quantities (i.e. kinetic energy, potential energy can now be logged in any simulation)

21. Particle groups can now be created. Currently only analyze.msd makes use of them.

22. The CUDA toolkit no longer needs to be installed to run a packaged HOOMD binary in windows.

23. User documentation can now be downloaded as a pdf.

24. Analyzers and updaters now count time 0 as being the time they were created, instead of time step 0.

25. Added job test scripts to aid in validating HOOMD

26. HOOMD will now build with default settings on a linux/unix-like OS where the boost static libraries are not installed, but the dynamic ones are.

Version 0.7.1 (2008-09-12)

1. Fixed bug where extremely large box dimensions resulted in an argument error - ticket:118

2. Fixed bug where simulations ran incorrectly with extremely small box dimensions - ticket:138

Version 0.7.0 (2008-08-12)

Note: only major changes are listed here.

1. Stability and performance improvements.

2. Cleaned up the hoomd_xml file format.

3. Improved detection of errors in hoomd_xml files significantly.

4. Users no longer need to manually specify HOOMD_ROOT, unless their installation is non-standard

5. Particle charge can now be read in from a hoomd_xml file

6. Consistency changes in the hoomd_xml file format: HOOMD 0.6.0 XML files are not compatible. No more compatibility breaking changes are planned after 0.7.0

7. Enabled parallel builds in MSVC for faster compilation times on multicore systems

8. Numerous small bug fixes

9. New force compute for implementing walls

10. Documentation updates

11. Support for CUDA 2.0

12. Bug fixed allowing simulations with no integrator

13. Support for boost#35.0

14. Cleaned up GPU code interface

15. NVT integrator now uses tau (period) instead of Q (the mass of the extra degree of freedom).

16. Added option to NVE integration to limit the distance a particle moves in a single time step

17. Added code to dump system snapshots in the DCD file format

18. Particle types can be named by strings

19. A snapshot of the initial configuration can now be written in the .mol2 file format

20. The default build settings now enable most of the optional features

21. Separated the user and developer documentation

22. Mixed polymer systems can now be generated inside HOOMD

23. Support for CMake 2.6.0

24. Wrote the user documentation

25. GPU selection from the command line

26. Implementation of the job scripting system

27. GPU can now handle neighbor lists that overflow

28. Energies are now calculated

29. Added a logger for logging energies during a simulation run

30. Code now actually compiles on Mac OS X

31. Benchmark and demo scripts now use the new scripting system

32. Consistent error message format that is more visible.

33. Multiple types of bonds each with the own coefficients are now supported

34. Added python scripts to convert from HOOMD's XML file format to LAMMPS input and dump files

35. Fixed a bug where empty xml nodes in input files resulted in an error message

36. Fixed a bug where HOOMD seg faulted when a particle left the simulation , vis=True)* is now a convenient short hand for what was previously box now works fine on mac os x

37. Fixed erroneously reported dangerous neighbor list builds when using –mode=cpu

38. Small tweaks to the XML file format.

39. Numerous performance enhancements

40. Workaround for ULF on compute#1 devices in place

41. dump.xml can now be given the option

2.4 Command line options

2.4.1 Overview

Arguments are processed in *hoomd.context.initialize()*. Call *hoomd.context.initialize()* immediately after importing hoomd so that the requested MPI and GPU options can be initialized as early as possible.

There are two ways to specify arguments.

1. On the command line: `python script.py [options]`:

```
import hoomd
hoomd.context.initialize()
```

2. Within your script:

```
import hoomd
hoomd.context.initialize("[options]")
```

With no arguments, *hoomd.context.initialize()* will attempt to parse **all** arguments from the command line, whether it understands them or not. When you pass a string, it ignores the command line (`sys.argv`) and parses the given string as if it were issued on the command line. In jupyter notebooks, use `context.initialize("")` to avoid errors from jupyter specific command line arguments.

2.4.2 Options

- **no options given**

    hoomd will automatically detect the fastest GPU and run on it, or fall back on the CPU if no GPU is found.

- **-h, –help**

    print a description of all the command line options

- **–mode=**{cpu | gpu}

    force hoomd to run either on the cpu or gpu

- **–gpu=**#

    specify the GPU id or comma-separated list of GPUs (with NVLINK) that hoomd will use. Implies `--mode=gpu`.

- **–ignore-display-gpu**

    prevent hoomd from using any GPU that is attached to a display

- **–minimize-cpu-usage**

    minimize the CPU usage of hoomd when it runs on a GPU at reduced performance

- **–gpu_error_checking**

    enable error checks after every GPU kernel call

- **–notice-level=**#

    specifies the level of notice messages to print

- **–msg-file=**filename

    specifies a file to write messages (the file is overwritten)

- **–single-mpi**

    allow single-threaded HOOMD builds in MPI jobs

- **–user**

    user options

- *MPI only options*

    - **–nx=**#

        Number of domains along the x-direction

    - **–ny=**#

        Number of domains along the y-direction

    - **–nz=**#

        Number of domains along the z-direction

    - **–linear**

        Force a slab (1D) decomposition along the z-direction

    - **–nrank=**#

        Number of ranks per partition

    - **–shared-msg-file=**prefix

        specifies the prefix of files to write per-partition output to (filename: *prefix.<partition_id>*)

- *Option available only when compiled with TBB support*

    - **–nthreads=**#

        Number of TBB threads to use, by default use all CPUs in the system

2.4.3 Detailed description

Control hoomd execution

HOOMD-blue can run on the CPU or the GPU. To control which, set the `--mode` option on the script command line. Valid settings are `cpu` and `gpu`:

```
python script.py --mode=cpu
```

When `--mode` is set to `gpu` and no other options are specified, hoomd will choose a GPU automatically. It will prioritize the GPU choice based on speed and whether it is attached to a display. Unless you take steps to configure your system (see below), then running a second instance of HOOMD-blue will place it on the same GPU as the first. HOOMD-blue will run correctly with more than one simulation on a GPU as long as there is enough memory, but at reduced performance.

You can select the GPU on which to run using the `--gpu` command line option:

```
python script.py --gpu=1
```

Note: `--gpu` implies `--mode=gpu`. To find out which id is assigned to each GPU in your system, download the CUDA SDK for your system from http://www.nvidia.com/object/cuda_get.html and run the *deviceQuery* sample.

If you run a script without any options:

```
python script.py
```

hoomd first checks if there are any GPUs in the system. If it finds one or more, it makes the same automatic choice described previously. If none are found, it runs on the CPU.

Multi-GPU (and multi-CPU) execution with MPI

HOOMD-blue uses MPI domain decomposition for parallel execution. Execute python with `mpirun`, `mpiexec`, or whatever the appropriate launcher is on your system. For more information, see *MPI domain decomposition*:

```
mpirun -n 8 python script.py
```

All command line options apply to MPI execution in the same way as single process runs.

When `n > 1` and no explicit GPU is specified, HOOMD uses the the local MPI rank to assign GPUs to ranks on each node. This is the default behavior and works on most cluster schedulers.

Multi-GPU execution with NVLINK

You can run HOOMD on multiple GPUs in the same compute node that are connected with NVLINK. To find out if your node supports it, run:

```
nvidia-smi -m topo
```

If the GPUs *are* connected by NVLINK, launch HOOMD with:

```
python script.py --gpu=0,1,2
```

to execute on GPUs 0,1 and 2. For multi-GPU execution it is required that all GPUs have the same compute capability >= 6.0. Not all kernels are currently NVLINK enabled; performance may depend on the subset of features used.

Multi-GPU execution with NVLINK may be combined with MPI parallel execution (see above). It is especially beneficial when further decomposition of the domain using MPI is not feasible or slower, but speed-ups are still possible.

Automatic free GPU selection

You can configure your system for HOOMD-blue to choose free GPUs automatically when each instance is run. To utilize this capability, the system administrator (root) must first use the `nvidia-smi` utility to enable the compute-exclusive mode on all GPUs in the system. With this mode enabled, running hoomd with no options or with the `--mode=gpu` option will result in an automatic choice of the first free GPU from the prioritized list.

The compute-exclusive mode allows *only* a **single CUDA application** to run on each GPU. If you have 4 compute-exclusive GPUs available in the system, executing a fifth instance of hoomd with `python script.py` will result in the error: `***Error! no CUDA-capable device is available.`

Most compute clusters do not support automatic free GPU selection. Insteady the schedulers pin jobs to specific GPUs and bind the host processes to attached cores. In this case, HOOMD uses the rank-based GPU selection described above. HOOMD only applies exclusive mode automatic GPU selection when built without MPI support (ENABLE_MPI=off) or executing on a single rank.

Minimize the CPU usage of HOOMD-blue

When hoomd is running on a GPU, it uses 100% of one CPU core by default. This CPU usage can be decreased significantly by specifying the `--minimize-cpu-usage` command line option:

```
python script.py --minimize-cpu-usage
```

Enabling this option incurs a 10% overall performance reduction, but the CPU usage of hoomd is reduced to only 10% of a single CPU core.

Prevent HOOMD-blue from running on the display GPU

Running hoomd on the display GPU works just fine, but it does moderately slow the simulation and causes the display to lag. If you wish to prevent hoomd from running on the display, add the `--ignore-display-gpu` command line flag:

```
python script.py --ignore-display-gpu
```

Enable error checking on the GPU

Detailed error checking is off by default to enable the best performance. If you have trouble that appears to be caused by the failure of a calculation to run on the GPU, you should run with GPU error checking enabled to check for any errors returned by the GPU.

To do this, run the script with the `--gpu_error_checking` command line option:

```
python script.py --gpu_error_checking
```

Control message output

You can adjust the level of messages written to `sys.stdout` by a running hoomd script. Set the notice level to a high value to help debug where problems occur. Or set it to a low number to suppress messages. Set it to 0 to remove all notices (warnings and errors are still output):

```
python script.py --notice-level=10
```

All messages (notices, warnings, and errors) can be redirected to a file. The file is overwritten:

```
python script.py --msg-file=messages.out
```

In MPI simulations, messages can be aggregated per partition. To write output for partition 0,1,.. in files `messages.0`, `messages.1`, etc., use:

```
mpirun python script.py --shared-msg-file=messages
```

Set the MPI domain decomposition

When no MPI options are specified, HOOMD uses a minimum surface area selection of the domain decomposition strategy:

```
mpirun -n 8 python script.py
# 2x2x2 domain
```

The linear option forces HOOMD-blue to use a 1D slab domain decomposition, which may be faster than a 3D decomposition when running jobs on a single node:

```
mpirun -n 4 python script.py --linear
# 1x1x4 domain
```

You can also override the automatic choices completely:

```
mpirun -n 4 python script.py --nx=1 --ny=2 --nz=2
# 1x2x2 domain
```

You can group multiple MPI ranks into partitions, to simulate independent replicas:

```
mpirun -n 12 python script.py --nrank=3
```

This sub-divides the total of 12 MPI ranks into four independent partitions, with to which 3 GPUs each are assigned.

User options

User defined options may be passed to a job script via `--user` and retrieved by calling *hoomd.option.get_user()*. For example, if hoomd is executed with:

```
python script.py --gpu=2 --ignore-display-gpu --user="--N=5 --rho=0.5"
```

then *hoomd.option.get_user()* will return `['--N=5', '--rho=0.5']`, which is a format suitable for processing by standard tools such as `optparse`.

Execution with CPU threads (Intel TBB support)

Some classes in HOOMD support CPU threads using Intel's Threading Building Blocks (TBB). TBB can speed up the calculation considerably, depending on the number of CPU cores available in the system. If HOOMD was compiled with support for TBB, the number of threads can be set. On the command line, this is done using:

```
python script.py --mode=cpu --nthreads=20
```

Alternatively, the same option can be passed to `hoomd.context.initialize()`, and the number of threads can be updated any time using `hoomd.option.set_num_threads()`. If no number of threads is specified, TBB by default uses all CPUs in the system. For compatibility with OpenMP, HOOMD also honors a value set in the environment variable **OMP_NUM_THREADS**.

2.5 Units

HOOMD-blue stores and computes all values in a system of generic, fully self-consistent set of units. No conversion factors need to be applied to values at every step. For example, a value with units of force comes from dividing energy by distance.

2.5.1 Fundamental Units

The three fundamental units are:

- distance - $\mathcal{D}$
- energy - $\mathcal{E}$
- mass - $\mathcal{M}$

All other units that appear in HOOMD-blue are derived from these. Values can be converted into any other system of units by assigning the desired units to $\mathcal{D}$, $\mathcal{E}$, and $\mathcal{M}$ and then multiplying by the appropriate conversion factors.

The standard *Lennard-Jones* symbols σ and ϵ are intentionally not referred to here. When you assign a value to ϵ in hoomd, for example, you are assigning it in units of energy: $\epsilon = 5\mathcal{E}$. ϵ is **NOT** the unit of energy - it is a value with units of energy.

2.5.2 Temperature (thermal energy)

HOOMD-blue accepts all temperature inputs and provides all temperature output values in units of energy: kT, where k is Boltzmann's constant. When using physical units, the value k_B is determined by the choices for distance, energy, and mass. In reduced units, one usually reports the value $T^* = \frac{kT}{\mathcal{E}}$.

Most of the argument inputs in HOOMD take the argument name `kT` to make it explicit. A few areas of the code may still refer to this as `temperature`.

2.5.3 Charge

The unit of charge used in HOOMD-blue is also reduced, but is not represented using just the 3 fundamental units - the permittivity of free space ε_0 is also present. The units of charge are: $(4\pi\varepsilon_0\mathcal{D}\mathcal{E})^{1/2}$. Divide a given charge by this quantity to convert it into an input value for HOOMD-blue.

2.5.4 Common derived units

Here are some commonly used derived units:

- time - $\tau = \sqrt{\frac{\mathcal{M}\mathcal{D}^2}{\mathcal{E}}}$
- volume - $\mathcal{D}^3$
- velocity - $\frac{\mathcal{D}}{\tau}$
- momentum - $\mathcal{M}\frac{\mathcal{D}}{\tau}$
- acceleration - $\frac{\mathcal{D}}{\tau^2}$
- force - $\frac{\mathcal{E}}{\mathcal{D}}$
- pressure - $\frac{\mathcal{E}}{\mathcal{D}^3}$

2.5.5 Example physical units

There are many possible choices of physical units that one can assign. One common choice is:

- distance - $\mathcal{D} = \mathrm{nm}$
- energy - $\mathcal{E} = \mathrm{kJ/mol}$
- mass - $\mathcal{M} = \mathrm{amu}$

Derived units / values in this system:

- time - picoseconds
- velocity - nm/picosecond
- k = 0.00831445986144858 kJ/mol/Kelvin

2.6 Periodic boundary conditions

2.6.1 Introduction

All simulations executed in HOOMD-blue occur in a triclinic simulation box with periodic boundary conditions in all three directions. A triclinic box is defined by six values: the extents L_x, L_y and L_z of the box in the three directions, and three tilt factors xy, xz and yz.

The parameter matrix $\mathbf{h}$ is defined in terms of the lattice vectors $\vec{a}_1$, $\vec{a}_2$ and $\vec{a}_3$:

$$\mathbf{h} \equiv (\vec{a}_1, \vec{a}_2, \vec{a}_3)$$

By convention, the first lattice vector $\vec{a}_1$ is parallel to the unit vector $\vec{e}_x = (1, 0, 0)$. The tilt factor xy indicates how the second lattice vector $\vec{a}_2$ is tilted with respect to the first one. It specifies many units along the x-direction correspond to one unit of the second lattice vector. Similarly, xz and yz indicate the tilt of the third lattice vector $\vec{a}_3$ with respect to the first and second lattice vector.

2.6.2 Definitions and formulas for the cell parameter matrix

The full cell parameter matrix is:

$$\mathbf{h} \quad = \quad \begin{pmatrix} L_x & xyL_y & xzL_z \\ 0 & L_y & yzL_z \\ 0 & 0 & L_z \end{pmatrix}$$

The tilt factors xy, xz and yz are dimensionless. The relationships between the tilt factors and the box angles α, β and γ are as follows:

$$\cos\gamma \equiv \cos(\angle\vec{a}_1, \vec{a}_2) \quad = \quad \frac{xy}{\sqrt{1 + xy^2}}$$

$$\cos\beta \equiv \cos(\angle\vec{a}_1, \vec{a}_3) \quad = \quad \frac{xz}{\sqrt{1 + xz^2 + yz^2}}$$

$$\cos\alpha \equiv \cos(\angle\vec{a}_2, \vec{a}_3) \quad = \quad \frac{xy \cdot xz + yz}{\sqrt{1 + xy^2}\sqrt{1 + xz^2 + yz^2}}$$

Given an arbitrarily oriented lattice with box vectors $\vec{v}_1, \vec{v}_2, \vec{v}_3$, the HOOMD-blue box parameters for the rotated box can be found as follows.

$$L_x \quad = \quad v_1$$

$$a_{2x} \quad = \quad \frac{\vec{v}_1 \cdot \vec{v}_2}{v_1}$$

$$L_y \quad = \quad \sqrt{v_2^2 - a_{2x}^2}$$

$$xy \quad = \quad \frac{a_{2x}}{L_y}$$

$$L_z \quad = \quad \vec{v}_3 \cdot \frac{\vec{v}_1 \times \vec{v}_2}{|\vec{v}_1 \times \vec{v}_2|}$$

$$a_{3x} \quad = \quad \frac{\vec{v}_1 \cdot \vec{v}_3}{v_1}$$

$$xz \quad = \quad \frac{a_{3x}}{L_z}$$

$$yz \quad = \quad \frac{\vec{v}_2 \cdot \vec{v}_3 - a_{2x}a_{3x}}{L_yL_z}$$

Example:

```
# boxMatrix contains an arbitrarily oriented right-handed box matrix.
v[0] = boxMatrix[:,0]
v[1] = boxMatrix[:,1]
v[2] = boxMatrix[:,2]
Lx = numpy.sqrt(numpy.dot(v[0], v[0]))
a2x = numpy.dot(v[0], v[1]) / Lx
Ly = numpy.sqrt(numpy.dot(v[1],v[1]) - a2x*a2x)
xy = a2x / Ly
v0xv1 = numpy.cross(v[0], v[1])
v0xv1mag = numpy.sqrt(numpy.dot(v0xv1, v0xv1))
Lz = numpy.dot(v[2], v0xv1) / v0xv1mag
a3x = numpy.dot(v[0], v[2]) / Lx
xz = a3x / Lz
yz = (numpy.dot(v[1],v[2]) - a2x*a3x) / (Ly*Lz)
```

2.6.3 Initializing a system with a triclinic box

You can specify all parameters of a triclinic box in a GSD file.

You can also pass a *hoomd.data.boxdim* argument to the constructor of any initialization method. Here is an example for *hoomd.deprecated.init.create_random()*:

```
init.create_random(box=data.boxdim(L=18, xy=0.1, xz=0.2, yz=0.3), N=1000))
```

This creates a triclinic box with edges of length 18, and tilt factors $xy = 0.1$, $xz = 0.2$ and $yz = 0.3$.

You can also specify a 2D box to any of the initialization methods:

```
init.create_random(N=1000, box=data.boxdim(xy=1.0, volume=2000, dimensions=2), min_
→dist=1.0)
```

2.6.4 Change the simulation box

The triclinic unit cell can be updated in various ways.

Resizing the box

The simulation box can be gradually resized during a simulation run using *hoomd.update.box_resize*.

To update the tilt factors continuously during the simulation (shearing the simulation box with **Lees-Edwards** boundary conditions), use:

```
update.box_resize(xy = variant.linear_interp([(0,0), (1e6, 1)]))
```

This command applies shear in the xy -plane so that the angle between the x and y-directions changes continuously from 0 to $45°$ during 10^6 time steps.

hoomd.update.box_resize can change any or all of the six box parameters.

NPT or NPH integration

In a constant pressure ensemble, the box is updated every time step, according to the anisotropic stresses in the system. This is supported by:

- *hoomd.md.integrate.npt*
- *hoomd.md.integrate.nph*

2.7 Rotational degrees of freedom

2.7.1 Overview

HOOMD-blue natively supports the integration of rotational degrees of freedom. Every particle in a hoomd simulation may have rotational degrees of freedom. When any torque-producing potential or constraint is defined in the system, integrators automatically integrate both the rotational and translational degrees of freedom of the system. Anisotropic integration can also be explicitly enabled or disabled through the `aniso` argument of *hoomd.md.integrate.mode_standard*. *hoomd.md.pair.gb*, *hoomd.dem*, *hoomd.md.constrain.rigid* are examples of potentials and constraints that produce torques on particles.

The integrators detect what rotational degrees of freedom exist per particle. Each particle has a diagonal moment of inertia tensor that specifies the moment of inertia about the 3 principle axes in the particle's local reference frame.

Integrators only operate on rotational degrees of freedom about axes where the moment of inertia is non-zero. Ensure that you set appropriate moments of inertia for all particles that have them in the system.

Particles have a number of properties related to rotation accessible using the particle data API (`hoomd.data`):

- orientation - Quaternion to rotate the particle from its base orientation to its current orientation, in the order $(real, imag_x, imag_y, imag_z)$

- angular_momentum - Conjugate quaternion representing the particle's angular momentum

- moment_inertia - principal moments of inertia (I_{xx}, I_{yy}, I_{zz})

- net_torque - net torque on the particle in the global reference frame

GSD files store the orientation, moment of inertia, and angular momentum of particles.

2.7.2 Quaternions for angular momentum

Particle angular momenta are stored in quaternion form as defined in Kamberaj 2005 : the angular momentum quaternion $\mathbf{P}$ is defined with respect to the orientation quaternion of the particle $\mathbf{q}$ and the angular momentum of the particle, lifted into pure imaginary quaternion form $\mathbf{S}^{(4)}$ as:

$$\mathbf{P} = 2\mathbf{q} \times \mathbf{S}^{(4)}$$

in other words, the angular momentum vector $\vec{S}$ with respect to the principal axis of the particle is

$$\vec{S} = \frac{1}{2} im(\mathbf{q}^* \times \mathbf{P})$$

where $\mathbf{q}^*$ is the conjugate of the particle's orientation quaternion and $\times$ is quaternion multiplication.

2.8 Neighbor lists

2.8.1 Overview

Neighbor lists accelerate the search for pairs of atoms that are within a certain *cutoff radius* of each other. They are most commonly used in `hoomd.md.pair` to accelerate the calculation of pair forces between atoms. This significantly reduces the number of pairwise distances that are evaluated, which is $O(N^2)$ if all possible pairs are checked. A small *buffer radius* (skin layer) r_buff is typically added to the cutoff radius so that the neighbor list can be computed less frequently. The neighbor list must only be rebuilt any time a particle diffuses r_buff/2. However, increasing r_buff also increases the number of particles that are included in the neighbor list, which slows down the pair force evaluation. A balance can be obtained between the two by optimizing r_buff.

A simple neighbor list is built by checking all possible pairs of atoms periodically, which makes the overall algorithm $O(N^2)$. The neighbor list can be computed more efficiently using an *acceleration structure* which further reduces the complexity of the problem. There are three accelerators implemented in HOOMD-blue:

- *Cell list*

- *Stenciled cell list*

- *LBVH tree*

More details for each can be found below and in M.P. Howard et al. 2016 and M.P. Howard et al. 2019 . Each neighbor list style has its own advantages and disadvantages that the user should consider on a case-by-case basis.

2.8.2 Cell list

The cell-list neighbor list (`hoomd.md.nlist.cell`) spatially sorts particles into bins that are sized by the **largest** cutoff radius of all pair potentials attached to the neighbor list. For example, in the figure below, there are small A particles and large B particles. The bin size is based on the cutoff radius of the largest particles r_{BB}. To find neighbors, each particle searches the 27 cells that are adjacent to its cell, which are shaded around each particle. Binning particles is $O(N)$, and so neighbor search from the cell list is also $O(N)$.
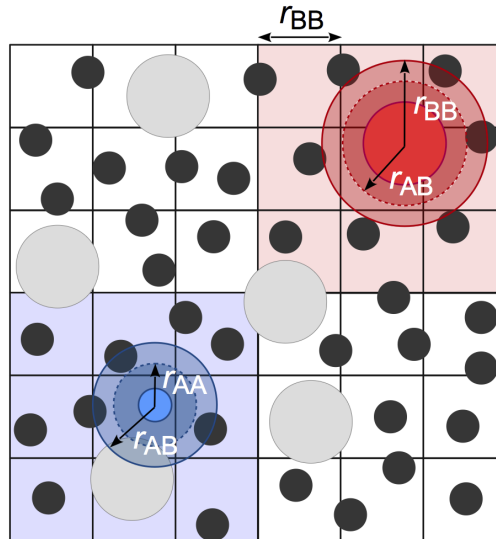
This method is very efficient for systems with nearly monodisperse cutoffs, but performance degrades for large cutoff radius asymmetries due to the significantly increased number of particles per cell and increased search volume. For example, the small A particles, who have a majority of neighbors who are also A particles within cutoff r_{AA} must now search through the full volume defined by r_{BB}. In practice, we have found that this neighbor list style is the best option for most users when the asymmetry between the largest and smallest cutoff radius is less than 2:1, but the performance of `hoomd.md.nlist.tree` may still be competitive at smaller asymmetries.

Note: Users may find that the cell-list neighbor list consumes a significant amount of memory, especially on CUDA devices. One cause of this can be non-uniform density distributions because the memory allocated for the cell list is proportional the maximum number of particles in any cell. Another common cause is large system volumes combined with small cutoffs, which results in a very large number of cells in the system. In these cases, consider using `hoomd.md.nlist.stencil` or `hoomd.md.nlist.tree`.

2.8.3 Stenciled cell list

Performance of the simple cell-list can be improved in the size asymmetric case by basing the bin size of the cell list on the **smallest** cutoff radius of all pair potentials attached to the neighbor list (P.J. in't Veld et al. 2008). From the previous example, the bin size is now based on r_{AA}. A *stencil* is then constructed on a per-pair basis that defines the bins to search. Some particles can now be excluded without distance check if they lie in bins outside the stencil. The small A particles only need to distance check other A particles in the dark blue cells (dashed outline). This reduces both the number of distances evaluations and the amount of particle data that is read.
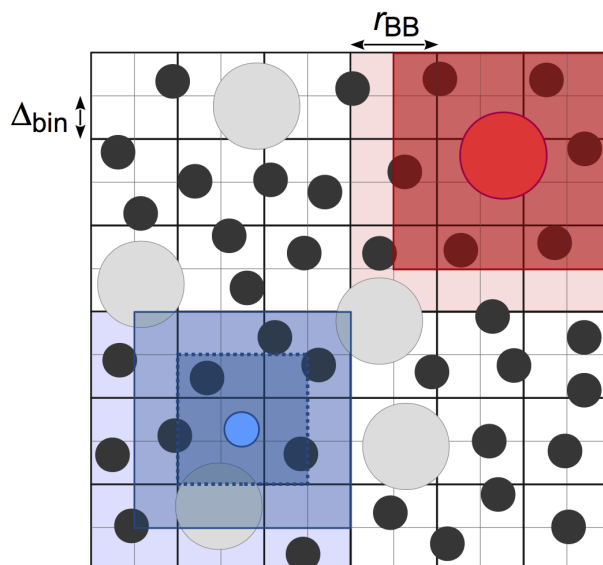
We have found that the stenciled cell list (`hoomd.md.nlist.stencil`) is most useful when a cell list performs well, but is too memory intensive. It may also be useful for some systems with modest size asymmetry or many types. The memory consumed by the stenciled cell list is typically much lower than that used for a comparable simple cell list because of the way the stencils constructed to query the cell list. However, this comes at the expense of higher register usage on CUDA devices, which may lead to reduced performance compared to the simple cell list in some cases depending on your CUDA device's architecture.

Note: Users may still find that the stenciled cell list consumes a significant amount of memory for systems with large volumes and small cutoffs. In this case, the bin size should be made larger (possibly at the expense of performance), or `hoomd.md.nlist.tree` should be used instead.

2.8.4 LBVH tree

Linear bounding volume hierarchies (LBVHs) are an entirely different approach to accelerating the neighbor search. LBVHs are binary tree structures that partition the system based on *objects* rather than space (see schematic below). This means that the memory they require scales with the number of particles in the system rather than the system volume, which may be particularly advantageous for large, sparse systems. Because of their lightweight memory footprint, LBVHs can also be constructed per-type, and this makes searching the trees very efficient in size asymmetric systems. The LBVH algorithm is *O(N* log *N)* to search the tree.
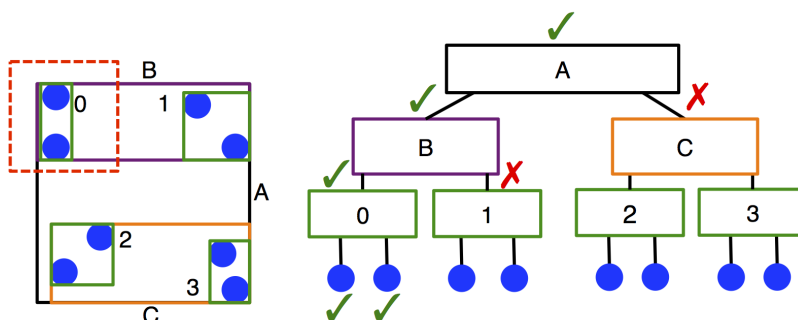
We have found that LBVHs (`hoomd.md.nlist.tree`) are very useful for systems with size asymmetry greater than 2:1 between the largest and smallest cutoffs. These conditions are typical of many colloidal systems. Addi-

tionally, LBVHs can be used advantageously in sparse systems or systems with large volumes, where they have less overhead and memory demands than cell lists. The performance of the LBVHs has been improved since their original implementation (see M.P. Howard et al. 2019 for details), making them more competitive for different types of systems.

2.8.5 Multiple neighbor lists

Multiple neighbor lists can be created to accelerate simulations where there is significant disparity in the pairwise cutoffs between pair potentials. If one pair force has a maximum cutoff radius much smaller than another pair force, the pair force calculation for the short cutoff will be slowed down considerably because many particles in the neighbor list will have to be read and skipped because they lie outside the shorter cutoff. Attaching each potential to a different neighbor list may improve performance of the pair force calculation at the expense of duplicate computation of the neighbor list. When using multiple neighbor lists, it may be advantageous to adopt two different neighbor list styles. For example, in a colloidal suspension of a small number of large colloids dispersed in many solvent particles, a modest performance gain may be achieved by computing the solvent-solvent neighbors using `hoomd.md.nlist.cell`, but the solvent-colloid and colloid-colloid interactions using `hoomd.md.nlist.tree`. Particles can be excluded from neighbor lists by setting their cutoff radius to `False` or a negative value.

2.9 MPI domain decomposition

2.9.1 Overview

HOOMD-blue supports multi-GPU (and multi-CPU) simulations using MPI. It uses a spatial domain decomposition approach similar to the one used by LAMMPS. Every GPU is assigned a sub-domain of the simulation box, the dimensions of which are calculated by dividing the lengths of the simulation box by the number of processors per dimension. These domain boundaries can also be adjusted to different fractional widths while still maintaining a 3d grid, which can be advantageous in systems with density gradients. The product of the number of processors along all dimensions must equal the number of processors in the MPI job. As in single-GPU simulations, there is a one-to-one mapping between host CPU cores (MPI ranks) and the GPUs.

Job scripts do not need to be modified to take advantage of multi-GPU execution. However, not all features are available in MPI mode. The list of single-GPU only features can be found below.

See J. Glaser et. al. 2015 for more implementation details.

2.9.2 Compilation

For detailed compilation instructions, see *Compile HOOMD-blue*.

Compilation flags pertinent to MPI simulations are:

- **ENABLE_MPI** (to enable multi-GPU simulations, must be set to b ON)
- **ENABLE_MPI_CUDA** (optional, enables CUDA-aware MPI library support, see below)

2.9.3 Usage

To execute a hoomd job script on multiple GPUs, run:

```
mpirun -n 8 python script.py --mode=gpu
```

This will execute HOOMD on 8 processors. HOOMD automatically detects which GPUs are available and assigns them to MPI ranks. The syntax and name of the `mpirun` command may be different between different MPI libraries and system architectures, check with your system documentation to find out what launcher to use. When running on multiple nodes, the job script must be available to all nodes via a network file system.

HOOMD chooses the best spatial sub-division according to a minimum-area rule. If needed, the dimensions of the decomposition be specified using the **linear**, **nx**, **ny** and **nz** *Command line options*. If your intention is to run HOOMD on a single GPU, you can invoke HOOMD with no MPI launcher:

```
python script.py
```

instead of giving the `-n 1` argument to `mpirun`.

> **Warning:** Some cluster environments do not allow this and require the MPI launcher be used even for single rank jobs.

HOOMD-blue can also execute on many **CPU cores** in parallel:

```
mpirun -n 16 python script.py --mode=cpu
```

2.9.4 GPU selection in MPI runs

HOOMD-blue uses information from `mpirun` to determine the *local rank* on a node (0,1,2,...). Each rank will use the GPU id matching the local rank modulus the number of GPUs on the node. In this mode, do not run more ranks per node than there are GPUs or you will oversubscribe the GPUs. This selection mechanism selects GPUs from within the set of GPUs provided by the cluster scheduler.

In some MPI stacks, such as Intel MPI, this information is unavailable and HOOMD falls back on selecting `gpu_id = global_rank % num_gpus_on_node` and issues a notice message. This mode only works on clusters where scheduling is performed by node (not by core) and there are a uniform number of GPUs on each node.

In any case, a status message is printed on startup that lists which ranks are using which GPU ids. You can use this to verify proper GPU selection.

2.9.5 Best practices

HOOMD-blue's multi-GPU performance depends on many factors, such as the model of the actual GPU used, the type of interconnect between nodes, whether the MPI library supports CUDA, etc. Below we list some recommendations for obtaining optimal performance.

System size

Performance depends greatly on system size. Runs with fewer particles per GPU will execute slower due to communications overhead. HOOMD-blue has decent strong scaling down to small numbers of particles per GPU, but to obtain high efficiency (more than 60%) typical benchmarks need 100,000 or more particles per GPU. You should benchmark your own system of interest with short runs to determine a reasonable range of efficient scaling behavior. Different potentials and/or cutoff radii can greatly change scaling behavior.

CUDA-aware MPI libraries

The main benefit of using a CUDA-enabled MPI library is that it enables intra-node peer-to-peer (P2P) access between several GPUs on the same PCIe root complex, which increases bandwidth. Secondarily, it may offer some additional optimization for direct data transfer between the GPU and a network adapter. To use these features with an MPI library that supports it, set ENABLE_MPI_CUDA to **ON** for compilation.

Currently, we recommend building with ENABLE_MPI_CUDA **OFF**. On MPI libraries available at time of release, enabling ENABLE_MPI_CUDA cuts performance in half. Systems with *GPUDirect RDMA* enabled improve on this somewhat, but even on such systems typical benchmarks still run faster with ENABLE_MPI_CUDA **OFF**.

GPUDirect RDMA

HOOMD does support *GPUDirect RDMA* with network adapters that support it (i.e. Mellanox) and compatible GPUs (Kepler), through a CUDA-aware MPI library (i.e. OpenMPI 1.7.5 or MVAPICH 2.0b GDR). On HOOMD's side, nothing is required beyond setting ENABLE_MPI_CUDA to **ON** before compilation. On the side of the MPI library, special flags may need to be set to enable *GPUDirect RDMA*, consult the documentation of your MPI library for that.

Slab decomposition

For small numbers of GPUs per job (typically <= 8 for cubic boxes) that are non-prime, the performance may be increased by using a slab decomposition. A one-dimensional decomposition is enforced if the --linear command line option (*Command line options*) is given.

Neighbor list buffer length (r_buff)

The optimum value of the **r_buff** value of the neighbor list may be different between single- and multi-GPU runs. In multi-GPU runs, the buffering length also determines the width of the ghost layer runs and sets the size of messages exchanged between the processors. To determine the optimum value, use *hoomd.md.nlist.nlist.tune()*. command with the same number of MPI ranks that will be used for the production simulation.

Running with multiple partitions (–nrank command-line option)

HOOMD-blue supports simulation of multiple independent replicas, with the same number of GPUs per replica. To enable multi-replica mode, and to partition the total number of ranks **N** into **p = N/n** replicas, where **n** is the number of GPUs per replica, invoke HOOMD-blue with the **–nrank=n** command line option (see *Command line options*).

Inside the command script, the current partition can be queried using *hoomd.comm.get_partition()*.

2.9.6 Dynamic load balancing

HOOMD-blue supports non-uniform domain decomposition for systems with density gradients. A static domain decomposition on a regular 3d grid but non-uniform widths can be constructed using *hoomd.comm.decomposition*. Here, either the number of processors in a uniform decomposition or the fractional widths of $n-1$ domains can be set. Dynamic load balancing can be applied to any domain decomposition either one time or periodically throughout the simulation using *hoomd.update.balance*. The domain boundaries are adjusted to attempt to place an equal number of particles on each rank. The overhead from periodically updating the domain boundaries is reasonably small, so most simulations with non-uniform particle distributions will benefit from periodic dynamic load balancing.

Troubleshooting

- **My simulation does not run significantly faster on exactly two GPUs compared to one GPU.** This is expected. HOOMD uses special optimizations for single-GPU runs, which means that there is no overhead due to MPI calls. The communication overhead can be 20-25% of the total performance, and is only incurred when running on more than one GPU.

- **I get a message saying "Bond incomplete"** In multi-GPU simulations, there is an implicit restriction on the maximal length of a single bond. A bond cannot be longer than half the local domain size. If this happens, an error is thrown. The problem can be fixed by running HOOMD on fewer processors, or with a larger box size.

- **Simulations with large numbers of nodes are slow.** In simulations involving many nodes, collective MPI calls can take a significant portion of the run time. To find out if these are limiting you, run the simulation with the `profile=True` option to the *hoomd.run()* command. One reason for slow performance can be the distance check, which, by default, is applied every step to check if the neighbor list needs to be rebuild. It requires synchronization between all MPI ranks and is therefore slow. See *hoomd.md.nlist.nlist.set_params()* to increase the interval (**check_period**) between distance checks, to improve performance.

- **My simulation crashes on multiple GPUs when I set ENABLE_MPI_CUDA=ON** First, check that cuda-aware MPI support is enabled in your MPI library. Usually this is determined at compile time of the MPI library. For MVAPICH2, HOOMD automatically sets the required environment variable **MV2_USE_CUDA=1**. If you are using *GPUDirect RDMA* in a dual-rail configuration, special considerations need to be taken to ensure correct GPU-core affinity, not doing so may result in crashing or slow simulations.

2.10 Autotuner

2.10.1 Overview

HOOMD-blue uses run-time autotuning to optimize GPU performance. Every time you run a hoomd script, hoomd starts autotuning values from a clean slate. Performance may vary during the first time steps of a simulation when the autotuner is scanning through possible values. Once the autotuner completes the first scan, performance will stabilize at optimized values. After approximately *period* steps, the autotuner will activate again and perform a quick scan to update timing data. With continual updates, tuned parameters will adapt to simulation conditions - so as you switch your simulation from NVT to NPT, compress the box, or change forces, the autotuner will keep everything running at optimal performance.

2.10.2 Benchmarking hoomd

Care must be taken in performance benchmarks. The initial warm up time of the tuner is significant, and performance measurements should only be taken after warm up. The total time needed for a scan may vary from system to system depending on parameters. For example, the `lj-liquid-bmark` script requires 10,000 steps for the initial tuning pass (2000 for subsequent updates). You can monitor the autotuner with the command line option `--notice-level=4`. Each tuner will print a status message when it completes the warm up period. The `nlist_binned` tuner will most likely take the longest time to complete.

When obtaining profile traces, disable the autotuner after the warm up period so that it does not decide to re-tune during the profile.

2.10.3 Controlling the autotuner

Default parameters should be sufficient for the autotuner to work well in almost any situation. Controllable parameters are:

- `period`: Approximate number of time steps before retuning occurs

- `enabled`: Boolean to control whether the autotuner is enabled. If disabled after the warm up period, no retuning will occur, but it will still use the found optimal values. If disabled during the warm up period, a warning is issued and the system will use non-optimal values.

The defaults are `period=100000`, and `enabled=True`. Other parameters can be set by calling *hoomd. option.set_autotuner_params()*. This period is short enough to pick up changes after just a few hundred thousand time steps, but long enough so that the performance loss of occasionally running at nonoptimal parameters is small (most per time step calls can complete tuning in less than 200 time steps).

2.11 Restartable jobs

2.11.1 Overview

The ideal restartable job is a single job script that can be resubmitted over and over again to the job queue system. Each time the job starts, it picks up where it left off the last time and continues running until it is done. You can put all the logic necessary to do this in the hoomd python script itself, keeping the submission script simple:

```
# job.sh
mpirun hoomd run.py
```

With a properly configured python script, `qsub job.sh` is all that is necessary to submit the first run, continue a previous job that exited cleanly, and continue one that was prematurely killed.

2.11.2 Elements of a restartable script

A restartable needs to:

- Choose between an initial condition and the restart file when initializing.

- Write a restart file periodically.

- Set a phase for all analysis, dump, and update commands.

- Use *hoomd.run_upto()* to skip over time steps that were run in previous job submissions.

- Use only commands that are restart capable.

- Optionally ensure that jobs cleanly exit before the job walltime limit.

Choose the appropriate initialization file

Let's assume that the initial condition for the simulation is in `init.gsd`, and `restart.gsd` is saved periodically as the job runs. A single *hoomd.init.read_gsd()* command will load the restart file if it exists, otherwise it will load the initial file. It is easiest to think about dump files, temperature ramps, etc... if `init.gsd` is at time step 0:

```
init.read_gsd(filename='init.gsd', restart='restart.gsd')
```

If you generate your initial configuration in python, you will need to add some logic to read `restart.gsd` if it exists or generate if not. This logic is left as an exercise to the reader.

Write restart files

You cannot predict when a hardware failure will cause your job to fail, so you need to save restart files at regular intervals as your run progresses. You will also need periodic restart files at a fast rate if you don't manage wall time to ensure clean job exits.

First, you need to select a restart period. The compute center you run on may offer a tool to help you determine an optimal restart period in minutes. A good starting point is to write a restart file every hour. Based on performance benchmarks, select a restart period in time steps:

```
dump.gsd(filename="restart.gsd", group=group.all(), truncate=True, period=10000,
→phase=0)
```

Use the phase option

Set a a `phase >= 0` for all analysis routines, file dumps, and updaters you use with period > 1 (the default is 0). With `phase >= 0`, these routines will continue to run in a restarted job on the correct timesteps as if the job had not been restarted.

Do not use, `phase=-1`, as then these routines will start running immediately when a restart job begins:

```
dump.dcd(filename="trajectory.dcd", period=1e6, phase=0)
analyze.log(filename='temperature.log', quantities=['temperature'], period=5000,
→phase=0)
zeroer= update.zero_momentum(period=1e6, phase=0)
```

Use run_upto

hoomd.run_upto() runs the simulation up to timestep n. Use this in restartable jobs to allow them to run a given number of steps, independent of the number of submissions needed to reach that:

```
run_upto(100e6)
```

Use restart capable commands

Most commands in hoomd that output to files are capable of appending to the end of a file so that restarted jobs continue adding data to the file as if the job had never been restarted.

However, not all features in hoomd are capable of restarting. Some are not even capable of appending to files. See the documentation for each individual command you use to tell whether it is compatible with restartable jobs. For those that are restart capable, do not set *overwrite=True*, or each time the job restarts it will erase the file and start writing a new one.

Some analysis routines in HOOMD-blue store internal state and may require a period that is commensurate with the restart period. See the documentation on the individual command you use to see if this is the case.

Cleanly exit before the walltime limit

Job queues will kill your job when it reaches the walltime limit. HOOMD can stop your run before that happens and give your job time to exit cleanly. Set the environment variable HOOMD_WALLTIME_STOP to enable this. Any *hoomd.run()* or *hoomd.run_upto()* command will exit before the specified time is reached. HOOMD monitors run performance and tries to ensure that it will end *before* HOOMD_WALLTIME_STOP. Set the variable to a unix

epoch time. For example in a job script that should run 12 hours, set `HOOMD_WALLTIME_STOP` to 12 hours from now, minus 10 minutes to allow for job cleanup:

```
# job.sh
export HOOMD_WALLTIME_STOP=$((`date +%s` + 12 * 3600 - 10 * 60))
mpirun hoomd run.py
```

When using `HOOMD_WALLTIME_STOP`, *hoomd.run()* will throw the exception `WalltimeLimitReached` when it exits due to the walltime limit. Catch this exception so that your job can exit cleanly. Also, make sure to write out a final restart file at the end of your job so you have the final system state to continue from. Set the `limit_multiple` for the run to the restart period so that any analyzers that must run commensurate with the restart file have a chance to run. If you don't use any such commands, you can omit `limit_multiple` and the run will be free to end on any time step:

```
gsd_restart = dump.gsd(filename="restart.gsd", group=group.all(), truncate=True,
→period=10000, phase=0)

try:
    run_upto(1e6, limit_multiple=10000)

    # Perform additional actions here that should only be done after the job has
→completed all time steps.
except WalltimeLimitReached:
    # Perform actions here that need to be done each time you run into the wall clock
→limit, or just pass
    pass

gsd_restart.write_restart()
# Perform additional job cleanup actions here. These will be executed each time the
→job ends due to reaching the
# walltime limit AND when the job completes all of its time steps.
```

2.11.3 Examples

Simple example

Here is a simple example that puts all of these elements together:

```
# job.sh
export HOOMD_WALLTIME_STOP=$((`date +%s` + 12 * 3600 - 10 * 60))
mpirun hoomd run.py
```

```
# run.py
from hoomd import *
from hoomd import md
context.initialize()

init.read_gsd(filename='init.gsd', restart='restart.gsd')

lj = md.pair.lj(r_cut=2.5)
lj.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)

md.integrate.mode_standard(dt=0.005)
md.integrate.nvt(group=group.all(), T=1.2, tau=0.5)
```

(continues on next page)

```
gsd_restart = dump.gsd(filename="restart.gsd", group=group.all(), truncate=True,
↪period=10000, phase=0)
dump.dcd(filename="trajectory.dcd", period=1e5, phase=0)
analyze.log(filename='temperature.log', quantities=['temperature'], period=5000,
↪phase=0)

try:
    run_upto(1e6, limit_multiple=10000)
except WalltimeLimitReached:
    pass

gsd_restart.write_restart()
```

Temperature ramp

Runs often have temperature ramps. These are trivial to make restartable using a variant. Just be sure to set the `zero=0` option so that the ramp starts at timestep 0 and does not begin at the top every time the job is submitted. The only change needed from the previous simple example is to use the variant in `integrate.nvt()`:

```
T_variant = variant.linear_interp(points = [(0, 2.0), (2e5, 0.5)], zero=0)
integrate.nvt(group=group.all(), T=T_variant, tau=0.5)
```

Multiple stage jobs

Not all ramps or staged job protocols can be expressed as variants. However, it is easy to implement multi-stage jobs using run_upto and `HOOMD_WALLTIME_STOP`. Here is an example of a more complex job that involves multiple stages:

```
# run.py
from hoomd import *
from hoomd import md
context.initialize()

init.read_gsd(filename='init.gsd', restart='restart.gsd')

lj = md.pair.lj(r_cut=2.5)
lj.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)

md.integrate.mode_standard(dt=0.005)

gsd_restart = dump.gsd(filename="restart.gsd", group=group.all(), truncate=True,
↪period=10000, phase=0)

try:
    # randomize at high temperature
    nvt = md.integrate.nvt(group=group.all(), T=5.0, tau=0.5)
    run_upto(1e6, limit_multiple=10000)

    # equilibrate
    nvt.set_params(T=1.0)
    run_upto(2e6, limit_multiple=10000)

    # switch to nve and start saving data for the production run
```

```
    nvt.disable();
    md.integrate.nve(group=group.all())
    dump.dcd(filename="trajectory.dcd", period=1e5, phase=0)
    analyze.log(filename='temperature.log', quantities=['temperature'], period=5000,␣
→phase=0)

    run_upto(12e6);

except WalltimeLimitReached:
    pass

gsd_restart.write_restart()
```

And here is another example that changes interaction parameters:

```
try:
    for i in range(1,11):
        lj.pair_coeff.set('A', 'A', epsilon=0.1*i)
        run_upto(1e6*i);
except WalltimeLimitReached:
    pass
```

Multiple hoomd invocations

`HOOMD_WALLTIME_STOP` is a global variable set at the start of a job script. So you can launch hoomd scripts multiple times from within a job script and any of those individual runs will exit cleanly when it reaches the walltime. You need to take care that you don't start any new scripts once the first exits due to a walltime limit. The BASH script logic necessary to implement this behavior is workflow dependent and left as an exercise to the reader.

2.12 Variable period specification

Most updaters and analyzers in hoomd accept a variable period specification. Just specify a function taking a single argument to the period parameter.

For example, dump gsd files at time steps 1, 10, 100, 1000, . . . :

```
dump.gsd(filename="dump.gsd", period = lambda n: 10**n)
```

More examples:

```
dump.gsd(filename="dump.gsd", period = lambda n: n**2)
dump.gsd(filename="dump.gsd", period = lambda n: 2**n)
dump.gsd(filename="dump.gsd", period = lambda n: 1005 + 0.5 * 10**n)
```

The object passed into *period* must be callable, accept one argument, and return a floating point number or integer. The function should also be monotonically increasing.

- First, the current time step of the simulation is saved when the analyzer is created.

- *n* is also set to 1 when the analyzer is created

- Every time the analyzer performs it's output, it evaluates the given function at the current value of *n* and records that as the next time step to perform the analysis. *n* is then incremented by 1

2.13 Developer Topics

2.13.1 Plugins and Components

HOOMD-Blue can be tuned for particular use cases in several ways. Many smaller workloads and higher-level use cases can be handled through python-level `hoomd.run()` callbacks. For heavier-duty work such as pair potential evaluation, HOOMD-Blue can be extended through `components`. Components provide sets of functionality with a common overarching goal; for example, the `hoomd.hpmc` component provides code for hard particle Monte Carlo methods within HOOMD-Blue.

Components can be compiled and installed as **builtin** components or as **external** components. Builtin components are built and installed alongside the rest of HOOMD-Blue, while external components are compiled after HOOMD-Blue has already been compiled and installed at its destination. They have the same capabilities, but builtin components are simpler to build while external components are more flexible for packaging purposes.

The HOOMD-Blue source provides an example component template in the *example_plugin* subdirectory which supports installation either as a builtin component or as an external component, depending on how it is configured.

To set up the example component as a builtin component, simply create a symbolic link to the **internal** *example_plugin* directory (*example_plugin/example_plugin*) inside the *hoomd* subdirectory:

```
$ cd /path/to/hoomd-blue/hoomd
$ ln -s ../example_plugin/example_plugin example_plugin
$ cd ../build && make install
```

Note that this has already been done for the case of the example component.

Alternatively, one can use the example component as an external component. This relies on the *FindHOOMD.cmake* cmake script to set up cmake in a way that closely mirrors the cmake environment that HOOMD Blue was originally compiled with. The process is very similar to the process of installing HOOMD Blue itself. For ease of configuration, it is best to make sure that the *hoomd* module that is automatically imported by python is the one you wish to configure the component against and install to:

```
$ cd /path/to/component
$ mkdir build && cd build
$ # This python command should print the location you wish to install into
$ python -c 'import hoomd;print(hoomd.__file__)'
$ # Add any extra cmake arguments you need here (like -DPYTHON_EXECUTABLE)
$ cmake ..
$ make install
```

2.14 hoomd

Overview

`hoomd.get_step`	Get the current simulation time step.
`hoomd.run`	Runs the simulation for a given number of time steps.
`hoomd.run_upto`	Runs the simulation up to a given time step number.

Details

HOOMD-blue python API

hoomd provides a high level user interface for executing simulations using HOOMD:

```python
import hoomd
from hoomd import md
hoomd.context.initialize()

# create a 10x10x10 square lattice of particles with name A
hoomd.init.create_lattice(unitcell=hoomd.lattice.sc(a=2.0, type_name='A'), n=10)
# specify Lennard-Jones interactions between particle pairs
nl = md.nlist.cell()
lj = md.pair.lj(r_cut=3.0, nlist=nl)
lj.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
# integrate at constant temperature
all = hoomd.group.all();
md.integrate.mode_standard(dt=0.005)
hoomd.md.integrate.langevin(group=all, kT=1.2, seed=4)
# run 10,000 time steps
hoomd.run(10e3)
```

Stability

hoomd is **stable**. When upgrading from version 2.x to 2.y (y > x), existing job scripts that follow *documented* interfaces for functions and classes will not require any modifications. **Maintainer:** Joshua A. Anderson

> **Attention:** This stability guarantee only applies to modules in the *hoomd* package. Subpackages (*hoomd.hpmc*, *hoomd.md*, etc...) may or may not have a stable API. The documentation for each subpackage specifies the level of API stability it provides.

hoomd.**get_step**()
> Get the current simulation time step.
>
> > **Returns** The current simulation time step.
>
> Example:
>
> ```python
> print(hoomd.get_step())
> ```

hoomd.**run**(*tsteps*, *profile=False*, *limit_hours=None*, *limit_multiple=1*, *callback_period=0*, *callback=None*, *quiet=False*)
> Runs the simulation for a given number of time steps.
>
> > **Parameters**
> >
> > - **tsteps** (*int*) – Number of time steps to advance the simulation.
> >
> > - **profile** (*bool*) – Set to True to enable high level profiling output at the end of the run.
> >
> > - **limit_hours** (*float*) – If not None, limit this run to a given number of hours.
> >
> > - **limit_multiple** (*int*) – When stopping the run due to walltime limits, only stop when the time step is a multiple of limit_multiple.
> >
> > - **callback** (*callable*) – Sets a Python function to be called regularly during a run.
> >
> > - **callback_period** (*int*) – Sets the period, in time steps, between calls made to callback.

- **quiet** (*bool*) – Set to True to disable the status information printed to the screen by the run.

Example:

```
hoomd.run(10)
hoomd.run(10e6, limit_hours=1.0/3600.0, limit_multiple=10)
hoomd.run(10, profile=True)
hoomd.run(10, quiet=True)
hoomd.run(10, callback_period=2, callback=lambda step: print(step))
```

Execute the *run()* command to advance the simulation forward in time. During the run, all previously specified analyzers, updaters and the integrator are executed at the specified regular periods.

After *run()* completes, you may change parameters of the simulation and continue the simulation by executing *run()* again. Time steps are added cumulatively, so calling run(1000) and then run(2000) would run the simulation up to time step 3000.

run() cannot be executed before the system is initialized. In most cases, *run()* should only be called after after pair forces, bond forces, and an integrator are specified.

When *profile* is **True**, a detailed breakdown of how much time was spent in each portion of the calculation is printed at the end of the run. Collecting this timing information slows the simulation.

Wallclock limited runs:

There are a number of mechanisms to limit the time of a running hoomd script. Use these in a job queuing environment to allow your script to cleanly exit before reaching the system enforced walltime limit.

Force *run()* to end only on time steps that are a multiple of limit_multiple. Set this to the period at which you dump restart files so that you always end a *run()* cleanly at a point where you can restart from. Use phase=0 on logs, file dumps, and other periodic tasks. With phase=0, these tasks will continue on the same sequence regardless of the restart period.

Set the environment variable HOOMD_WALLTIME_STOP prior to starting a hoomd script to stop the *run()* at a given wall clock time. *run()* monitors performance and tries to ensure that it will end *before* HOOMD_WALLTIME_STOP. This environment variable works even with multiple stages of runs in a script (use *run_upto()*. Set the variable to a unix epoch time. For example in a job script that should run 12 hours, set HOOMD_WALLTIME_STOP to 12 hours from now, minus 10 minutes to allow for job cleanup:

```
export HOOMD_WALLTIME_STOP=$((`date +%s` + 12 * 3600 - 10 * 60))
```

When using HOOMD_WALLTIME_STOP, *run()* will throw the exception WalltimeLimitReached if it exits due to the walltime limit.

limit_hours is another way to limit the length of a *run()*. Set it to a number of hours (use fractional values for minutes) to limit this particular *run()* to that length of time. This is less useful than HOOMD_WALLTIME_STOP in a job queuing environment.

Callbacks:

If callback is set to a Python function then this function will be called regularly at callback_period intervals. The callback function must receive one integer as argument and can return an integer. The argument passed to the callback is the current time step number. If the callback function returns a negative number, the run is immediately aborted.

If callback_period is set to 0 (the default) then the callback is only called once at the end of the run. Otherwise the callback is executed whenever the current time step number is a multiple of callback_period.

hoomd.**run_upto**(*step*, ***keywords*)

Runs the simulation up to a given time step number.

Parameters

- **step** (*int*) – Final time step of the simulation which to run

- **keywords** – Catch for all keyword arguments to pass on to *run()*

run_upto() runs the simulation, but only until it reaches the given time step. If the simulation has already reached the specified step, a message is printed and no simulation steps are run.

It accepts all keyword options that *run()* does.

Examples:

```
run_upto(1000)
run_upto(10000, profile=True)
run_upto(1e9, limit_hours=11)
```

Modules

2.14.1 hoomd.analyze

Overview

hoomd.analyze.callback	Callback analyzer.
hoomd.analyze.imd	Send simulation snapshots to VMD in real-time.
hoomd.analyze.log	Log a number of calculated quantities to a file.

Details

Commands that analyze the system and provide some output.

An analyzer examines the system state in some way every *period* time steps and generates some form of output based on the analysis. Check the documentation for individual analyzers to see what they do.

class hoomd.analyze.**callback**(*callback*, *period*, *phase=0*)

Callback analyzer.

Parameters

- **callback** (*callable*) – The python callback object

- **period** (*int*) – The callback is called every a period time steps

- **phase** (*int*) – When -1, start on the current time step. When >= 0, execute on steps where (step + phase) % period == 0.

Create an analyzer that runs a given python callback method at a defined period.

Examples:

```
def my_callback(timestep):
  print(timestep)

analyze.callback(callback = my_callback, period = 100)
```

disable()

Disable the analyzer.

Examples:

```
my_analyzer.disable()
```

Executing the disable command will remove the analyzer from the system. Any `hoomd.run()` command executed after disabling an analyzer will not use that analyzer during the simulation. A disabled analyzer can be re-enabled with `enable()`.

enable()
　　Enables the analyzer

　　Examples:

```
my_analyzer.enable()
```

　　See `disable()`.

restore_state()
　　Restore the state information from the file used to initialize the simulations

set_period(*period*)
　　Changes the period between analyzer executions

　　　　Parameters period (`int`) – New period to set (in time steps)

　　Examples:

```
analyzer.set_period(100)
analyzer.set_period(1)
```

　　While the simulation is running (`hoomd.run()`, the action of each analyzer is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.analyze.**imd**(*port*, *period=1*, *rate=1*, *pause=False*, *force=None*, *force_scale=0.1*, *phase=0*)
　　Send simulation snapshots to VMD in real-time.

　　Parameters

- **port** (`int`) – TCP/IP port to listen on.
- **period** (`int`) – Number of time steps to run before checking for new IMD messages.
- **rate** (`int`) – Number of periods between coordinate data transmissions.
- **pause** (`bool`) – Set to *True* to pause the simulation at the first time step until an imd connection is made.
- **force** (`hoomd.md.force.constant`) – A force that apply forces received from VMD.
- **force_scale** (`float`) – Factor by which to scale all forces received from VMD.
- **phase** (`int`) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0*.

`hoomd.analyze.imd` listens on a specified TCP/IP port for connections from VMD. Once that connection is established, it begins transmitting simulation snapshots to VMD every *rate* time steps.

To connect to a simulation running on the local host, issue the command:

```
imd connect localhost 54321
```

in the VMD command window (where 54321 is replaced with the port number you specify for `hoomd.analyze.imd`.

Note: If a period larger than 1 is set, the actual rate at which time steps are transmitted is `rate * period`.

Examples:

```
analyze.imd(port=54321, rate=100)
analyze.imd(port=54321, rate=100, pause=True)
imd = analyze.imd(port=12345, rate=1000)
```

disable()
> Disable the analyzer.

> Examples:

> ```
> my_analyzer.disable()
> ```

> Executing the disable command will remove the analyzer from the system. Any *hoomd.run()* command executed after disabling an analyzer will not use that analyzer during the simulation. A disabled analyzer can be re-enabled with *enable()*.

enable()
> Enables the analyzer

> Examples:

> ```
> my_analyzer.enable()
> ```

> See *disable()*.

restore_state()
> Restore the state information from the file used to initialize the simulations

set_period(*period*)
> Changes the period between analyzer executions

> > **Parameters period** (*int*) – New period to set (in time steps)

> Examples:

> ```
> analyzer.set_period(100)
> analyzer.set_period(1)
> ```

> While the simulation is running (*hoomd.run()*, the action of each analyzer is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.analyze.**log**(*filename*, *quantities*, *period*, *header_prefix=''*, *overwrite=False*, *phase=0*)
> Log a number of calculated quantities to a file.

> **Parameters**

> > - **filename** (*str*) – File to write the log to, or *None* for no file output.

> > - **quantities** (*list*) – List of quantities to log.

> > - **period** (*int*) – Quantities are logged every *period* time steps.

> > - **header_prefix** (*str*) – Specify a string to print before the header.

> > - **overwrite** (*bool*) – When False (the default) an existing log will be appended to. When True, an existing log file will be overwritten instead.

- **phase** (`int`) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0*.

`hoomd.analyze.log` reads a variety of calculated values, like energy and temperature, from specified forces, integrators, and updaters. It writes a single line to the specified output file every *period* time steps. The resulting file is suitable for direct import into a spreadsheet, MATLAB, or other software that can handle simple delimited files. See *Units* for information on the units in hoomd.

Quantities that can be logged at any time:

- **volume** - Volume of the simulation box (in volume units)
- **N** - Particle number (dimensionless)
- **lx** - Box length in x direction (in length units)
- **ly** - Box length in y direction (in length units)
- **lz** - Box length in z direction (in length units)
- **xy** - Box tilt factor in xy plane (dimensionless)
- **xz** - Box tilt factor in xz plane (dimensionless)
- **yz** - Box tilt factor in yz plane (dimensionless)
- **momentum** - Magnitude of the average momentum of all particles (in momentum units)
- **time** - Wall-clock running time from the start of the log (in seconds)

Thermodynamic properties: - The following quantities are always available and computed over all particles in the system (see `hoomd.compute.thermo` for detailed definitions):

- **num_particles**
- **ndof**
- **translational_ndof**
- **rotational_ndof**
- **potential_energy** (in energy units)
- **kinetic_energy** (in energy units)
- **translational_kinetic_energy** (in energy units)
- **rotational_kinetic_energy** (in energy units)
- **temperature** (in thermal energy units)
- **pressure** (in pressure units)
- **pressure_xx**, **pressure_xy**, **pressure_xz**, **pressure_yy**, **pressure_yz**, **pressure_zz** (in pressure units)

- The above quantities, tagged with a *_groupname* suffix are automatically available for any group passed to an integrate command
- Specify a compute.thermo directly to enable additional quantities for user-specified groups.

The following quantities are only available if the command is parentheses has been specified and is active for logging:

- Pair potentials
    - **pair_dpd_energy** (`hoomd.md.pair.dpd`) - Total DPD conservative potential energy (in energy units)

- **pair_dpdlj_energy** (`hoomd.md.pair.dpdlj`) - Total DPDLJ conservative potential energy (in energy units)

- **pair_eam_energy** (`hoomd.metal.pair.eam`) - Total EAM potential energy (in energy units)

- **pair_ewald_energy** (`hoomd.md.pair.ewald`) - Short ranged part of the electrostatic energy (in energy units)

- **pair_gauss_energy** (`hoomd.md.pair.gauss`) - Total Gaussian potential energy (in energy units)

- **pair_lj_energy** (`hoomd.md.pair.lj`) - Total Lennard-Jones potential energy (in energy units)

- **pair_morse_energy** (`hoomd.md.pair.yukawa`) - Total Morse potential energy (in energy units)

- **pair_table_energy** (`hoomd.md.pair.table`) - Total potential energy from Tabulated potentials (in energy units)

- **pair_slj_energy** (`hoomd.md.pair.slj`) - Total Shifted Lennard-Jones potential energy (in energy units)

- **pair_yukawa_energy** (`hoomd.md.pair.yukawa`) - Total Yukawa potential energy (in energy units)

- **pair_force_shifted_lj_energy** (`hoomd.md.pair.force_shifted_lj`) - Total Force-shifted Lennard-Jones potential energy (in energy units)

- **pppm_energy** (`hoomd.md.charge.pppm`) - Long ranged part of the electrostatic energy (in energy units)

- Bond potentials

  - **bond_fene_energy** (`hoomd.md.bond.fene`) - Total fene bond potential energy (in energy units)

  - **bond_harmonic_energy** (`hoomd.md.bond.harmonic`) - Total harmonic bond potential energy (in energy units)

  - **bond_table_energy** (`hoomd.md.bond.table`) - Total table bond potential energy (in energy units)

- Angle potentials

  - **angle_harmonic_energy** (`hoomd.md.angle.harmonic`) - Total harmonic angle potential energy (in energy units)

- Dihedral potentials

  - **dihedral_harmonic_energy** (`hoomd.md.dihedral.harmonic`) - Total harmonic dihedral potential energy (in energy units)

- Special pair interactions - **special_pair_lj_energy** (`hoomd.md.special_pair.lj`) - Total energy of special pair interactions (in energy units)

- External potentials

  - **external_periodic_energy** (`hoomd.md.external.periodic`) - Total periodic potential energy (in energy units)

  - **external_e_field_energy** (`hoomd.md.external.e_field`) - Total e_field potential energy (in energy units)

- Wall potentials

  - **external_wall_lj_energy** (`hoomd.md.wall.lj`) - Total Lennard-Jones wall energy (in energy units)

- **external_wall_gauss_energy** (`hoomd.md.wall.gauss`) - Total Gauss wall energy (in energy units)

- **external_wall_slj_energy** (`hoomd.md.wall.slj`) - Total Shifted Lennard-Jones wall energy (in energy units)

- **external_wall_yukawa_energy** (`hoomd.md.wall.yukawa`) - Total Yukawa wall energy (in energy units)

- **external_wall_mie_energy** (`hoomd.md.wall.mie`) - Total Mie wall energy (in energy units)

- Integrators

  - **langevin_reservoir_energy_groupname** (`hoomd.md.integrate.langevin`) - Energy reservoir for the Langevin integrator (in energy units)

  - **nvt_reservoir_energy_groupname** (`hoomd.md.integrate.nvt`) - Energy reservoir for the NVT thermostat (in energy units)

  - **nvt_mtk_reservoir_energy_groupname** (`hoomd.md.integrate.nvt`) - Energy reservoir for the NVT MTK thermostat (in energy units)

  - **npt_thermostat_energy** (`hoomd.md.integrate.npt`) - Energy of the NPT thermostat

  - **npt_barostat_energy** (`hoomd.md.integrate.npt` & `hoomd.md.integrate.nph`) - Energy of the NPT (or NPH) barostat

Additionally, all pair and bond potentials can be provided user-defined names that are appended as suffixes to the logged quantity (e.g. with `pair.lj(r_cut=2.5, name="alpha")`, the logged quantity would be pair_lj_energy_alpha):

By specifying a force, disabling it with the *log=True* option, and then logging it, different energy terms can be computed while only a subset of them actually drive the simulation. Common use-cases of this capability include separating out pair energy of given types (shown below) and free energy calculations. Be aware that the globally chosen *r_cut* value is the largest of all active pair potentials and those with *log=True*, so you will observe performance degradation if you *disable(log=True)* a potential with a large *r_cut*.

File output from analyze.log is optional. Specify *None* for the file name and no file will be output. Use this with the `query()` method to query the values of properties without the overhead of writing them to disk.

You can register custom python callback functions to provide logged quantities with `register_callback()`.

Examples:

```
lj1 = pair.lj(r_cut=3.0, name="lj1")
lj1.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
lj1.pair_coeff.set('A', 'B', epsilon=1.0, sigma=1.0)
lj1.pair_coeff.set('B', 'B', epsilon=1.0, sigma=1.0)

lj2 = pair.lj(r_cut=3.0, name="lj2")
lj2.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
lj2.pair_coeff.set('A', 'B', epsilon=0.0, sigma=1.0)
lj2.pair_coeff.set('B', 'B', epsilon=0.0, sigma=1.0)
lj2.disable(log=True)

analyze.log(filename='mylog.log', quantities=['pair_lj_energy_lj1', 'pair_lj_
→energy_lj2'],
            period=100, header_prefix='#')


logger = analyze.log(filename='mylog.log', period=100,
```

```
                                quantities=['pair_lj_energy'])

analyze.log(quantities=['pair_lj_energy', 'bond_harmonic_energy',
            'kinetic_energy'], period=1000, filename='full.log')

analyze.log(filename='mylog.log', quantities=['pair_lj_energy'],
            period=100, header_prefix='#')

analyze.log(filename='mylog.log', quantities=['bond_harmonic_energy'],
            period=10, header_prefix='Log of harmonic energy, run 5\\n')
logger = analyze.log(filename='mylog.log', period=100,
                     quantities=['pair_lj_energy'], overwrite=True)

log = analyze.log(filename=None, quantities=['potential_energy'], period=1)
U = log.query('potential_energy')
```

By default, columns in the log file are separated by tabs, suitable for importing as a tab-delimited spreadsheet. The delimiter can be changed to any string using *set_params()*

The *header_prefix* can be used in a number of ways. It specifies a simple string that will be printed before the header line of the output file. One handy way to use this is to specify header_prefix='#' so that gnuplot will ignore the header line automatically. Another use-case would be to specify a descriptive line containing details of the current run. Examples of each of these cases are given above.

> **Warning:** When an existing log is appended to, the header is not printed. For the log to remain consistent with the header already in the file, you must specify the same quantities to log and in the same order for all runs of hoomd that append to the same log.

disable()
> Disable the logger.

> Examples:

```
logger.disable()
```

> Executing the disable command will remove the logger from the system. Any *hoomd.run()* command executed after disabling the logger will not use that logger during the simulation. A disabled logger can be re-enabled with *enable()*.

enable()
> Enables the logger

> Examples:

```
logger.enable()
```

> See *disable()*.

query(*quantity*)
> Get the current value of a logged quantity.

>> **Parameters** **quantity** (*str*) – Name of the quantity to return.

> *query()* works in two different ways depending on how the logger is configured. If the logger is writing to a file, *query()* returns the last value written to the file. If filename is *None*, then *query()* returns the value of the quantity computed at the current timestep.

Examples:

```
logdata = logger.query('pair_lj_energy')
log = analyze.log(filename=None, quantities=['potential_energy'], period=1)
U = log.query('potential_energy')
```

register_callback(*name*, *callback*)
    Register a callback to produce a logged quantity.

    Parameters

    - **name** (*str*) – Name of the quantity

    - **callback** (*callable*) – A python callable object (i.e. a lambda, function, or class that implements __call__)

    The callback method must take a single argument, the current timestep, and return a single floating point value to be logged.

    ___

    Note: One callback can query the value of another, but logged quantities are evaluated in order from left to right.

    ___

    Examples:

```
logger = analyze.log(filename='log.dat', quantities=['my_quantity', 'cosm'],
↪period=100)
logger.register_callback('my_quantity', lambda timestep: timestep**2)
logger.register_callback('cosm', lambda timestep: math.cos(logger.query('my_
↪quantity')))
```

restore_state()
    Restore the state information from the file used to initialize the simulations

set_params(*quantities=None*, *delimiter=None*)
    Change the parameters of the log.

    Parameters

    - **quantities** (*list*) – New list of quantities to log (if specified)

    - **delimiter** (*str*) – New delimiter between columns in the output file (if specified)

    Examples:

```
logger.set_params(quantities=['bond_harmonic_energy'])
logger.set_params(delimiter=',');
logger.set_params(quantities=['bond_harmonic_energy'], delimiter=',');
```

set_period(*period*)
    Changes the period between analyzer executions

    Parameters period (*int*) – New period to set (in time steps)

    Examples:

```
analyzer.set_period(100)
analyzer.set_period(1)
```

While the simulation is running (*hoomd.run()*, the action of each analyzer is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

2.14.2 hoomd.benchmark

Overview

hoomd.benchmark.series	Perform a series of benchmark runs.

Details

Benchmark utilities

Commands that help in benchmarking HOOMD-blue performance.

hoomd.benchmark.**series**(*warmup=100000*, *repeat=20*, *steps=10000*, *limit_hours=None*)
   Perform a series of benchmark runs.

   Parameters

   - **warmup** (*int*) – Number of time steps to *hoomd.run()* to warm up the benchmark
   - **repeat** (*int*) – Number of times to repeat the benchmark *steps*.
   - **steps** (*int*) – Number of time steps to *hoomd.run()* at each benchmark point.
   - **limit_hours** (*float*) – Limit each individual *hoomd.run()* length to this time.

   series() executes *warmup* time steps. After that, it calls run(steps), *repeat* times and returns a list containing the average TPS for each of those runs.

2.14.3 hoomd.cite

Overview

hoomd.cite.save	Saves the automatically generated bibliography to a BibTeX file

Details

Commands to support automatic citation generation.

Certain features of HOOMD-blue should be cited because they represent significant contributions from developers. In order to make these citations transparent and easy, HOOMD-blue will automatically print citation notices at run time when you use a feature that should be cited. Users should read and cite these publications in their work. Citations can be saved as a BibTeX file for easy incorporation into bibliographies.

hoomd.cite.**save**(*file='hoomd.bib'*)
   Saves the automatically generated bibliography to a BibTeX file

   Parameters file (*str*) – File name for the saved bibliography

   After *save()* is called for the first time, the bibliography will (re-)generate each time that a new feature is added to ensure that all citations have been included. If file already exists, it will be overwritten.

   Examples:

   ```
   cite.save()
   cite.save(file='cite.bib')
   ```

2.14.4 hoomd.comm

Overview

hoomd.comm.barrier	Perform a MPI barrier synchronization across all ranks in the partition.
hoomd.comm.barrier_all	Perform a MPI barrier synchronization across the whole MPI run.
hoomd.comm.decomposition	Set the domain decomposition.
hoomd.comm.get_num_ranks	Get the number of ranks in this partition.
hoomd.comm.get_partition	Get the current partition index.
hoomd.comm.get_rank	Get the current rank.

Details

MPI communication interface

Use methods in this module to query the number of MPI ranks, the current rank, etc. . .

hoomd.comm.**barrier**()
> Perform a MPI barrier synchronization across all ranks in the partition.

> **Note:** Does nothing in in non-MPI builds.

hoomd.comm.**barrier_all**()
> Perform a MPI barrier synchronization across the whole MPI run.

> **Note:** Does nothing in in non-MPI builds.

class hoomd.comm.**decomposition**(*x=None*, *y=None*, *z=None*, *nx=None*, *ny=None*, *nz=None*)
> Set the domain decomposition.

> **Parameters**
>> - **x** (*list*) – First nx-1 fractional domain widths (if *nx* is None)
>> - **y** (*list*) – First ny-1 fractional domain widths (if *ny* is None)
>> - **z** (*list*) – First nz-1 fractional domain widths (if *nz* is None)
>> - **nx** (*int*) – Number of processors to uniformly space in x dimension (if *x* is None)
>> - **ny** (*int*) – Number of processors to uniformly space in y dimension (if *y* is None)
>> - **nz** (*int*) – Number of processors to uniformly space in z dimension (if *z* is None)

> A single domain decomposition is defined for the simulation. A standard domain decomposition divides the simulation box into equal volumes along the Cartesian axes while minimizing the surface area between domains. This works well for systems where particles are uniformly distributed and there is equal computational load for each domain, and is the default behavior in HOOMD-blue. If no decomposition is specified for an MPI run, a uniform decomposition is automatically constructed on initialization.

> In simulations with density gradients, such as a vapor-liquid interface, there can be a considerable imbalance of particles between different ranks. The simulation time then becomes limited by the slowest processor. It may then be advantageous in certain systems to create domains of unequal volume, for example, by increasing the volume of less dense regions of the simulation box in order to balance the number of particles.

The decomposition command allows the user to control the geometry and positions of the decomposition. The fractional width of the first $n_i - 1$ domains is specified along each dimension, where n_i is the number of ranks desired along dimension i. If no cut planes are specified, then a uniform spacing is assumed. The number of domains with uniform spacing can also be specified. If the desired decomposition is not commensurate with the number of ranks available (for example, a 3x3x3 decomposition when only 8 ranks are available), then a default uniform spacing is chosen. For the best control, the user should specify the number of ranks in each dimension even if uniform spacing is desired.

decomposition can only be called *before* the system is initialized, at which point the particles are decomposed. An error is raised if the system is already initialized.

The decomposition can be adjusted dynamically if the best static decomposition is not known, or the system composition is changing dynamically. For this associated command, see update.balance().

Priority is always given to specified arguments over the command line arguments. If one of these is not set but a command line option is, then the command line option is used. Otherwise, a default decomposition is chosen.

Examples:

```
comm.decomposition(x=0.4, ny=2, nz=2)
comm.decomposition(nx=2, y=0.8, z=[0.2,0.3])
```

Warning: The decomposition command will override specified command line options.

Warning: This command must be invoked *before* the system is initialized because particles are decomposed at this time.

Note: The domain size cannot be chosen arbitrarily small. There are restrictions placed on the decomposition by the ghost layer width set by the pair potentials. An error will be raised at run time if the ghost layer width exceeds half the shortest domain size.

Warning: Both fractional widths and the number of processors cannot be set simultaneously, and an error will be raised if both are set.

set_params (*x=None, y=None, z=None, nx=None, ny=None, nz=None*)
    Set parameters for the decomposition before initialization.

        Parameters

- **x** (`list`) – First nx-1 fractional domain widths (if *nx* is None)
- **y** (`list`) – First ny-1 fractional domain widths (if *ny* is None)
- **z** (`list`) – First nz-1 fractional domain widths (if *nz* is None)
- **nx** (`int`) – Number of processors to uniformly space in x dimension (if *x* is None)
- **ny** (`int`) – Number of processors to uniformly space in y dimension (if *y* is None)
- **nz** (`int`) – Number of processors to uniformly space in z dimension (if *z* is None)

    Examples:

```
decomposition.set_params(x=[0.2])
decomposition.set_params(nx=1, y=[0.3,0.4], nz=2)
```

hoomd.comm.**get_num_ranks**()
>   Get the number of ranks in this partition.

>   >   **Returns** The number of MPI ranks in this partition.

> **Note:** Returns 1 in non-mpi builds.

---

hoomd.comm.**get_partition**()
>   Get the current partition index.

>   >   **Returns** Index of the current partition.

> **Note:** Always returns 0 in non-mpi builds.

---

hoomd.comm.**get_rank**()
>   Get the current rank.

>   >   **Returns** Index of the current rank in this partition.

> **Note:** Always returns 0 in non-mpi builds.

2.14.5 hoomd.compute

Overview

[*hoomd.compute.thermo*](#)	Compute thermodynamic properties of a group of particles.

Details

Compute system properties

A compute calculates properties of the system on demand. Most computes are automatically generated by the command that needs them (e.g. integrate.nvt creates a compute.thermo for temperature calculations). User-specified computes can be used when more flexibility is needed. Properties calculated by specified computes (automatically, or by the user) can be logged with analyze.log.

class hoomd.compute.**thermo**(*group*)
>   Compute thermodynamic properties of a group of particles.

>   >   **Parameters group** (*hoomd.group*) – Group to compute thermodynamic properties for.

>   *hoomd.compute.thermo* acts on a given group of particles and calculates thermodynamic properties of those particles when requested. A default *hoomd.compute.thermo* is created that operates on the group of all particles. Integration methods such as *hoomd.md.integrate.nvt* automatically create an internal *hoomd.compute.thermo* for the group that they operate on. If thermodynamic properties are needed on additional groups, a user can specify additional *hoomd.compute.thermo* commands.

>   Whether they are automatically created or created by a user, all specified thermos are available for logging via the

hoomd.analyze.log command. Each one provides a set of quantities for logging, suffixed with _group-name_, so that values for different groups are differentiated in the log file. The default _hoomd.compute._ _thermo_ specified on the group of all particles has no suffix placed on its quantity names.

The quantities provided are (where **groupname** is replaced with the name of the group):

- **num_particles_groupname** - N number of particles in the group
- **ndof_groupname** - N_{dof} number of degrees of freedom given to the group by integrate commands
- **translational_ndof_groupname** - N_{dof} number of translational degrees of freedom given to the group by integrate commands
- **rotational_ndof_groupname** - N_{dof} number of rotational degrees of freedom given to the group by integrate commands
- **potential_energy_groupname** - U potential energy that the group contributes to the entire system (in energy units)
- **kinetic_energy_groupname** - K total kinetic energy of all particles in the group (in energy units)
- **translational_kinetic_energy_groupname** - K translational kinetic energy of all particles in the group (in energy units)
- **rotational_kinetic_energy_groupname** - K rotational kinetic energy of all particles in the group (in energy units)
- **temperature_groupname** - kT instantaneous thermal energy of the group (in energy units). Calculated as

$$kT = 2 \cdot \frac{K}{N_{\text{dof}}}$$

- **pressure_groupname** - P instantaneous pressure of the group (in pressure units). Calculated as

$$W = \frac{1}{2} \sum_i \sum_{j \neq i} \vec{F}_{ij} \cdot \vec{r_{ij}} + \sum_k \vec{F}_k \cdot \vec{r_k}$$

  where $\vec{F}_{ij}$ are pairwise forces between particles and $\vec{F}_k$ are forces due to explicit constraints, implicit rigid body constraints, external walls, and fields. In 2D simulations, $P = (K + \frac{1}{2} \cdot W)/A$ where A is the area of the simulation box. of the simulation box.

- **pressure_xx_groupname**, **pressure_xy_groupname**, **pressure_xz_groupname**, **pressure_yy_groupname**, **pressure_yz_groupname**, **pressure_zz_groupname** - instantaneous pressure tensor of the group (in pressure units).

$$P_{ij} = \left[\sum_{k \in [0..N)} m_k v_{k,i} v_{k,j} + \sum_{k \in [0..N)} \sum_{l > k} \frac{1}{2} \left(\vec{r}_{kl,i} \vec{F}_{kl,j} + \vec{r}_{kl,j} \vec{F}_{kl,i} \right) \right] / V$$

See also:

hoomd.analyze.log.

Examples:

```
g = group.type(name='typeA', type='A')
compute.thermo(group=g)
```

disable()
    Disables the thermo.

    Examples:

```
my_thermo.disable()
```

Executing the disable command will remove the thermo compute from the system. Any *hoomd.run()* command executed after disabling a thermo compute will not be able to log computed values with *hoomd. analyze.log*.

A disabled thermo compute can be re-enabled with *enable()*.

enable()
:   Enables the thermo compute.

    Examples:

```
my_thermo.enable()
```

    See *disable()*.

restore_state()
:   Restore the state information from the file used to initialize the simulations

2.14.6 hoomd.context

Overview

hoomd.context.SimulationContext	Simulation context
hoomd.context.initialize	Initialize the execution context

Details

Manage execution contexts.

Every hoomd simulation needs an execution context that describes what hardware it should execute on, the MPI configuration for the job, etc. . .

class hoomd.context.**SimulationContext**
:   Simulation context

    Store all of the context related to a single simulation, including the system state, forces, updaters, integration methods, and all other commands specified on this simulation. All such commands in hoomd apply to the currently active simulation context. You swap between simulation contexts by using this class as a context manager:

```python
sim1 = context.SimulationContext();
sim2 = context.SimulationContext();
with sim1:
  init.read_xml('init1.xml');
  lj = pair.lj(...)
  ...

with sim2:
  init.read_xml('init2.xml');
  gauss = pair.gauss(...)
  ...

# run simulation 1 for a bit
with sim1:
```

(continues on next page)

```
    run(100)

# run simulation 2 for a bit
with sim2:
    run(100)

# set_current sets the current context without needing to use with
sim1.set_current()
run(100)
```

If you do not need to maintain multiple contexts, you can call *context.initialize()* to initialize a new context and erase the existing one:

```
context.initialize()
init.read_xml('init1.xml');
lj = pair.lj(...)
...
run(100);

context.initialize()
init.read_xml('init2.xml');
gauss = pair.gauss(...)
...
run(100)
```

sorter
>   Global particle sorter.
>
>   **Type** *hoomd.update.sort*

system_definition
>   System definition.
>
>   **Type** *hoomd.data.system_data*

The attributes are global to the context. User scripts may access documented attributes to control settings, access particle data, etc. . . See the linked documentation of each attribute for more details. For example, to disable the global sorter:

```
c = context.initialize();
c.sorter.disable();
```

on_gpu()
>   Test whether this job is running on a GPU.
>
>   **Returns** True if this invocation of HOOMD-blue is executing on a GPU. False if it is on the CPU.

set_current()
>   Force this to be the current context

hoomd.context.**initialize**(*args=None*, *memory_traceback=False*, *mpi_comm=None*)
>   Initialize the execution context
>
>   **Parameters**
>
>   • **args** (*str*) – Arguments to parse. When *None*, parse the arguments passed on the command line.

- **memory_traceback** (*bool*) – If true, enable memory allocation tracking (*only for debugging/profiling purposes*)

- **mpi_comm** – Accepts an mpi4py communicator. Use this argument to perform many independent hoomd simulations where you communicate between those simulations using your own mpi4py code.

hoomd.context.initialize() parses the command line arguments given, sets the options and initializes MPI and GPU execution (if any). By default, *hoomd.context.initialize()* reads arguments given on the command line. Provide a string to *hoomd.context.initialize()* to set the launch configuration within the job script.

hoomd.context.initialize() can be called more than once in a script. However, the execution parameters are fixed on the first call and *args* is ignored. Subsequent calls to *hoomd.context.initialize()* create a new *SimulationContext* and set it current. This behavior is primarily to support use of hoomd in jupyter notebooks, so that a new clean simulation context is set when rerunning the notebook within an existing kernel.

Example:

```python
from hoomd import *
context.initialize();
context.initialize("--mode=gpu --nrank=64");
context.initialize("--mode=cpu --nthreads=64");


world = MPI.COMM_WORLD
comm = world.Split(world.Get_rank(), 0)
hoomd.context.initialize(mpi_comm=comm)
```

2.14.7 hoomd.data

Overview

hoomd.data.SnapshotParticleData	Snapshot of particle data properties.
hoomd.data.angle_data_proxy	Access a single angle via a proxy.
hoomd.data.bond_data_proxy	Access a single bond via a proxy.
hoomd.data.boxdim	Define box dimensions.
hoomd.data.constraint_data_proxy	Access a single constraint via a proxy.
hoomd.data.dihedral_data_proxy	Access a single dihedral via a proxy.
hoomd.data.force_data_proxy	Access the force on a single particle via a proxy.
hoomd.data.gsd_snapshot	Read a snapshot from a GSD file.
hoomd.data.particle_data_proxy	Access a single particle via a proxy.
hoomd.data.make_snapshot	Make an empty snapshot.
hoomd.data.system_data	Access system data

Details

Access system configuration data.

Code in the data package provides high-level access to all of the particle, bond and other data that define the current state of the system. You can use python code to directly read and modify this data, allowing you to analyze simulation results while the simulation runs, or to create custom initial configurations with python code.

There are two ways to access the data.

1. Snapshots record the system configuration at one instant in time. You can store this state to analyze the data, restore it at a future point in time, or to modify it and reload it. Use snapshots for initializing simulations, or when you need to access or modify the entire simulation state.

2. Data proxies directly access the current simulation state. Use data proxies if you need to only touch a few particles or bonds at a a time.

Snapshots

Relevant methods:

- *hoomd.data.system_data.take_snapshot()* captures a snapshot of the current system state. A snapshot is a copy of the simulation state. As the simulation continues to progress, data in a captured snapshot will remain constant.

- *hoomd.data.system_data.restore_snapshot()* replaces the current system state with the state stored in a snapshot.

- *hoomd.data.make_snapshot()* creates an empty snapshot that you can populate with custom data.

- *hoomd.init.read_snapshot()* initializes a simulation from a snapshot.

Examples:

```
snapshot = system.take_snapshot()
system.restore_snapshot(snapshot)
snapshot = data.make_snapshot(N=100, particle_types=['A', 'B'], box=data.boxdim(L=10))
# ... populate snapshot with data ...
init.read_snapshot(snapshot)
```

Snapshot and MPI

In MPI simulations, the snapshot is only valid on rank 0 by default. make_snapshot, read_snapshot, and take_snapshot, restore_snapshot are collective calls, and need to be called on all ranks. But only rank 0 can access data in the snapshot:

```
snapshot = system.take_snapshot(all=True)
if comm.get_rank() == 0:
    s = init.create_random(N=100, phi_p=0.05);numpy.mean(snapshot.particles.velocity))
    snapshot.particles.position[0] = [1,2,3];

system.restore_snapshot(snapshot);
snapshot = data.make_snapshot(N=10, box=data.boxdim(L=10))
if comm.get_rank() == 0:
    snapshot.particles.position[:] = ....
init.read_snapshot(snapshot)
```

You can explicitly broadcast the information contained in the snapshot to all other ranks, using **broadcast**.

> snapshot = system.take_snapshot(all=True) snapshot.broadcast() # broadcast from rank 0 to all other ranks using MPI snapshot.broadcast_all() # broadcast from partition 0 to all other ranks and partitions using MPI

Simulation box

You can access the simulation box from a snapshot:

```
>>> print(snapshot.box)
Box: Lx=17.3646569289 Ly=17.3646569289 Lz=17.3646569289 xy=0.0 xz=0.0 yz=0.0
 →dimensions=3
```

and can change it:

```
>>> snapshot.box = data.boxdim(Lx=10, Ly=20, Lz=30, xy=1.0, xz=0.1, yz=2.0)
>>> print(snapshot.box)
Box: Lx=10 Ly=20 Lz=30 xy=1.0 xz=0.1 yz=2.0 dimensions=3
```

All particles must be inside the box before using the snapshot to initialize a simulation or restoring it. The dimensionality of the system (2D/3D) cannot change after initialization.

Particle properties

Particle properties are present in *snapshot.particles*. Each property is stored in a numpy array that directly accesses the memory of the snapshot. References to these arrays will become invalid when the snapshot itself is garbage collected.

- *N* is the number of particles in the particle data snapshot:

```
>>> print(snapshot.particles.N)
64000
```

- Change the number of particles in the snapshot with resize. Existing particle properties are preserved after the resize. Any newly created particles will have default values. After resizing, existing references to the numpy arrays will be invalid, access them again from *snapshot.particles.**:

```
>>> snapshot.particles.resize(1000);
```

- The list of all particle types in the simulation can be accessed and modified:

```
>>> print(snapshot.particles.types)
['A', 'B', 'C']
>>> snapshot.particles.types = ['1', '2', '3', '4'];
```

- Individual particles properties are stored in numpy arrays. Vector quantities are stored in Nx3 arrays of floats (or doubles) and scalar quantities are stored in N length 1D arrays:

```
>>> print(snapshot.particles.position[10])
[ 1.2398  -10.2687  100.6324]
```

- Various properties can be accessed of any particle, and the numpy arrays can be sliced or passed whole to other routines:

```
>>> print(snapshot.particles.typeid[10])
2
>>> print(snapshot.particles.velocity[10])
(-0.60267972946166992, 2.6205904483795166, -1.7868227958679199)
>>> print(snapshot.particles.mass[10])
1.0
>>> print(snapshot.particles.diameter[10])
1.0
```

- Particle properties can be set in the same way. This modifies the data in the snapshot, not the current simulation state:

```
>>> snapshot.particles.position[10] = [1,2,3]
>>> print(snapshot.particles.position[10])
[ 1.  2.  3.]
```

- Snapshots store particle types as integers that index into the type name array:

```
>>> print(snapshot.particles.typeid)
[ 0.  1.  2.  0.  1.  2.  0.  1.  2.  0.]
>>> snapshot.particles.types = ['A', 'B', 'C'];
>>> snapshot.particles.typeid[0] = 2;   # C
>>> snapshot.particles.typeid[1] = 0;   # A
>>> snapshot.particles.typeid[2] = 1;   # B
```

For a list of all particle properties in the snapshot see *hoomd.data.SnapshotParticleData*.

Bonds

Bonds are stored in *snapshot.bonds*. *hoomd.data.system_data.take_snapshot()* does not record the bonds by default, you need to request them with the argument *bonds=True*.

- *N* is the number of bonds in the bond data snapshot:

```
>>> print(snapshot.bonds.N)
100
```

- Change the number of bonds in the snapshot with resize. Existing bonds are preserved after the resize. Any newly created bonds will be initialized to 0. After resizing, existing references to the numpy arrays will be invalid, access them again from *snapshot.bonds.**:

```
>>> snapshot.bonds.resize(1000);
```

- Bonds are stored in an Nx2 numpy array *group*. The first axis accesses the bond *i*. The second axis *j* goes over the individual particles in the bond. The value of each element is the tag of the particle participating in the bond:

```
>>> print(snapshot.bonds.group)
[[0 1]
[1 2]
[3 4]
[4 5]]
>>> snapshot.bonds.group[0] = [10,11]
```

- Snapshots store bond types as integers that index into the type name array:

```
>>> print(snapshot.bonds.typeid)
[ 0.  1.  2.  0.  1.  2.  0.  1.  2.  0.]
>>> snapshot.bonds.types = ['A', 'B', 'C'];
>>> snapshot.bonds.typeid[0] = 2;   # C
>>> snapshot.bonds.typeid[1] = 0;   # A
>>> snapshot.bonds.typeid[2] = 1;   # B
```

Angles, dihedrals and impropers

Angles, dihedrals, and impropers are stored similar to bonds. The only difference is that the group array is sized appropriately to store the number needed for each type of bond.

- *snapshot.angles.group* is Nx3

- *snapshot.dihedrals.group* is Nx4

- *snapshot.impropers.group* is Nx4

Special pairs

Special pairs are exactly handled like bonds. The snapshot entry is called **pairs**.

Constraints

Pairwise distance constraints are added and removed like bonds. They are defined between two particles. The only difference is that instead of a type, constraints take a distance as parameter.

- *N* is the number of constraints in the constraint data snapshot:

```
>>> print(snapshot.constraints.N)
99
```

- Change the number of constraints in the snapshot with resize. Existing constraints are preserved after the resize. Any newly created constraints will be initialized to 0. After resizing, existing references to the numpy arrays will be invalid, access them again from *snapshot.constraints.**:

```
>>> snapshot.constraints.resize(1000);
```

- Bonds are stored in an Nx2 numpy array *group*. The first axis accesses the constraint *i*. The second axis *j* goes over the individual particles in the constraint. The value of each element is the tag of the particle participating in the constraint:

```
>>> print(snapshot.constraints.group)
[[4 5]
 [6 7]
 [6 8]
 [7 8]]
>>> snapshot.constraints.group[0] = [10,11]
```

- Snapshots store constraint distances as floats:

```
>>> print(snapshot.constraints.value)
[ 1.5 2.3 1.0 0.1 ]
```

data_proxy Proxy access

For most of the cases below, it is assumed that the result of the initialization command was saved at the beginning of the script:

```
system = init.read_xml(filename="input.xml")
```

> **Warning:** The performance of the proxy access is very slow. Use snapshots to access the whole system configuration efficiently.

Simulation box

You can access the simulation box:

```
>>> print(system.box)
Box: Lx=17.3646569289 Ly=17.3646569289 Lz=17.3646569289 xy=0.0 xz=0.0 yz=0.0
```

and can change it:

```
>>> system.box = data.boxdim(Lx=10, Ly=20, Lz=30, xy=1.0, xz=0.1, yz=2.0)
>>> print(system.box)
Box: Lx=10 Ly=20 Lz=30 xy=1.0 xz=0.1 yz=2.0
```

All particles must **always** remain inside the box. If a box is set in this way such that a particle ends up outside of the box, expect errors to be thrown or for hoomd to just crash. The dimensionality of the system cannot change after initialization.

Particle properties

For a list of all particle properties that can be read and/or set, see *hoomd.data.particle_data_proxy*. The examples here only demonstrate changing a few of them.

`system.particles` is a window into all of the particles in the system. It behaves like standard python list in many ways.

- Its length (the number of particles in the system) can be queried:

```
>>> len(system.particles)
64000
```

- A short summary can be printed of the list:

```
>>> print(system.particles)
Particle Data for 64000 particles of 1 type(s)
```

- The list of all particle types in the simulation can be accessed:

```
>>> print(system.particles.types)
['A']
>>> print system.particles.types
Particle types: ['A']
```

- Particle types can be added between *hoomd.run()* commands:

```
>>> system.particles.types.add('newType')
```

- Individual particles can be accessed at random:

```
>>> i = 4
>>> p = system.particles[i]
```

- Various properties can be accessed of any particle (note that p can be replaced with system.particles[i] and the results are the same):

```
>>> p.tag
4
>>> p.position
```

(continues on next page)

```
(27.296911239624023, -3.5986068248748779, 10.364067077636719)
>>> p.velocity
(-0.60267972946166992, 2.6205904483795166, -1.7868227958679199)
>>> p.mass
1.0
>>> p.diameter
1.0
>>> p.type
'A'
>>> p.tag
4
```

- Particle properties can be set in the same way:

```
>>> p.position = (1,2,3)
>>> p.position
(1.0, 2.0, 3.0)
```

- Finally, all particles can be easily looped over:

```
for p in system.particles:
    p.velocity = (0,0,0)
```

Particles may be added at any time in the job script, and a unique tag is returned:

```
>>> system.particles.add('A')
>>> t = system.particles.add('B')
```

Particles may be deleted by index:

```
>>> del system.particles[0]
>>> print(system.particles[0])
tag         : 1
position    : (23.846603393554688, -27.558368682861328, -20.501256942749023)
image       : (0, 0, 0)
velocity    : (0.0, 0.0, 0.0)
acceleration: (0.0, 0.0, 0.0)
charge      : 0.0
mass        : 1.0
diameter    : 1.0
type        : A
typeid      : 0
body        : 4294967295
orientation : (1.0, 0.0, 0.0, 0.0)
net_force   : (0.0, 0.0, 0.0)
net_energy  : 0.0
net_torque  : (0.0, 0.0, 0.0)
```

Note: The particle with tag 1 is now at index 0. No guarantee is made about how the order of particles by index will or will not change, so do not write any job scripts which assume a given ordering.

To access particles in an index-independent manner, use their tags. For example, to remove all particles of type 'A', do:

```
tags = []
for p in system.particles:
    if p.type == 'A'
        tags.append(p.tag)
```

Then remove each of the particles by their unique tag:

```
for t in tags:
    system.particles.remove(t)
```

Particles can also be accessed through their unique tag:

```
t = system.particles.add('A')
p = system.particles.get(t)
```

Any defined group can be used in exactly the same way as `system.particles` above, only the particles accessed will be those just belonging to the group. For a specific example, the following will set the velocity of all particles of type A to 0:

```
groupA = group.type(name="a-particles", type='A')
for p in groupA:
    p.velocity = (0,0,0)
```

Bond Data

Bonds may be added at any time in the job script:

```
>>> system.bonds.add("bondA", 0, 1)
>>> system.bonds.add("bondA", 1, 2)
>>> system.bonds.add("bondA", 2, 3)
>>> system.bonds.add("bondA", 3, 4)
```

Individual bonds may be accessed by index:

```
>>> bnd = system.bonds[0]
>>> print(bnd)
tag          : 0
typeid       : 0
a            : 0
b            : 1
type         : bondA
>>> print(bnd.type)
bondA
>>> print(bnd.a)
0
>>> print(bnd.b)
1
```

> **Warning:** The order in which bonds appear by index is not static and may change at any time!

Bonds may be deleted by index:

```
>>> del system.bonds[0]
>>> print(system.bonds[0])
tag          : 3
typeid       : 0
a            : 3
b            : 4
type         : bondA
```

To access bonds in an index-independent manner, use their tags. For example, to delete all bonds which connect to particle 2, first loop through the bonds and build a list of bond tags that match the criteria:

```
tags = []
for b in system.bonds:
    if b.a == 2 or b.b == 2:
        tags.append(b.tag)
```

Then remove each of the bonds by their unique tag:

```
for t in tags:
    system.bonds.remove(t)
```

Bonds can also be accessed through their unique tag:

```
t = system.bonds.add('polymer',0,1)
p = system.bonds.get(t)
```

Angle, Dihedral, and Improper Data

Angles, Dihedrals, and Impropers may be added at any time in the job script:

```
>>> system.angles.add("angleA", 0, 1, 2)
>>> system.dihedrals.add("dihedralA", 1, 2, 3, 4)
>>> system.impropers.add("dihedralA", 2, 3, 4, 5)
```

Individual angles, dihedrals, and impropers may be accessed, deleted by index or removed by tag with the same syntax as described for bonds, just replace *bonds* with *angles*, *dihedrals*, or, *impropers* and access the appropriate number of tag elements (a,b,c for angles) (a,b,c,d for dihedrals/impropers).

Constraints

Constraints may be added and removed from within the job script.

To add a constraint of length 1.5 between particles 0 and 1:

```
>>> t = system.constraints.add(0, 1, 1.5)
```

To remove it again:

```
>>> system.constraints.remove(t)
```

Forces

Forces can be accessed in a similar way:

```
>>> lj = pair.lj(r_cut=3.0)
>>> lj.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
>>> print(lj.forces[0])
tag          : 0
force        : (-0.077489577233791351, -0.029512746259570122, -0.13215918838977814)
virial       : -0.0931386947632
energy       : -0.0469368174672
>>> f0 = lj.forces[0]
>>> print(f0.force)
(-0.077489577233791351, -0.029512746259570122, -0.13215918838977814)
>>> print(f0.virial)
-0.093138694763n
>>> print(f0.energy)
-0.0469368174672
```

In this manner, forces due to the lj pair force, bonds, and any other force commands in hoomd can be accessed independently from one another. See *hoomd.data.force_data_proxy* for a definition of each data field.

For advanced code using the particle data access from python, it is important to understand that the hoomd particles, forces, bonds, et cetera, are accessed as proxies. This means that after:

```
p = system.particles[i]
```

is executed, *p* **does not** store the position, velocity, . . . of particle *i*. Instead, it stores *i* and provides an interface to get/set the properties on demand. This has some side effects you need to be aware of.

- First, it means that *p* (or any other proxy reference) always references the current state of the particle. As an example, note how the position of particle p moves after the run() command:

```
>>> p.position
(-21.317455291748047, -23.883811950683594, -22.159387588500977)
>>> run(1000)
** starting run **
** run complete **
>>> p.position
(-19.774742126464844, -23.564577102661133, -21.418502807617188)
```

- Second, it means that copies of the proxy reference cannot be changed independently:

```
p.position
>>> a = p
>>> a.position
(-19.774742126464844, -23.564577102661133, -21.418502807617188)
>>> p.position = (0,0,0)
>>> a.position
(0.0, 0.0, 0.0)
```

class hoomd.data.**SnapshotParticleData**

Snapshot of particle data properties.

Users should not create SnapshotParticleData directly. Use *hoomd.data.make_snapshot()* or *hoomd. data.system_data.take_snapshot()* to make snapshots.

N

Number of particles in the snapshot

Type int

types

List of string type names (assignable)

> **Type** list

position
> (Nx3) numpy array containing the position of each particle (float or double)
>
> > **Type** numpy.ndarray

orientation
> (Nx4) numpy array containing the orientation quaternion of each particle (float or double)
>
> > **Type** numpy.ndarray

velocity
> (Nx3) numpy array containing the velocity of each particle (float or double)
>
> > **Type** numpy.ndarray

acceleration
> (Nx3) numpy array containing the acceleration of each particle (float or double)
>
> > **Type** numpy.ndarray

typeid
> Length N numpy array containing the type id of each particle (32-bit unsigned int)
>
> > **Type** numpy.ndarray

mass
> Length N numpy array containing the mass of each particle (float or double)
>
> > **Type** numpy.ndarray

charge
> Length N numpy array containing the charge of each particle (float or double)
>
> > **Type** numpy.ndarray

diameter
> Length N numpy array containing the diameter of each particle (float or double)
>
> > **Type** numpy.ndarray

image
> (Nx3) numpy array containing the image of each particle (32-bit int)
>
> > **Type** numpy.ndarray

body
> Length N numpy array containing the body of each particle (32-bit unsigned int). -1 indicates a free particle, and larger negative numbers indicate floppy bodies.
>
> > **Type** numpy.ndarray

moment_inertia
> (Nx3) numpy array containing the principal moments of inertia of each particle (float or double)
>
> > **Type** numpy.ndarray

angmom
> (Nx4) numpy array containing the angular momentum quaternion of each particle (float or double)
>
> > **Type** numpy.ndarray

See also:

hoomd.data

---

resize(*N*)

> Resize the snapshot to hold N particles.
>
> > **Parameters N** (*int*) – new size of the snapshot.
>
> *resize()* changes the size of the arrays in the snapshot to hold *N* particles. Existing particle properties are preserved after the resize. Any newly created particles will have default values. After resizing, existing references to the numpy arrays will be invalid, access them again from *snapshot.particles.**

class hoomd.data.**angle_data_proxy**(*adata*, *tag*)

> Access a single angle via a proxy.
>
> angle_data_proxy provides access to all of the properties of a single angle in the system. See *hoomd.data* for examples.
>
> **tag**
>
> > A unique integer attached to each angle (not in any particular range). A angle's tag remains fixed during its lifetime. (Tags previously used by removed angles may be recycled).
> >
> > > **Type** int
>
> **typeid**
>
> > Type id of the angle.
> >
> > > **Type** int
>
> **a**
>
> > The tag of the first particle in the angle.
> >
> > > **Type** int
>
> **b**
>
> > The tag of the second particle in the angle.
> >
> > > **Type** int
>
> **c**
>
> > The tag of the third particle in the angle.
> >
> > > **Type** int
>
> **type**
>
> > angle type name.
> >
> > > **Type** str
>
> In the current version of the API, only already defined type names can be used. A future improvement will allow dynamic creation of new type names from within the python API.

class hoomd.data.**bond_data_proxy**(*bdata*, *tag*)

> Access a single bond via a proxy.
>
> bond_data_proxy provides access to all of the properties of a single bond in the system. See *hoomd.data* for examples.
>
> **tag**
>
> > A unique integer attached to each bond (not in any particular range). A bond's tag remains fixed during its lifetime. (Tags previously used by removed bonds may be recycled).
> >
> > > **Type** int
>
> **typeid**
>
> > Type id of the bond.
> >
> > > **Type** int

a
> The tag of the first particle in the bond.
>
> > **Type** int

b
> The tag of the second particle in the bond.
>
> > **Type** int

type
> Bond type name.
>
> > **Type** str

In the current version of the API, only already defined type names can be used. A future improvement will allow dynamic creation of new type names from within the python API.

class hoomd.data.**boxdim**(*Lx=1.0, Ly=1.0, Lz=1.0, xy=0.0, xz=0.0, yz=0.0, dimensions=3, L=None, volume=None*)
> Define box dimensions.
>
> > **Parameters**
> >
> > - **Lx** (*float*) – box extent in the x direction (distance units)
> >
> > - **Ly** (*float*) – box extent in the y direction (distance units)
> >
> > - **Lz** (*float*) – box extent in the z direction (distance units)
> >
> > - **xy** (*float*) – tilt factor xy (dimensionless)
> >
> > - **xz** (*float*) – tilt factor xz (dimensionless)
> >
> > - **yz** (*float*) – tilt factor yz (dimensionless)
> >
> > - **dimensions** (*int*) – Number of dimensions in the box (2 or 3).
> >
> > - **L** (*float*) – shorthand for specifying Lx=Ly=Lz=L (distance units)
> >
> > - **volume** (*float*) – Scale the given box dimensions up to the this volume (area if dimensions=2)

Simulation boxes in hoomd are specified by six parameters, *Lx*, *Ly*, *Lz*, *xy*, *xz* and *yz*. For full details, see *Periodic boundary conditions*. A boxdim provides a way to specify all six parameters for a given box and perform some common operations with them. Modifying a boxdim does not modify the underlying simulation box in hoomd. A boxdim can be passed to an initialization method or to assigned to a saved sysdef variable (system.box = new_box) to set the simulation box.

Access attributes directly:

```
b = data.boxdim(L=20)
b.xy = 1.0
b.yz = 0.5
b.Lz = 40
```

Two dimensional systems

2D simulations in hoomd are embedded in 3D boxes with short heights in the z direction. To create a 2D box, set dimensions=2 when creating the boxdim. This will force Lz=1 and xz=yz=0. init commands that support 2D boxes will pass the dimensionality along to the system. When you assign a new boxdim to an already initialized system, the dimensionality flag is ignored. Changing the number of dimensions during a simulation run is not supported.

In 2D boxes, *volume* is in units of area.

Shorthand notation

data.boxdim accepts the keyword argument L=x as shorthand notation for `Lx=x, Ly=x, Lz=x` in 3D and `Lx=x, Ly=x, Lz=1` in 2D. If you specify both `L` and `Lx`, `Ly`, or `Lz`, then the value for `L` will override the others.

Examples:

- Cubic box with given volume: `data.boxdim(volume=V)`

- Triclinic box in 2D with given area: `data.boxdim(xy=1.0, dimensions=2, volume=A)`

- Rectangular box in 2D with given area and aspect ratio: `data.boxdim(Lx=1, Ly=aspect, dimensions=2, volume=A)`

- Cubic box with given length: `data.boxdim(L=10)`

- Fully define all box parameters: `data.boxdim(Lx=10, Ly=20, Lz=30, xy=1.0, xz=0.5, yz=0.1)`

get_lattice_vector(*i*)
    Get a lattice vector.

> **Parameters** **i** (*int*) – (=0,1,2) direction of lattice vector

> **Returns** The lattice vector (3-tuple) along direction *i*.

get_volume()
    Get the box volume.

> **Returns** The box volume (area in 2D).

make_fraction(*v*)
    Scale a vector to fractional coordinates.

> **Parameters** **v** (*tuple*) – The vector to convert to fractional coordinates

> make_fraction() takes a vector in a box and computes a vector where all components are between 0 and 1.

> **Returns** The scaled vector.

min_image(*v*)
    Apply the minimum image convention to a vector using periodic boundary conditions.

> **Parameters** **v** (*tuple*) – The vector to apply minimum image to

> **Returns** The minimum image as a tuple.

scale(*sx=1.0, sy=1.0, sz=1.0, s=None*)
    Scale box dimensions.

> **Parameters**
>
> - **sx** (*float*) – scale factor in the x direction
>
> - **sy** (*float*) – scale factor in the y direction
>
> - **sz** (*float*) – scale factor in the z direction
>
> - **s** (*float*) – Shorthand for sx=s, sy=x, sz=s

> Scales the box by the given scale factors. Tilt factors are not modified.

> **Returns** A reference to the modified box.

---

set_volume(*volume*)
>   Set the box volume.

>   >   **Parameters volume** ([*float*](#)) – new box volume (area if dimensions=2)

>   Scale the box to the given volume (or area).

>   >   **Returns** A reference to the modified box.

wrap(*v*, *img=(0, 0, 0)*)
>   Wrap a vector using the periodic boundary conditions.

>   >   **Parameters**

>   >   - **v** ([*tuple*](#)) – The vector to wrap

>   >   - **img** ([*tuple*](#)) – A vector of integer image flags that will be updated (optional)

>   >   **Returns** The wrapped vector and the image flags in a tuple.

class hoomd.data.**constraint_data_proxy**(*cdata*, *tag*)
>   Access a single constraint via a proxy.

>   constraint_data_proxy provides access to all of the properties of a single constraint in the system. See [*hoomd.data*](#) for examples.

>   **tag**
>   >   A unique integer attached to each constraint (not in any particular range). A constraint's tag remains fixed during its lifetime. (Tags previously used by removed constraints may be recycled).

>   >   **Type** [int](#)

>   **d**
>   >   The constraint distance.

>   >   **Type** [float](#)

>   **a**
>   >   The tag of the first particle in the constraint.

>   >   **Type** [int](#)

>   **b**
>   >   The tag of the second particle in the constraint.

>   >   **Type** [int](#)

class hoomd.data.**dihedral_data_proxy**(*ddata*, *tag*)
>   Access a single dihedral via a proxy.

>   dihedral_data_proxy provides access to all of the properties of a single dihedral in the system. See [*hoomd.data*](#) for examples.

>   **tag**
>   >   A unique integer attached to each dihedral (not in any particular range). A dihedral's tag remains fixed during its lifetime. (Tags previously used by removed dihedrals may be recycled).

>   >   **Type** [int](#)

>   **typeid**
>   >   Type id of the dihedral.

>   >   **Type** [int](#)

>   **a**
>   >   The tag of the first particle in the dihedral.

> **Type** int

b
> The tag of the second particle in the dihedral.

> > **Type** int

c
> The tag of the third particle in the dihedral.

> > **Type** int

d
> The tag of the fourth particle in the dihedral.

> > **Type** int

type
> dihedral type name.

> > **Type** str

In the current version of the API, only already defined type names can be used. A future improvement will allow dynamic creation of new type names from within the python API.

class hoomd.data.**force_data_proxy**(*force*, *tag*)
> Access the force on a single particle via a proxy.

> force_data_proxy provides access to the current force, virial, and energy of a single particle due to a single force computation. See *hoomd.data* for examples.

> **force**
> > (float, x, y, z) - the current force on the particle (force units)

> > > **Type** tuple

> **virial**
> > This particle's contribution to the total virial tensor.

> > > **Type** tuple

> **energy**
> > This particle's contribution to the total potential energy (energy units)

> > > **Type** float

> **torque**
> > (float x, y, z) - current torque on the particle (torque units)

> > > **Type** float

hoomd.data.**gsd_snapshot**(*filename*, *frame=0*)
> Read a snapshot from a GSD file.

> > **Parameters**

> > > • **filename** (*str*) – GSD file to read the snapshot from.

> > > • **frame** (*int*) – Frame to read from the GSD file. Negative values index from the end of the file.

> *hoomd.data.gsd_snapshot()* opens the given GSD file and reads a snapshot from it.

hoomd.data.**make_snapshot**(*N*, *box*, *particle_types=['A']*, *bond_types=[]*, *angle_types=[]*, *dihedral_types=[]*, *improper_types=[]*, *pair_types=[]*, *dtype='float'*)
> Make an empty snapshot.

Parameters

- **N** (*int*) – Number of particles to create.
- **box** (*hoomd.data.boxdim*) – Simulation box parameters.
- **particle_types** (*list*) – Particle type names (must not be zero length).
- **bond_types** (*list*) – Bond type names (may be zero length).
- **angle_types** (*list*) – Angle type names (may be zero length).
- **dihedral_types** (*list*) – Dihedral type names (may be zero length).
- **improper_types** (*list*) – Improper type names (may be zero length).
- **pair_types** (*list*) – Special pair type names (may be zero length). .. versionadded:: 2.1
- **dtype** (*str*) – Data type for the real valued numpy arrays in the snapshot. Must be either 'float' or 'double'.

Examples:

```
snapshot = data.make_snapshot(N=1000, box=data.boxdim(L=10))
snapshot = data.make_snapshot(N=64000, box=data.boxdim(L=1, dimensions=2,
→volume=1000), particle_types=['A', 'B'])
snapshot = data.make_snapshot(N=64000, box=data.boxdim(L=20), bond_types=['polymer
→'], dihedral_types=['dihedralA', 'dihedralB'], improper_types=['improperA',
→'improperB', 'improperC'])
... set properties in snapshot ...
init.read_snapshot(snapshot);
```

hoomd.data.make_snapshot() creates all particles with **default properties**. You must set reasonable values for particle properties before initializing the system with *hoomd.init.read_snapshot()*.

The default properties are:

- position 0,0,0
- velocity 0,0,0
- image 0,0,0
- orientation 1,0,0,0
- typeid 0
- charge 0
- mass 1.0
- diameter 1.0

See also:

hoomd.init.read_snapshot()

class hoomd.data.**particle_data_proxy**(*pdata*, *tag*)

Access a single particle via a proxy.

particle_data_proxy provides access to all of the properties of a single particle in the system. See *hoomd.data* for examples.

tag

A unique name for the particle in the system. Tags run from 0 to N-1.

> **Type** int

acceleration
> A 3-tuple of floats (x, y, z). Acceleration is a calculated quantity and cannot be set. (in acceleration units)
>
> > **Type** tuple

typeid
> The type id of the particle.
>
> > **Type** int

position
> (x, y, z) (float, in distance units).
>
> > **Type** tuple

image
> (x, y, z) (int).
>
> > **Type** tuple

velocity
> (x, y, z) (float, in velocity units).
>
> > **Type** tuple

charge
> Particle charge.
>
> > **Type** float

mass
> (in mass units).
>
> > **Type** float

diameter
> (in distance units).
>
> > **Type** float

type
> Particle type name.
>
> > **Type** str

body
> Body id. -1 for free particles, 0 or larger for rigid bodies, and -2 or lesser for floppy bodies.
>
> > **Type** int

orientation
> (w,x,y,z) (float, quaternion).
>
> > **Type** tuple

net_force
> Net force on particle (x, y, z) (float, in force units).
>
> > **Type** tuple

net_energy
> Net contribution of particle to the potential energy (in energy units).
>
> > **Type** float

net_torque
>   Net torque on the particle (x, y, z) (float, in torque units).

> > **Type** [tuple](#)

net_virial
>   Net virial for the particle (xx,yy,zz, xy, xz, yz)

> > **Type** [tuple](#)

class hoomd.data.**system_data**(*sysdef*)
>   Access system data

> system_data provides access to the different data structures that define the current state of the simulation. See
> [*hoomd.data*](#) for a full explanation of how to use by example.

> **box**

> > **Type** [*hoomd.data.boxdim*](#)

> **particles**

> > **Type** [*hoomd.data.particle_data_proxy*](#)

> **bonds**

> > **Type** [*hoomd.data.bond_data_proxy*](#)

> **angles**

> > **Type** [*hoomd.data.angle_data_proxy*](#)

> **dihedrals**

> > **Type** [*hoomd.data.dihedral_data_proxy*](#)

> **impropers**

> > **Type** [*hoomd.data.dihedral_data_proxy*](#)

> **constraint**

> > **Type** [*hoomd.data.constraint_data_proxy*](#)

> **pairs**
> >   New in version 2.1.

> > **Type** [*hoomd.data.bond_data_proxy*](#)

> **replicate**(*nx=1*, *ny=1*, *nz=1*)
> >   Replicates the system along the three spatial dimensions.

> > **Parameters**

> > > - **nx** ([*int*](#)) – Number of times to replicate the system along the x-direction
> > > - **ny** ([*int*](#)) – Number of times to replicate the system along the y-direction
> > > - **nz** ([*int*](#)) – Number of times to replicate the system along the z-direction

> > This method replicates particles along all three spatial directions, as opposed to replication implied by
> > periodic boundary conditions. The box is resized and the number of particles is updated so that the new
> > box holds the specified number of replicas of the old box along all directions. Particle coordinates are
> > updated accordingly to fit into the new box. All velocities and other particle properties are replicated as
> > well. Also bonded groups between particles are replicated.

> > Examples:

```
system = init.read_xml("some_file.xml")
system.replicate(nx=2,ny=2,nz=2)
```

Note: The dimensions of the processor grid are not updated upon replication. For example, if an initially cubic box is replicated along only one spatial direction, this could lead to decreased performance if the processor grid was optimal for the original box dimensions, but not for the new ones.

restore_snapshot (*snapshot*)
Re-initializes the system from a snapshot.

> **Parameters snapshot** – . The snapshot to initialize the system from.

Snapshots temporarily store system data. Snapshots contain the complete simulation state in a single object. They can be used to restart a simulation.

Example use cases in which a simulation may be restarted from a snapshot include python-script-level Monte-Carlo schemes, where the system state is stored after a move has been accepted (according to some criterion), and where the system is re-initialized from that same state in the case when a move is not accepted.

Example:

```
system = init.read_xml("some_file.xml")

... run a simulation ...

snapshot = system.take_snapshot(all=True)
...
system.restore_snapshot(snapshot)
```

Warning: restore_snapshot() may invalidate force coefficients, neighborlist r_cut values, and other per type quantities if called within a callback during a run(). You can restore a snapshot during a run only if the snapshot is of a previous state of the currently running system. Otherwise, you need to use restore_snapshot() between run() commands to ensure that all per type coefficients are updated properly.

take_snapshot (*particles=True,   bonds=False,   pairs=False,   integrators=False,   all=False,   dtype='float'*)
Take a snapshot of the current system data.

> **Parameters**
>
> - **particles** (*bool*) – When True, particle data is included in the snapshot.
> - **bonds** (*bool*) – When true, bond, angle, dihedral, improper and constraint data is included.
> - **pairs** (*bool*) – When true, special pair data is included .. versionadded:: 2.1
> - **integrators** (*bool*) – When true, integrator data is included the snapshot.
> - **all** (*bool*) – When true, the entire system state is saved in the snapshot.
> - **dtype** (*str*) – Datatype for the snapshot numpy arrays. Must be either 'float' or 'double'.
>
> **Returns** The snapshot object.

This functions returns a snapshot object. It contains the current. partial or complete simulation state. With appropriate options it is possible to select which data properties should be included in the snapshot

Examples:

```
snapshot = system.take_snapshot()
snapshot = system.take_snapshot()
snapshot = system.take_snapshot(bonds=true)
```

2.14.8 hoomd.dump

Overview

hoomd.dump.dcd	Writes simulation snapshots in the DCD format
hoomd.dump.getar	Analyzer for dumping system properties to a getar file at intervals.
hoomd.dump.gsd	Writes simulation snapshots in the GSD format

Details

Write system configurations to files.

Commands in the dump package write the system state out to a file every *period* time steps. Check the documentation for details on which file format each command writes.

class hoomd.dump.**dcd**(*filename*, *period*, *group=None*, *overwrite=False*, *unwrap_full=False*, *unwrap_rigid=False*, *angle_z=False*, *phase=0*)
   Writes simulation snapshots in the DCD format

   Parameters

   - **filename** (*str*) – File name to write.

   - **period** (*int*) – Number of time steps between file dumps.

   - **group** (*hoomd.group*) – Particle group to output to the dcd file. If left as None, all particles will be written.

   - **overwrite** (*bool*) – When False, (the default) an existing DCD file will be appended to. When True, an existing DCD file *filename* will be overwritten.

   - **unwrap_full** (*bool*) – When False, (the default) particle coordinates are always written inside the simulation box. When True, particles will be unwrapped into their current box image before writing to the dcd file.

   - **unwrap_rigid** (*bool*) – When False, (the default) individual particles are written inside the simulation box which breaks up rigid bodies near box boundaries. When True, particles belonging to the same rigid body will be unwrapped so that the body is continuous. The center of mass of the body remains in the simulation box, but some particles may be written just outside it. *unwrap_rigid* is ignored when *unwrap_full* is True.

   - **angle_z** (*bool*) – When True, the particle orientation angle is written to the z component (only useful for 2D simulations)

   - **phase** (*int*) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0*.

Every *period* time steps a new simulation snapshot is written to the specified file in the DCD file format. DCD only stores particle positions, in distance units - see *Units*.

Due to constraints of the DCD file format, once you stop writing to a file via `disable()`, you cannot continue writing to the same file, nor can you change the period of the dump at any time. Either of these tasks can be performed by creating a new dump file with the needed settings.

Examples:

```
dump.dcd(filename="trajectory.dcd", period=1000)
dcd = dump.dcd(filename"data/dump.dcd", period=1000)
```

> **Warning:** When you use dump.dcd to append to an existing dcd file:
>
> • The period must be the same or the time data in the file will not be consistent.
>
> • dump.dcd will not write out data at time steps that already are present in the dcd file to maintain a consistent timeline

disable()
> Disable the analyzer.
>
> Examples:
>
> ```
> my_analyzer.disable()
> ```
>
> Executing the disable command will remove the analyzer from the system. Any `hoomd.run()` command executed after disabling an analyzer will not use that analyzer during the simulation. A disabled analyzer can be re-enabled with `enable()`.

enable()
> The DCD dump writer cannot be re-enabled

restore_state()
> Restore the state information from the file used to initialize the simulations

set_period(*period*)
> Changes the period between analyzer executions
>
> > **Parameters** **period** (*int*) – New period to set (in time steps)
>
> Examples:
>
> ```
> analyzer.set_period(100)
> analyzer.set_period(1)
> ```
>
> While the simulation is running (`hoomd.run()`, the action of each analyzer is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.dump.**getar**(*filename*, *mode='w'*, *static=[]*, *dynamic={}*, *_register=True*)
> Analyzer for dumping system properties to a getar file at intervals.
>
> Getar files are a simple interface on top of archive formats (such as zip and tar) for storing trajectory data efficiently. A more thorough description of the format and a description of a python API to read and write these files is available at the libgetar documentation.
>
> Properties to dump can be given either as a `getar.DumpProp` object or a name. Supported property names are specified in the Supported Property Table in `hoomd.init.read_getar`.

Files can be opened in write, append, or one-shot mode. Write mode overwrites files with the same name, while append mode adds to them. One-shot mode is intended for restorable system backups and is described below.

One-shot mode

In one-shot mode, activated by passing mode='1' to the getar constructor, properties are written to a temporary file, which then overwrites the file with the given filename. In this way, the file with the given filename should always have the most recent frame of successfully written data. This mode is designed for being able to dump restoration data often without wasting large amounts of space saving earlier data. Note that this create-and-overwrite process can be stressful on filesystems, particularly lustre filesystems, and can get your account blocked on some supercomputer resources if overused.

For convenience, you can also specify **composite properties**, which are expanded according to the table below.

twidth.take_snapshotdNameResult	
twidthdimglobal_box,all	
	dimensions
twidth.angle_type_names,	
	angle_tag,
	angle_type
twidth.bond_all_type_names,	
	bond_tag,
	bond_type
twidth.dihedral_all_type_names,	
	dihedral_tag,
	dihedral_type
twidth.improper_all_type_names,	
	improper_tag,
	improper_type
twidth.particle_all_momentum,	
	body,
	charge,
	diameter,
	image,
	mass,
	moment_inertia,
	orientation,
	position,
	type,
	type_names,
	velocity
twidth.particle_all,	
	angle_all,
	bond_all,
	dihedral_all,
	improper_all,
	global_all

Particle-related metadata

Metadata about particle shape (for later visualization or use in restartable scripts) can be stored in a simple form through *hoomd.dump.getar.writeJSON()*, which encodes JSON records as strings and stores them inside the dump file. Currently, classes inside *hoomd.dem* and *hoomd.hpmc* are equipped with *get_type_shapes()* methods which can provide per-particle-type shape information as a list.

Example:

```
dump = hoomd.dump.getar.simple('dump.sqlite', 1e3,
    static=['viz_static'],
    dynamic=['viz_aniso_dynamic'])

dem_wca = hoomd.dem.WCA(nlist, radius=0.5)
dem_wca.setParams('A', vertices=vertices, faces=faces)
dump.writeJSON('type_shapes.json', dem_wca.get_type_shapes())

mc = hpmc.integrate.convex_polygon(seed=415236)
mc.shape_param.set('A', vertices=[(-0.5, -0.5), (0.5, -0.5), (0.5, 0.5), (-0.5, 0.
↪5)])
dump.writeJSON('type_shapes.json', mc.get_type_shapes(), dynamic=True)
```

class DumpProp(*name*, *highPrecision=False*, *compression=hoomd.dump.getar.Compression.FastCompress*)
    Create a dump property specification.

        Parameters

- **name** – Name of the property to dump

- **highPrecision** – True if the property should be dumped in high precision, if possible

- **compression** – Compression level to save the property with, if possible

__init__(*filename*, *mode='w'*, *static=[]*, *dynamic={}*, *_register=True*)
    Initialize a getar dumper. Creates or appends an archive at the given file location according to the mode and prepares to dump the given sets of properties.

        Parameters

- **filename** (*str*) – Name of the file to open

- **mode** (*str*) – Run mode; see mode list below.

- **static** (*list*) – List of static properties to dump immediately

- **dynamic** (*dict*) – Dictionary of {prop: period} periodic dumps

- **_register** (*bool*) – If True, register as a hoomd analyzer (internal)

Note that zip32-format archives can not be appended to at the moment; for details and solutions, see the libgetar documentation, section "Zip vs. Zip64." The gtar.fix module was explicitly made for this purpose, but be careful not to call it from within a running GPU HOOMD simulation due to strangeness in the CUDA driver.

Valid mode arguments:

- 'w': Write, and overwrite if file exists

- 'a': Write, and append if file exists

- '1': One-shot mode: keep only one frame of data. For details on one-shot mode, see the "One-shot mode" section of *getar*.

Property specifications can be either a property name (as a string) or *DumpProp* objects if you desire greater control over how the property will be dumped.

Example:

```
# detailed API; see `dump.getar.simple` for simpler wrappers
zip = dump.getar('dump.zip', static=['types'],
          dynamic={'orientation': 10000,
                   'velocity': 5000,
                   dump.getar.DumpProp('position', highPrecision=True): 10000}
↪)
```

close()
   Closes the trajectory if it is open. Finalizes any IO beforehand.

disable()
   Disable the analyzer.

   Examples:

```
my_analyzer.disable()
```

   Executing the disable command will remove the analyzer from the system. Any *hoomd.run()* command executed after disabling an analyzer will not use that analyzer during the simulation. A disabled analyzer can be re-enabled with *enable()*.

enable()
   Enables the analyzer

   Examples:

```
my_analyzer.enable()
```

   See *disable()*.

classmethod immediate(*filename*, *static*, *dynamic*)
   Immediately dump the given static and dynamic properties to the given filename.

   For detailed explanation of arguments, see *getar*.

   Example:

```
hoomd.dump.getar.immediate(
    'snapshot.tar', static=['viz_static'], dynamic=['viz_dynamic'])
```

restore_state()
   Restore the state information from the file used to initialize the simulations

classmethod simple(*filename*, *period*, *mode='w'*, *static=[]*, *dynamic=[]*, *high_precision=False*)
   Create a *getar* dump object with a simpler interface.

   Static properties will be dumped once immediately, and dynamic properties will be dumped every *period* steps. For detailed explanation of arguments, see *getar*.

   > **Parameters**
   >
   >   • **filename** (*str*) – Name of the file to open
   >
   >   • **period** (*int*) – Period to dump the given dynamic properties with
   >
   >   • **mode** (*str*) – Run mode; see mode list in *getar*.
   >
   >   • **static** (*list*) – List of static properties to dump immediately

- **dynamic** (*list*) – List of properties to dump every *period* steps

- **high_precision** (*bool*) – If True, dump precision properties

Example:

```
# [optionally] dump metadata beforehand with libgetar
with gtar.GTAR('dump.sqlite', 'w') as trajectory:
    metadata = json.dumps(hoomd.meta.dump_metadata())
    trajectory.writeStr('hoomd_metadata.json', metadata)
# for later visualization of anisotropic systems
zip2 = hoomd.dump.getar.simple(
    'dump.sqlite', 100000, 'a', static=['viz_static'], dynamic=['viz_aniso_
→dynamic'])
# as backup to restore from later
backup = hoomd.dump.getar.simple(
    'backup.tar', 10000, '1', static=['viz_static'], dynamic=['viz_aniso_
→dynamic'])
```

writeJSON (*name*, *contents*, *dynamic=True*)

Encodes the given JSON-encodable object as a string and writes it (immediately) as a quantity with the given name. If dynamic is True, writes the record as a dynamic record with the current timestep.

Parameters

- **name** (*str*) – Name of the record to save

- **contents** (*str*) – Any datatype encodable by the json module

- **dynamic** (*bool*) – If True, dump a dynamic quantity with the current timestep; otherwise, dump a static quantity

Example:

```
dump = hoomd.dump.getar.simple('dump.sqlite', 1e3,
    static=['viz_static'], dynamic=['viz_dynamic'])
dump.writeJSON('params.json', dict(temperature=temperature,
→pressure=pressure))
dump.writeJSON('metadata.json', hoomd.meta.dump_metadata())
```

class hoomd.dump.**gsd** (*filename*, *period*, *group*, *overwrite=False*, *truncate=False*, *phase=0*, *time_step=None*, *static=None*, *dynamic=None*)

Writes simulation snapshots in the GSD format

Parameters

- **filename** (*str*) – File name to write

- **period** (*int*) – Number of time steps between file dumps, or None to write a single file immediately.

- **group** (*hoomd.group*) – Particle group to output to the gsd file.

- **overwrite** (*bool*) – When False (the default), any existing GSD file will be appended to. When True, an existing GSD file *filename* will be overwritten.

- **truncate** (*bool*) – When False (the default), frames are appended to the GSD file. When True, truncate the file and write a new frame 0 every time.

- **phase** (*int*) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0*.

- **time_step** (*int*) – Time step to write to the file (only used when period is None)

- **dynamic** (*list*) – A list of quantity categories to save every frame. (added in version 2.2)
- **static** (*list*) – A list of quantity categories save only in frame 0 (may not be set in conjunction with *dynamic*, deprecated in version 2.2).

Write a simulation snapshot to the specified GSD file at regular intervals. GSD is capable of storing all particle and bond data fields in hoomd, in every frame of the trajectory. This allows GSD to store simulations where the number of particles, number of particle types, particle types, diameter, mass, charge, and other quantities change over time. GSD can also store integrator state information necessary for restarting simulations and user-defined log quantities.

To save on space, GSD does not write values that are all set at defaults. So if all masses, orientations, angular momenta, etc... are left default, these fields will not take up any space in the file. Additionally, only **dynamic** quantities are written to all frames, non-dynamic quantities are only written to frame 0. The GSD schema defines that data not present in frame *i* is to be read from frame 0. This makes every single frame of a GSD file fully specified and simulations initialized with *hoomd.init.read_gsd()* can select any frame of the file.

You can control what quantities are dynamic by category. `property` is always dynamic. The categories listed in the **dynamic** will also be written out to every frame, but only if they have changed from the defaults.

- `attribute`
  - particles/N
  - particles/types
  - particles/typeid
  - particles/mass
  - particles/charge
  - particles/diameter
  - particles/body
  - particles/moment_inertia
- `property`
  - particles/position
  - particles/orientation (*only written when changed from default*)
- `momentum`
  - particles/velocity
  - particles/angmom (*only written when changed from default*)
  - particles/image
- `topology`
  - bonds/
  - angles/
  - dihedrals/
  - impropers/
  - constraints/
  - pairs/

See https://github.com/glotzerlab/gsd and http://gsd.readthedocs.io/ for more information on GSD files.

If you only need to store a subset of the system, you can save file size and time spent analyzing data by specifying a group to write out. *gsd* will write out all of the particles in the group in ascending tag order. When the group is not *hoomd.group.all()*, *gsd* will not write the topology fields.

To write restart files with gsd, set *truncate=True*. This will cause *gsd* to write a new frame 0 to the file every period steps.

State data

gsd can save internal state data for the following hoomd objects:

- *HPMC integrators*

Call *dump_state()* with the object as an argument to enable saving its state. State saved in this way can be restored after initializing the system with *hoomd.init.read_gsd()*.

User-defined log quantities

Associate a name with a callable python object that returns a numpy array in *log*, and *gsd* will save the data you provide on every frame. Prefix per-particle quantities with `particles/` and per-bond quantities with `bonds/` so that visualization tools such as OVITO will make them available in their pipelines. OVITO also understand scalar values (length 1 numpy arrays) and strings encoded as uint8 numpy arrays.

Examples:

```python
dump.gsd(filename="trajectory.gsd", period=1000, group=group.all(), phase=0)
dump.gsd(filename="restart.gsd", truncate=True, period=10000, group=group.all(),
→phase=0)
dump.gsd(filename="configuration.gsd", overwrite=True, period=None, group=group.
→all(), time_step=0)
dump.gsd(filename="momentum_too.gsd", period=1000, group=group.all(), phase=0,
→dynamic=['momentum'])
dump.gsd(filename="saveall.gsd", overwrite=True, period=1000, group=group.all(),
→dynamic=['attribute', 'momentum', 'topology'])
```

disable()
    Disable the analyzer.

    Examples:

```python
my_analyzer.disable()
```

    Executing the disable command will remove the analyzer from the system. Any *hoomd.run()* command executed after disabling an analyzer will not use that analyzer during the simulation. A disabled analyzer can be re-enabled with *enable()*.

dump_shape(*obj*)
    Writes particle shape information stored by a hoomd object.

    This method writes particle shape information into a GSD file, in the chunk `particle/type_shapes`. This information can be used by other libraries for visualization. The following classes support writing shape information to GSD files:

    - *hoomd.hpmc.integrate.sphere*
    - *hoomd.hpmc.integrate.convex_polyhedron*

- *hoomd.hpmc.integrate.convex_spheropolyhedron*

- *hoomd.hpmc.integrate.polyhedron*

- *hoomd.hpmc.integrate.convex_polygon*

- *hoomd.hpmc.integrate.convex_spheropolygon*

- *hoomd.hpmc.integrate.simple_polygon*

- *hoomd.hpmc.integrate.ellipsoid*

- *hoomd.dem.pair.WCA*

- *hoomd.dem.pair.SWCA*

- *hoomd.md.pair.gb*

See the Shape Visualization Specification section of the GSD package documentation for a detailed description of shape definitions.

New in version 2.7.

dump_state(*obj*)

Write state information for a hoomd object.

Call *dump_state()* if you want to write the state of a hoomd object to the gsd file.

New in version 2.2.

enable()

Enables the analyzer

Examples:

```
my_analyzer.enable()
```

See *disable()*.

log

Dictionary mapping user-defined names to callbacks.

Add an item to *log* to save user-defined data in the gsd file. The key provides the name of the data chunk in the gsd file (e.g. particles/lj_potential_energy). The value is a callable python object that takes the current time step as an argument and returns a numpy array that has 1 or 2 dimensions and has a data type supported by gsd.

Delete a key from *log* to stop logging that quantity.

Note: All logged data chunks must be present in the first frame in the gsd file to provide the default value. Some (or all) chunks may be omitted on later frames:

Note: In MPI parallel simulations, the callback will be called on all ranks. *gsd* will write the data returned by the root rank. Return values from all other ranks are ignored (and may be None).

New in version 2.7.

restore_state()

Restore the state information from the file used to initialize the simulations

set_period(*period*)

Changes the period between analyzer executions

> **Parameters period** (*int*) – New period to set (in time steps)

Examples:

```
analyzer.set_period(100)
analyzer.set_period(1)
```

While the simulation is running (*hoomd.run()*, the action of each analyzer is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

write_restart()
    Write a restart file at the current time step.

    Call *write_restart()* at the end of a simulation where are writing a gsd restart file with `truncate=True` to ensure that you have the final frame of the simulation written before exiting. See *Restartable jobs* for examples.

2.14.9 hoomd.group

Overview

hoomd.group.all	Groups all particles.
hoomd.group.charged	Groups particles that are charged.
hoomd.group.cuboid	Groups particles in a cuboid.
hoomd.group.difference	Create a new group from the set difference or complement of two existing groups.
hoomd.group.group	Defines a group of particles
hoomd.group.intersection	Create a new group from the set intersection of two existing groups.
hoomd.group.nonrigid	Groups particles that do not belong to rigid bodies.
hoomd.group.rigid	Groups particles that belong to rigid bodies.
hoomd.group.rigid_center	Groups particles that are center particles of rigid bodies.
hoomd.group.tag_list	Groups particles by tag list.
hoomd.group.tags	Groups particles by tag.
hoomd.group.type	Groups particles by type.
hoomd.group.union	Create a new group from the set union of two existing groups.

Details

Commands for grouping particles

This package contains various commands for making groups of particles

hoomd.group.**all**()
    Groups all particles.

    Creates a particle group from all particles in the simulation.

    Examples:

```
all = group.all()
```

hoomd.group.**body**()
    Groups particles that belong to any bodies.

Creates a particle group from particles. All particles that belong to a body will be added to the group. The group is always named 'body'.

Examples:

```
body = group.body()
```

hoomd.group.**charged**(*name='charged'*)
    Groups particles that are charged.

>   **Parameters name** (`str`) – User-assigned name for this group.

Creates a particle group containing all particles that have a non-zero charge.

> **Warning:** This group currently does not support being updated when the number of particles changes.

Examples:

```
a = group.charged()
b = group.charged(name="cp")
```

hoomd.group.**cuboid**(*name, xmin=None, xmax=None, ymin=None, ymax=None, zmin=None, zmax=None*)
    Groups particles in a cuboid.

>   **Parameters**
>
>   - **name** (`str`) – User-assigned name for this group
>   - **xmin** (`float`) – (if set) Lower left x-coordinate of the cuboid (in distance units)
>   - **xmax** (`float`) – (if set) Upper right x-coordinate of the cuboid (in distance units)
>   - **ymin** (`float`) – (if set) Lower left y-coordinate of the cuboid (in distance units)
>   - **ymax** (`float`) – (if set) Upper right y-coordinate of the cuboid (in distance units)
>   - **zmin** (`float`) – (if set) Lower left z-coordinate of the cuboid (in distance units)
>   - **zmax** (`float`) – (if set) Upper right z-coordinate of the cuboid (in distance units)

If any of the above parameters is not set, it will automatically be placed slightly outside of the simulation box dimension, allowing easy specification of slabs.

Creates a particle group from particles that fall in the defined cuboid. Membership tests are performed via `xmin <= x < xmax` (and so forth for y and z) so that directly adjacent cuboids do not have overlapping group members.

> **Note:** Membership in `cuboid` is defined at time of group creation. Once created, any particles added to the system will not be added to the group. Any particles that move into the cuboid region will not be added automatically, and any that move out will not be removed automatically.

Between runs, you can force a group to update its membership with the particles currently in the originally defined region using `hoomd.group.group.force_update()`.

Examples:

```
slab = group.cuboid(name="slab", ymin=-3, ymax=3)
cube = group.cuboid(name="cube", xmin=0, xmax=5, ymin=0, ymax=5, zmin=0, zmax=5)
run(100)
# Remove particles that left the region and add particles that entered the region.
cube.force_update()
```

hoomd.group.**difference**(*name*, *a*, *b*)

Create a new group from the set difference or complement of two existing groups.

> **Parameters**
>
> - **name** (*str*) – User-assigned name for this group.
>
> - **a** (*group*) – First group.
>
> - **b** (*group*) – Second group.

The set difference of *a* and *b* is defined to be the set of particles that are in *a* and not in *b*. This can be useful for inverting the sense of a group (see below).

A new group called *name* is created.

> **Warning:** The group is static and will not update if particles are added to or removed from the system.

Examples:

```
groupA = group.type(name='groupA', type='A')
all = group.all()
nottypeA = group.difference(name="particles-not-typeA", a=all, b=groupA)
```

hoomd.group.**floppy**()

Groups particles that belong to any floppy body.

Creates a particle group from particles. All particles that belong to a floppy will be added to the group. The group is always named 'floppy'.

Examples:

```
floppy = group.floppy()
```

class hoomd.group.**group**(*name*, *cpp_group*)

Defines a group of particles

group should not be created directly in user code. The following methods can be used to create particle groups.

- *hoomd.group.all()*
- *hoomd.group.cuboid()*
- *hoomd.group.nonrigid()*
- *hoomd.group.rigid()*
- *hoomd.group.tags()*
- *hoomd.group.tag_list()*
- *hoomd.group.type()*
- *hoomd.group.charged()*

The above functions assign a descriptive name based on the criteria chosen. That name can be easily changed if desired:

```
groupA = group.type('A')
groupA.name = "my new group name"
```

Once a group has been created, it can be combined with others via set operations to form more complicated groups. Available operations are:

- *hoomd.group.difference()*
- *hoomd.group.intersection()*
- *hoomd.group.union()*

Note: Groups need to be consistent with the particle data. If a particle member is removed from the simulation, it will be temporarily removed from the group as well, that is, even though the group reports that tag as a member, it will act as if the particle was not existent. If a particle with the same tag is later added to the simulation, it will become member of the group again.

Examples:

```
# create a group containing all particles in group A and those with
# tags 100-199
groupA = group.type('A')
group100_199 = group.tags(100, 199);
group_combined = group.union(name="combined", a=groupA, b=group100_199);

# create a group containing all particles in group A that also have
# tags 100-199
group_combined2 = group.intersection(name="combined2", a=groupA, b=group100_199);

# create a group containing all particles that are not in group A
all = group.all()
group_notA = group.difference(name="notA", a=all, b=groupA)
```

A group can also be queried with python sequence semantics.

Examples:

```
groupA = group.type('A')
# print the number of particles in group A
print len(groupA)
# print the position of the first particle in the group
print groupA[0].position
# set the velocity of all particles in groupA to 0
for p in groupA:
    p.velocity = (0,0,0)
```

For more information and examples on accessing the data in this way, see *hoomd.data*.

force_update()
> Force an update of the group.

> Re-evaluate all particles against the original group selection criterion and build a new member list based on the current state of the system. For example, call *hoomd.group.group.force_update()* set set a cuboid group's membership to particles that are currently in the defined region.

Groups made by a combination (union, intersection, difference) of other groups will not update their membership, they are always static.

hoomd.group.**intersection**(*name*, *a*, *b*)

Create a new group from the set intersection of two existing groups.

Parameters

- **name** (*str*) – User-assigned name for this group.
- **a** (*group*) – First group.
- **b** (*group*) – Second group.

A new group is created that contains all particles of *a* that are also in *b*, and is given the name *name*.

> **Warning:** The group is static and will not update if particles are added to or removed from the system.

Examples:

```
groupA = group.type(name='groupA', type='A')
group100_199 = group.tags(name='100_199', tag_min=100, tag_max=199);
groupC = group.intersection(name="groupC", a=groupA, b=group100_199)
```

hoomd.group.**nonbody**()

Groups particles that do not belong to any body.

Creates a particle group from particles. All particles that **do not** belong to a body will be added to the group. The group is always named 'nonbody'.

Examples:

```
nonbody = group.nonbody()
```

hoomd.group.**nonfloppy**()

Groups particles that do not belong to any floppy body.

Creates a particle group from particles. All particles that **do not** belong to a floppy body will be added to the group. The group is always named 'nonfloppy'.

Examples:

```
nonfloppy = group.nonfloppy()
```

hoomd.group.**nonrigid**()

Groups particles that do not belong to rigid bodies.

Creates a particle group from particles. All particles that **do not** belong to a rigid body will be added to the group. The group is always named 'nonrigid'.

Examples:

```
nonrigid = group.nonrigid()
```

hoomd.group.**rigid**()

Groups particles that belong to rigid bodies.

Creates a particle group from particles. All particles that belong to a rigid body will be added to the group. The group is always named 'rigid'.

Examples:

```
rigid = group.rigid()
```

hoomd.group.**rigid_center**()
> Groups particles that are center particles of rigid bodies.

> Creates a particle group from particles. All particles that are central particles of rigid bodies be added to the group. The group is always named 'rigid_center'.

> Examples:

```
rigid = group.rigid_center()
```

hoomd.group.**tag_list**(*name*, *tags*)
> Groups particles by tag list.

> > **Parameters**
> >
> > - **tags** (*list*) – List of particle tags to include in the group
> >
> > - **name** (*str*) – User-assigned name for this group.

> Creates a particle group from particles with the given tags. Can be used to implement advanced grouping not available with existing group commands.

> Examples:

```
a = group.tag_list(name="a", tags = [0, 12, 18, 205])
b = group.tag_list(name="b", tags = range(20,400))
```

hoomd.group.**tags**(*tag_min*, *tag_max=None*, *name=None*, *update=False*)
> Groups particles by tag.

> > **Parameters**
> >
> > - **tag_min** (*int*) – First tag in the range to include (inclusive)
> >
> > - **tag_max** (*int*) – Last tag in the range to include (inclusive)
> >
> > - **name** (*str*) – User-assigned name for this group. If a name is not specified, a default one will be generated.
> >
> > - **update** (*bool*) – When True, update list of group members when particles are added to or removed from the simulation.

> Creates a particle group from particles that match the given tag range.

> The *tag_max* is optional. If it is not specified, then a single particle with tag=tag_min will be added to the group.

> Examples:

```
half1 = group.tags(name="first-half", tag_min=0, tag_max=999)
half2 = group.tags(name="second-half", tag_min=1000, tag_max=1999)
```

hoomd.group.**type**(*type*, *name=None*, *update=False*)
> Groups particles by type.

> > **Parameters**
> >
> > - **type** (*str*) – Name of the particle type to add to the group.
> >
> > - **name** (*str*) – User-assigned name for this group. If a name is not specified, a default one will be generated.

- **update** (*bool*) – When true, update list of group members when particles are added to or removed from the simulation.

Creates a particle group from particles that match the given type. The group can then be used by other hoomd commands (such as analyze.msd) to specify which particles should be operated on.

Note: Membership in *hoomd.group.type()* is defined at time of group creation. Once created, any particles added to the system will be added to the group if *update* is set to *True*. However, if you change a particle type it will not be added to or removed from this group.

Between runs, you can force a group to update its membership with the particles currently in the originally specified type using *hoomd.group.group.force_update()*.

Examples:

```
groupA = group.type(name='a-particles', type='A')
groupB = group.type(name='b-particles', type='B')
groupB = group.type(name='b-particles', type='B',update=True)
```

hoomd.group.**union**(*name*, *a*, *b*)
    Create a new group from the set union of two existing groups.

    Parameters

        - **name** (*str*) – User-assigned name for this group.
        - **a** (*group*) – First group.
        - **b** (*group*) – Second group.

A new group is created that contains all particles present in either group *a* or *b*, and is given the name *name*.

Warning: The group is static and will not update if particles are added to or removed from the system.

Examples:

```
groupA = group.type(name='groupA', type='A')
groupB = group.type(name='groupB', type='B')
groupAB = group.union(name="ab-particles", a=groupA, b=groupB)
```

2.14.10 hoomd.init

Overview

hoomd.init.create_lattice	Create a lattice.
hoomd.init.read_getar	Initialize a system from a trajectory archive (.tar, .getar, .sqlite) file.
hoomd.init.read_gsd	Read initial system state from an GSD file.
hoomd.init.read_snapshot	Initializes the system from a snapshot.

Details

Data initialization commands

Commands in the `hoomd.init` package initialize the particle system.

hoomd.init.**create_lattice**(*unitcell*, *n*)

> Create a lattice.
>
> > **Parameters**
> >
> > > • **unitcell** (`hoomd.lattice.unitcell`) – The unit cell of the lattice.
> > >
> > > • **n** (`list`) – Number of replicates in each direction.
>
> `create_lattice()` take a unit cell and replicates it the requested number of times in each direction. The resulting simulation box is commensurate with the given unit cell. A generic `hoomd.lattice.unitcell` may have arbitrary vectors $\vec{a}_1$, $\vec{a}_2$, and $\vec{a}_3$. `create_lattice()` will rotate the unit cell so that $\vec{a}_1$ points in the x direction and $\vec{a}_2$ is in the xy plane so that the lattice may be represented as a HOOMD simulation box.
>
> When *n* is a single value, the lattice is replicated *n* times in each direction. When *n* is a list, the lattice is replicated *n[0]* times in the $\vec{a}_1$ direction, *n[1]* times in the $\vec{a}_2$ direction and *n[2]* times in the $\vec{a}_3$ direction.
>
> Examples:

```
hoomd.init.create_lattice(unitcell=hoomd.lattice.sc(a=1.0),
                          n=[2,4,2]);

hoomd.init.create_lattice(unitcell=hoomd.lattice.bcc(a=1.0),
                          n=10);

hoomd.init.create_lattice(unitcell=hoomd.lattice.sq(a=1.2),
                          n=[100,10]);

hoomd.init.create_lattice(unitcell=hoomd.lattice.hex(a=1.0),
                          n=[100,58]);
```

hoomd.init.**read_getar**(*filename*, *modes={'any': 'any'}*)

> Initialize a system from a trajectory archive (.tar, .getar, .sqlite) file. Returns a HOOMD *system_data* object.
>
> > **Parameters**
> >
> > > • **filename** (`str`) – Name of the file to read from
> > >
> > > • **modes** (`dict`) – dictionary of {property: frame} values; see below
>
> Getar files are a simple interface on top of archive formats (such as zip and tar) for storing trajectory data efficiently. A more thorough description of the format and a description of a python API to read and write these files is available at the libgetar documentation.
>
> The **modes** argument is a dictionary. The keys of this dictionary should be either property names (see the Supported Property Table below) or tuples of property names.
>
> If the key is a tuple of property names, data for those names will be restored from the same frame. Other acceptable keys are "any" to restore any properties which are present from the file, "angle_any" to restore any angle-related properties present, "bond_any", and so forth. The values associated with each key in the dictionary should be "any" (in which case any frame present for the data will be restored, even if the frames are different for two property names in a tuple), "latest" (grab the most recent frame data), "earliest", or a specific timestep value.
>
> Example:

```
# creating file to initialize beforehand using libgetar
with gtar.GTAR('init.zip', 'w') as traj:
    traj.writePath('position.f32.ind', positions)
    traj.writePath('velocity.f32.ind', velocities)
```

```
    traj.writePath('metadata.json', json.dumps(metadata))
system = hoomd.init.read_getar('init.zip')
# using the backup created in the `hoomd.dump.getar.simple` example
system = hoomd.init.read_getar('backup.tar')
```

Supported Property Table

twidth Nkurd TypeShape nodes			
twidth angle JSON types_distant_types,)	[String con-tain-ing the name of each an-gle type in JSON for-mat		
twidth angleidswidth(Qangle, int 3)	of par-ti-cle tags for each an-gle in-ter-ac-tion		
twidth angleidswidth(Qangle,) int	of an-gle in-ter-ac-tion types		
twidth angularidth momentum 4)	particle an-gu-lar mo-men-tum quater-nion		
twidth bodywidth(N)	particle rigid body in-dex		
twidth bond types JSON bond types,)	[String con-tain-ing the		

`hoomd.init.`**`read_gsd`**(*filename*, *restart=None*, *frame=0*, *time_step=None*)
    Read initial system state from an GSD file.

> **Parameters**
>
> - **filename** (*str*) – File to read.
> - **restart** (*str*) – If it exists, read the file *restart* instead of *filename*.
> - **frame** (*int*) – Index of the frame to read from the GSD file. Negative values index from the end of the file.
> - **time_step** (*int*) – (if specified) Time step number to initialize instead of the one stored in the GSD file.

All particles, bonds, angles, dihedrals, impropers, constraints, and box information are read from the given GSD file at the given frame index. To read and write GSD files outside of hoomd, see http://gsd.readthedocs.io/. `hoomd.dump.gsd` writes GSD files.

For restartable jobs, specify the initial condition in *filename* and the restart file in *restart*. `hoomd.init.read_gsd()` will read the restart file if it exists, otherwise it will read *filename*.

If *time_step* is specified, its value will be used as the initial time step of the simulation instead of the one read from the GSD file *filename*. *time_step* is not applied when the file *restart* is read.

The result of `hoomd.init.read_gsd()` can be saved in a variable and later used to read and/or change particle properties later in the script. See `hoomd.data` for more information.

See also:

`hoomd.dump.gsd`

`hoomd.init.`**`read_snapshot`**(*snapshot*)
    Initializes the system from a snapshot.

> **Parameters snapshot** (`hoomd.data` snapshot) – The snapshot to initialize the system.

Snapshots temporarily store system data. Snapshots contain the complete simulation state in a single object. Snapshots are set to time_step 0, and should not be used to restart a simulation.

Example use cases in which a simulation may be started from a snapshot include user code that generates initial particle positions.

Example:

```
snapshot = my_system_create_routine(.. parameters ..)
system = init.read_snapshot(snapshot)
```

See also:

`hoomd.data`

`hoomd.init.`**`restore_getar`**(*filename*, *modes={'any': 'any'}*)
    Restore a subset of the current system's parameters from a trajectory archive (.tar, .zip, .sqlite) file. For a detailed discussion of arguments, see `read_getar()`.

> **Parameters**
>
> - **filename** (*str*) – Name of the file to read from
> - **modes** (*dict*) – dictionary of {property: frame} values, as described in `read_getar()`

2.14.11 hoomd.lattice

Overview

hoomd.lattice.bcc	Create a body centered cubic lattice (3D).
hoomd.lattice.fcc	Create a face centered cubic lattice (3D).
hoomd.lattice.hex	Create a hexagonal lattice (2D).
hoomd.lattice.sc	Create a simple cubic lattice (3D).
hoomd.lattice.sq	Create a square lattice (2D).
hoomd.lattice.unitcell	Define a unit cell.

Details

Define lattices.

hoomd.lattice provides a general interface to define lattices to initialize systems.

See also:

hoomd.init.create_lattice().

hoomd.lattice.**bcc**(*a*, *type_name='A'*)
    Create a body centered cubic lattice (3D).

> **Parameters**
>
> - **a** (*float*) – Lattice constant.
>
> - **type_name** (*str*) – Particle type name.

The body centered cubic unit cell has 2 particles:

$$\vec{r} = \begin{pmatrix} 0 & 0 & 0 \\ \frac{a}{2} & \frac{a}{2} & \frac{a}{2} \end{pmatrix}$$

And the box matrix:

$$\mathbf{h} = \begin{pmatrix} a & 0 & 0 \\ 0 & a & 0 \\ 0 & 0 & a \end{pmatrix}$$

hoomd.lattice.**fcc**(*a*, *type_name='A'*)
    Create a face centered cubic lattice (3D).

> **Parameters**
>
> - **a** (*float*) – Lattice constant.
>
> - **type_name** (*str*) – Particle type name.

The face centered cubic unit cell has 4 particles:

$$\vec{r} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & \frac{a}{2} & \frac{a}{2} \\ \frac{a}{2} & 0 & \frac{a}{2} \\ \frac{a}{2} & \frac{a}{2} & 0 \end{pmatrix}$$

And the box matrix:

$$\mathbf{h} = \begin{pmatrix} a & 0 & 0 \\ 0 & a & 0 \\ 0 & 0 & a \end{pmatrix}$$

`hoomd.lattice.`**`hex`**`(a, type_name='A')`
   Create a hexagonal lattice (2D).

   Parameters

   - **a** (`float`) – Lattice constant.

   - **type_name** (`str`) – Particle type name.

   `hex` creates a hexagonal lattice in a rectangular box. It has 2 particles, one at the corner and one at the center of the rectangle. This is not the primitive unit cell, but is more convenient to work with because of its shape.

$$\vec{r} \;=\; \begin{pmatrix} 0 & 0 \\ \frac{a}{2} & \sqrt{3}\frac{a}{2} \end{pmatrix}$$

And the box matrix:

$$\mathbf{h} \;=\; \begin{pmatrix} a & 0 \\ 0 & \sqrt{3}a \\ 0 & 0 \end{pmatrix}$$

`hoomd.lattice.`**`sc`**`(a, type_name='A')`
   Create a simple cubic lattice (3D).

   Parameters

   - **a** (`float`) – Lattice constant.

   - **type_name** (`str`) – Particle type name.

   The simple cubic unit cell has 1 particle:

$$\vec{r} \;=\; \begin{pmatrix} 0 & 0 & 0 \end{pmatrix}$$

And the box matrix:

$$\mathbf{h} \;=\; \begin{pmatrix} a & 0 & 0 \\ 0 & a & 0 \\ 0 & 0 & a \end{pmatrix}$$

`hoomd.lattice.`**`sq`**`(a, type_name='A')`
   Create a square lattice (2D).

   Parameters

   - **a** (`float`) – Lattice constant.

   - **type_name** (`str`) – Particle type name.

   The simple square unit cell has 1 particle:

$$\vec{r} \;=\; \begin{pmatrix} 0 & 0 \end{pmatrix}$$

And the box matrix:

$$\mathbf{h} \;=\; \begin{pmatrix} a & 0 \\ 0 & a \end{pmatrix}$$

class `hoomd.lattice.`**`unitcell`**`(N, a1, a2, a3, dimensions=3, position=None, type_name=None, mass=None, charge=None, diameter=None, moment_inertia=None, orientation=None)`
   Define a unit cell.

Parameters

- **N** (`int`) – Number of particles in the unit cell.
- **a1** (`list`) – Lattice vector (3-vector).
- **a2** (`list`) – Lattice vector (3-vector).
- **a3** (`list`) – Lattice vector (3-vector). Set to [0,0,1] in 2D lattices.
- **dimensions** (`int`) – Dimensionality of the lattice (2 or 3).
- **position** (`list`) – List of particle positions.
- **type_name** (`list`) – List of particle type names.
- **mass** (`list`) – List of particle masses.
- **charge** (`list`) – List of particle charges.
- **diameter** (`list`) – List of particle diameters.
- **moment_inertia** (`list`) – List of particle moments of inertia.
- **orientation** (`list`) – List of particle orientations.

A unit cell is a box definition (*a1*, *a2*, *a3*, *dimensions*), and particle properties for *N* particles. You do not need to specify all particle properties. Any property omitted will be initialized to defaults (see `hoomd.data.make_snapshot()`). `hoomd.init.create_lattice` initializes the system with many copies of a unit cell.

`unitcell` is a completely generic unit cell representation. See other classes in the `hoomd.lattice` module for convenience wrappers for common lattices.

Example:

```
uc = hoomd.lattice.unitcell(N = 2,
                            a1 = [1,0,0],
                            a2 = [0.2,1.2,0],
                            a3 = [-0.2,0, 1.0],
                            dimensions = 3,
                            position = [[0,0,0], [0.5, 0.5, 0.5]],
                            type_name = ['A', 'B'],
                            mass = [1.0, 2.0],
                            charge = [0.0, 0.0],
                            diameter = [1.0, 1.3],
                            moment_inertia = [[1.0, 1.0, 1.0], [0.0, 0.0, 0.0]],
                            orientation = [[0.707, 0, 0, 0.707], [1.0, 0, 0, 0]]);
```

Note: *a1*, *a2*, *a3* must define a right handed coordinate system.

---

get_snapshot()
    Get a snapshot.

> **Returns** A snapshot representing the lattice.

Attention: HOOMD-blue requires upper-triangular box matrices. The general box matrix *(a1, a2, a3)* set for this `unitcell` and the particle positions and orientations will be rotated from provided values into upper triangular form.

---

get_type_list()
    Get a list of the unique type names in the unit cell.

> **Returns** A `list` of the unique type names present in the unit cell.

get_typeid_mapping()
    Get a type name to typeid mapping.

> **Returns** A `dict` that maps type names to integer type ids.

2.14.12 hoomd.meta

Overview

hoomd.meta.dump_metadata	Writes simulation metadata into a file.

Details

Write out simulation and environment context metadata.

Metadata is stored in form of key-value pairs in a JSON file and used to summarize the per-run simulation parameters so that they can be easily taken up by other scripts and stored in a database.

Example:

```
metadata = meta.dump_metadata()
meta.dump_metadata(filename = "metadata.json", user = {'debug': True}, indent=2)
```

hoomd.meta.**dump_metadata**(*filename=None*, *user=None*, *indent=4*)
    Writes simulation metadata into a file.

> **Parameters**
>
> - **filename** (*str*) – The name of the file to write JSON metadata to (optional)
> - **user** (*dict*) – Additional metadata.
> - **indent** (*int*) – The json indentation size
>
> **Returns** metadata as a dictionary

When called, this function will query all registered forces, updaters etc. and ask them to provide metadata. E.g. a pair potential will return information about parameters, the Logger will output the filename it is logging to, etc.

Custom metadata can be provided as a dictionary to *user*.

The output is aggregated into a dictionary and written to a JSON file, together with a timestamp. The file is overwritten if it exists.

2.14.13 hoomd.option

Overview

hoomd.option.get_user	Get user options.
hoomd.option.set_autotuner_params	Set autotuner parameters.

<div align="right">Continued on next page</div>

Details

Set global options.

Options may be set on the command line or from a job script using *hoomd.context.initialize()*. The option.set_* commands override any settings made previously.

hoomd.option.**get_user**()
> Get user options.
>
> > **Returns** List of user options passed in via –user="arg1 arg2 . . . "

hoomd.option.**set_autotuner_params**(*enable=True*, *period=100000*)
> Set autotuner parameters.
>
> > **Parameters**
> >
> > - **enable** (*bool*) –
> >
> > - **period** (*int*) – Approximate period in time steps between retuning.
>
> TODO: reference autotuner page here.

hoomd.option.**set_msg_file**(*fname*)
> Set the message file.
>
> > **Parameters fname** (*str*) – Specifies the name of the file to write. The file will be overwritten. Set to None to direct messages back to stdout/stderr.
>
> The message file may be changed before or after initialization, and may be changed many times during a job script. Changing the message file will only affect messages sent after the change.
>
> ---
>
> **Note:** Overrides `--msg-file` on the command line.
>
> ---

hoomd.option.**set_notice_level**(*notice_level*)
> Set the notice level.
>
> > **Parameters notice_level** (*int*) –
>
> The notice level may be changed before or after initialization, and may be changed many times during a job script.
>
> ---
>
> **Note:** Overrides `--notice-level` on the command line.
>
> ---

hoomd.option.**set_num_threads**(*num_threads*)
> Set the number of CPU (TBB) threads HOOMD uses
>
> > **Parameters num_threads** (*int*) – The number of threads
>
> ---
>
> **Note:** Overrides `--nthreads` on the command line.
>
> ---

2.14.14 hoomd.update

Overview

hoomd.update.balance	Adjusts the boundaries of a domain decomposition on a regular 3D grid.
hoomd.update.box_resize	Rescale the system box size.
hoomd.update.sort	Sorts particles in memory to improve cache coherency.

Details

Modify the system state periodically.

When an updater is specified, it acts on the particle system every *period* steps to change it in some way. See the documentation of specific updaters to find out what they do.

class hoomd.update.**balance**(*x=True*, *y=True*, *z=True*, *tolerance=1.02*, *maxiter=1*, *period=1000*, *phase=0*)

Adjusts the boundaries of a domain decomposition on a regular 3D grid.

> **Parameters**
>
> - **x** (*bool*) – If True, balance in x dimension.
> - **y** (*bool*) – If True, balance in y dimension.
> - **z** (*bool*) – If True, balance in z dimension.
> - **tolerance** (*float*) – Load imbalance tolerance (if <= 1.0, balance every step).
> - **maxiter** (*int*) – Maximum number of iterations to attempt in a single step.
> - **period** (*int*) – Balancing will be attempted every a period time steps
> - **phase** (*int*) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0*.

Every *period* steps, the boundaries of the processor domains are adjusted to distribute the particle load close to evenly between them. The load imbalance is defined as the number of particles owned by a rank divided by the average number of particles per rank if the particles had a uniform distribution:

$$I = \frac{N(i)}{N/P}$$

where :math:` N(i) ` is the number of particles on processor i, N is the total number of particles, and P is the number of ranks.

In order to adjust the load imbalance, the sizes are rescaled by the inverse of the imbalance factor. To reduce oscillations and communication overhead, a domain cannot move more than 5% of its current size in a single rebalancing step, and the edge of a domain cannot move more than half the distance to its neighbors.

Simulations with interfaces (so that there is a particle density gradient) or clustering should benefit from load balancing. The potential speedup is roughly $I - 1.0$, so that if the largest imbalance is 1.4, then the user can expect a roughly 40% speedup in the simulation. This is of course an estimate that assumes that all algorithms are roughly linear in N, all GPUs are fully occupied, and the simulation is limited by the speed of the slowest processor. It also assumes that all particles roughly equal. If you have a simulation where, for example, some particles have significantly more pair force neighbors than others, this estimate of the load imbalance may not produce the optimal results.

A load balancing adjustment is only performed when the maximum load imbalance exceeds a *tolerance*. The ideal load balance is 1.0, so setting *tolerance* less than 1.0 will force an adjustment every *period*. The load

balancer can attempt multiple iterations of balancing every *period*, and up to *maxiter* attempts can be made. The optimal values of *period* and *maxiter* will depend on your simulation.

Load balancing can be performed independently and sequentially for each dimension of the simulation box. A small performance increase may be obtained by disabling load balancing along dimensions that are known to be homogeneous. For example, if there is a planar vapor-liquid interface normal to the z axis, then it may be advantageous to disable balancing along x and y.

In systems that are well-behaved, there is minimal overhead of balancing with a small *period*. However, if the system is not capable of being balanced (for example, due to the density distribution or minimum domain size), having a small *period* and high *maxiter* may lead to a large performance loss. In such systems, it is currently best to either balance infrequently or to balance once in a short test run and then set the decomposition statically in a separate initialization.

Balancing is ignored if there is no domain decomposition available (MPI is not built or is running on a single rank).

disable()
>   Disables the updater.
>
>   Examples:

```
updater.disable()
```

>   Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()
>   Enables the updater.
>
>   Examples:

```
updater.enable()
```

>   **See also:**
>
>   *disable()*

restore_state()
>   Restore the state information from the file used to initialize the simulations

set_params(*x=None*, *y=None*, *z=None*, *tolerance=None*, *maxiter=None*)
>   Change load balancing parameters.
>
>   **Parameters**
>
>   - **x** (*bool*) – If True, balance in x dimension.
>   - **y** (*bool*) – If True, balance in y dimension.
>   - **z** (*bool*) – If True, balance in z dimension.
>   - **tolerance** (*float*) – Load imbalance tolerance (if <= 1.0, balance every step).
>   - **maxiter** (*int*) – Maximum number of iterations to attempt in a single step.
>
>   Examples:

```
balance.set_params(x=True, y=False)
balance.set_params(tolerance=0.02, maxiter=5)
```

set_period(*period*)
   Changes the updater period.

    Parameters **period** (*int*) – New period to set.

   Examples:

```
updater.set_period(100);
updater.set_period(1);
```

   While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.update.**box_resize**(*Lx=None*, *Ly=None*, *Lz=None*, *xy=None*, *xz=None*, *yz=None*, *period=1*, *L=None*, *phase=0*, *scale_particles=True*)
   Rescale the system box size.

    Parameters

- **L** (*hoomd.variant*) – (if set) box length in the x,y, and z directions as a function of time (in distance units)

- **Lx** (*hoomd.variant*) – (if set) box length in the x direction as a function of time (in distance units)

- **Ly** (*hoomd.variant*) – (if set) box length in the y direction as a function of time (in distance units)

- **Lz** (*hoomd.variant*) – (if set) box length in the z direction as a function of time (in distance units)

- **xy** (*hoomd.variant*) – (if set) X-Y tilt factor as a function of time (dimensionless)

- **xz** (*hoomd.variant*) – (if set) X-Z tilt factor as a function of time (dimensionless)

- **yz** (*hoomd.variant*) – (if set) Y-Z tilt factor as a function of time (dimensionless)

- **period** (*int*) – The box size will be updated every *period* time steps.

- **phase** (*int*) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0*.

- **scale_particles** (*bool*) – When True (the default), scale particles into the new box. When False, do not change particle positions when changing the box.

Every *period* time steps, the system box dimensions is updated to values given by the user (in a variant). As an option, the particles can either be left in place as the box is changed or their positions can be scaled with the box.

Note: If *period* is set to None, then the given box lengths are applied immediately and periodic updates are not performed.

L, Lx, Ly, Lz, xy, xz, yz can either be set to a constant number or a *hoomd.variant*. if any of the box parameters are not specified, they are set to maintain the same value in the current box.

Use L as a shorthand to specify Lx, Ly, and Lz to the same value.

By default, particle positions are rescaled with the box. Set *scale_particles=False* to leave particles in place when changing the box.

If, under rescaling, tilt factors get too large, the simulation may slow down due to too many ghost atoms being communicated. *hoomd.update.box_resize* does NOT reset the box to orthorhombic shape if this occurs (and does not move the next periodic image into the primary cell).

Examples:

```
update.box_resize(L = hoomd.variant.linear_interp([(0, 20), (1e6, 50)]))
box_resize = update.box_resize(L = hoomd.variant.linear_interp([(0, 20), (1e6,
↪50)]), period = 10)
update.box_resize(Lx = hoomd.variant.linear_interp([(0, 20), (1e6, 50)]),
                  Ly = hoomd.variant.linear_interp([(0, 20), (1e6, 60)]),
                  Lz = hoomd.variant.linear_interp([(0, 10), (1e6, 80)]))
update.box_resize(Lx = hoomd.variant.linear_interp([(0, 20), (1e6, 50)]), Ly = 10,
↪ Lz = 10)

# Shear the box in the xy plane using Lees-Edwards boundary conditions
update.box_resize(xy = hoomd.variant.linear_interp([(0,0), (1e6, 1)]))
```

disable()
> Disables the updater.
>
> Examples:
>
> ```
> updater.disable()
> ```
>
> Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()
> Enables the updater.
>
> Examples:
>
> ```
> updater.enable()
> ```
>
> **See also:**
>
> *disable()*

restore_state()
> Restore the state information from the file used to initialize the simulations

set_period(*period*)
> Changes the updater period.
>
> > **Parameters period** (*int*) – New period to set.
>
> Examples:
>
> ```
> updater.set_period(100);
> updater.set_period(1);
> ```
>
> While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.update.**sort**
> Sorts particles in memory to improve cache coherency.

> **Warning:** Do not specify *hoomd.update.sort* explicitly in your script. HOOMD creates a sorter by default.

Every *period* time steps, particles are reordered in memory based on a Hilbert curve. This operation is very efficient, and the reordered particles significantly improve performance of all other algorithmic steps in HOOMD.

The reordering is accomplished by placing particles in spatial bins. A Hilbert curve is generated that traverses these bins and particles are reordered in memory in the same order in which they fall on the curve. The grid dimension used over the course of the simulation is held constant, and the default is chosen to be as fine as possible without utilizing too much memory. The grid size can be changed with *set_params()*.

> **Warning:** Memory usage by the sorter grows quickly with the grid size:
>
> - grid=128 uses 8 MB
> - grid=256 uses 64 MB
> - grid=512 uses 512 MB
> - grid=1024 uses 4096 MB

Note: 2D simulations do not use any additional memory and default to grid=4096.

A sorter is created by default. To disable it or modify parameters, save the context and access the sorter through it:

```
c = context.initialize();
hoomd.init.create_random(N=1000, phi_p=0.2)
# the sorter is only available after initialization
c.sorter.disable()
```

disable()
> Disables the updater.
>
> Examples:
>
> ```
> updater.disable()
> ```
>
> Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()
> Enables the updater.
>
> Examples:
>
> ```
> updater.enable()
> ```
>
> **See also:**
>
> *disable()*

restore_state()
> Restore the state information from the file used to initialize the simulations

set_params(*grid=None*)
> Change sorter parameters.

> > **Parameters grid** (*int*) – New grid dimension (if set)

> **Examples::** sorter.set_params(grid=128)

set_period(*period*)
> Changes the updater period.

> > **Parameters period** (*int*) – New period to set.

> Examples:

```
updater.set_period(100);
updater.set_period(1);
```

> While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

2.14.15 hoomd.util

Overview

hoomd.util.cuda_profile_start	Start CUDA profiling.
hoomd.util.cuda_profile_stop	Stop CUDA profiling.
hoomd.util.quiet_status	Quiet the status line output.
hoomd.util.unquiet_status	Resume the status line output.

Details

Utilities.

hoomd.util.**cuda_profile_start**()
> Start CUDA profiling.

> When using nvvp to profile CUDA kernels in hoomd jobs, you usually don't care about all the initialization and startup. cuda_profile_start() allows you to not even record that. To use, uncheck the box "start profiling on application start" in your nvvp session configuration. Then, call cuda_profile_start() in your hoomd script when you want nvvp to start collecting information.

> Example:

```python
from hoomd import *
init.read_xml("init.xml");
# setup....
run(30000);  # warm up and auto-tune kernel block sizes
option.set_autotuner_params(enable=False);  # prevent block sizes from further
↪autotuning
cuda_profile_start();
run(100);
```

hoomd.util.**cuda_profile_stop**()
> Stop CUDA profiling.

> **See also:**

cuda_profile_start().

hoomd.util.**quiet_status**()

> Quiet the status line output.
>
> After calling *hoomd.util.quiet_status()*, hoomd will no longer print out the line of code that executes each hoomd script command. Call *hoomd.util.unquiet_status()* to enable the status messages again. Messages are only enabled after a number of *hoomd.util.unquiet_status()* calls equal to the number of prior *hoomd.util.quiet_status()* calls.

hoomd.util.**unquiet_status**()

> Resume the status line output.
>
> **See also:**
>
> *hoomd.util.quiet_status()*

2.14.16 hoomd.variant

Overview

hoomd.variant.linear_interp	Linearly interpolated variant.

Details

Specify values that vary over time.

This package contains various commands for creating quantities that can vary smoothly over the course of a simulation. For example, set the temperature in a NVT simulation to slowly heat or cool the system over a long simulation.

class hoomd.variant.**linear_interp**(*points*, *zero='now'*)

> Linearly interpolated variant.
>
> > **Parameters**
> >
> > - **points** (*list*) – Set points in the linear interpolation (see below)
> > - **zero** (*int*) – Specify absolute time step number location for 0 in *points*. Use 'now' to indicate the current step.
>
> *hoomd.variant.linear_interp* creates a time-varying quantity where the value at each time step is determined by linear interpolation between a given set of points.
>
> At time steps before the initial point, the value is identical to the value at the first given point. At time steps after the final point, the value is identical to the value at the last given point. All points between are determined by linear interpolation.
>
> Time steps given to *hoomd.variant.linear_interp* are relative to the current step of the simulation, and starts counting from 0 at the time of creation. Set *zero* to control the relative starting point.
>
> *points* is a list of (time step, set value) tuples. For example, to specify a series of points that goes from 10 at time step 0 to 20 at time step 100 and then back down to 5 at time step 200:

```
points = [(0, 10), (100, 20), (200, 5)]
```

> Any number of points can be specified in any order. However, listing them monotonically increasing in time will result in a much more human readable set of values.
>
> Examples:

```
L = variant.linear_interp(points = [(0, 10), (100, 20), (200, 5)])
V = variant.linear_interp(points = [(0, 10), (1e6, 20)], zero=80000)
integrate.nvt(group=all, tau = 0.5,
    T = variant.linear_interp(points = [(0, 1.0), (1e5, 2.0)])
```

2.14.17 hoomd.hdf5

Overview

hoomd.hdf5.File
hoomd.hdf5.log

Details

Commands that require the h5py package at runtime.

All commands that are part of this module require the h5py package a python API for hdf5. In addition, this module is an opt-in. As a consequence you'll need to import it via *import hoomd.hdf5* before you can use any command.

class hoomd.hdf5.**File**(**args*, ***kwargs*)

Thin wrapper of the h5py.File class.

This class ensures, that opening and close operations within a context manager are only executed on the root MPI rank.

Note: This class can be used like the h5py.File class, but the user has to make sure that all operations are only executed on the root rank.

---

class hoomd.hdf5.**log**(*h5file*, *period*, *quantities=[]*, *matrix_quantities=[]*, *phase=0*)

Log a number of calculated quantities or matrices to a hdf5 file.

> **Parameters**
>
> - **h5file** (*hoomd.hdf5.File*) – Instance describing the opened h5file.
> - **period** (*int*) – Quantities are logged every *period* time steps
> - **quantities** (*list*) – Quantities to log.
> - **matrix_quantities** (*list*) – Matrix quantities to log.
> - **overwrite** (*bool*) – When False (the default) the existing log will be append. When True the file will be overwritten.
> - **phase** (*int*) – When -1, start on the current time step. When >= 0 execute on steps where *(step +phase) % period == 0*.

For details on the loggable quantities refer *hoomd.analyze.log* for details.

The non-matrix quantities are combined in an array 'quantities' in the hdf5 file. The attributes list all the names of the logged quantities and their position in the file.

Matrix quantities are logged as a separate data set each in the file. The name of the data set corresponds to the name of the quantity. The first dimension of the data set is counting the logged time step. The other dimension correspond to the dimensions of the logged matrix.

Note: The number and order of non-matrix quantities cannot change compared to data which is already stored in the hdf5 file. As a result, if you append to a file make sure you are logging the same values as before. In addition, also during a run with multiple *hoomd.run()* commands the logged values can not change.

Note: The dimensions of logged matrix quantities cannot change compared to a matrix with same name stored in the file. This applies for appending files as well as during a single simulation run.

Examples:

```python
with hoomd.hdf5.File("log.h5", "w") as h5file:
   #general setup

   log = hoomd.hdf5.log(filename='log.h5', quantities=['my_quantity', 'cosm'],
→matrix_quantities = ['random_matrix'], period=100)
   log.register_callback('my_quantity', lambda timestep: timestep**2)
   log.register_callback('cosm', lambda timestep: math.cos(logger.query('my_
→quantity')))
   def random_matrix(timestep):
      return numpy.random.rand(23, 56)
   log.register_callback('random_matrix', random_matrix, True)
   #more setup
   run(200)
```

disable()
> Disable the logger.

> Examples:

> ```python
> logger.disable()
> ```

> Executing the disable command will remove the logger from the system. Any *hoomd.run()* command executed after disabling the logger will not use that logger during the simulation. A disabled logger can be re-enabled with *enable()*.

enable()
> Enables the logger

> Examples:

> ```python
> logger.enable()
> ```

> See *disable()*.

query(*quantity*, *force_matrix=False*)

> Get the last logged value of a quantity which has been written to the file. If quantity is registered as a non-matrix quantity, its value is returned. If it is not registered as a non-matrix quantity, it is assumed to be a matrix quantity. If a quantity exists as non-matrix and matrix quantity with the same name, force_matrix can be used to obtain the matrix value.

> **Parameters**

>> • **quantity** (*str*) – name of the quantity to query

>> • **force_matrix** (*bool*) – the name of the quantity is

Note: Matrix quantities are not efficiently cached by the class, so calling this function multiple time, may not be efficient.

---

register_callback(*name*, *callback*, *matrix=False*)
    Register a callback to produce a logged quantity.

> **Parameters**
>
> - **name** (*str*) – Name of the quantity
> - **callback** (*callable*) – A python callable object (i.e. a lambda, function, or class that implements __call__)
> - **matrix** (*bool*) – Is the callback a computing a matrix and thus returning a numpy array instead of a single float?

The callback method must take a single argument, the current timestep, and return a single floating point value to be logged. If the callback returns a matrix quantity the return value must be a numpy array constant dimensions of each call.

Note: One callback can query the value of another, but logged quantities are evaluated in order from left to right.

Examples:

```
log = hoomd.hdf5.log(filename='log.h5', quantities=['my_quantity', 'cosm'],
→matrix_quantities = ['random_matrix'], period=100)
log.register_callback('my_quantity', lambda timestep: timestep**2)
log.register_callback('cosm', lambda timestep: math.cos(logger.query('my_
→quantity')))
def random_matrix(timestep):
    return numpy.random.rand(23, 56)
log.register_callback('random_matrix', random_matrix, True)
```

set_params(*quantities=None*, *matrix_quantities=None*)
    Change the parameters of the log.

Warning: Do not change the number or order of logged non-matrix quantities compared to values stored in the file.

2.15 hpmc

Details

Hard particle Monte Carlo

HPMC performs hard particle Monte Carlo simulations of a variety of classes of shapes.

Overview

HPMC implements hard particle Monte Carlo in HOOMD-blue.

Logging

The following quantities are provided by the integrator for use in HOOMD-blue's *hoomd.analyze.log*.

- `hpmc_sweep` - Number of sweeps completed since the start of the MC integrator
- `hpmc_translate_acceptance` - Fraction of translation moves accepted (averaged only over the last time step)
- `hpmc_rotate_acceptance` - Fraction of rotation moves accepted (averaged only over the last time step)
- `hpmc_d` - Maximum move displacement
- `hpmc_a` - Maximum rotation move
- `hpmc_move_ratio` - Probability of making a translation move (1- P(rotate move))
- `hpmc_overlap_count` - Count of the number of particle-particle overlaps in the current system configuration

With non-interacting depletant (**implicit=True**), the following log quantities are available:

- `hpmc_fugacity` - The current value of the depletant fugacity (in units of density, volume^-1)
- `hpmc_ntrial` - The current number of configurational bias attempts per overlapping depletant
- `hpmc_insert_count` - Number of depletants inserted per colloid
- `hpmc_reinsert_count` - Number of overlapping depletants reinserted per colloid by configurational bias MC
- `hpmc_free_volume_fraction` - Fraction of free volume to total sphere volume after a trial move has been proposed (sampled inside a sphere around the new particle position)
- `hpmc_overlap_fraction` - Fraction of depletants in excluded volume after trial move to depletants in free volume before move
- `hpmc_configurational_bias_ratio` - Ratio of configurational bias attempts to depletant insertions

With patch energies defined, the following quantities are available: - `hpmc_patch_energy` - The potential energy of the system resulting from the patch interaction. - `hpmc_patch_rcut` - The cutoff radius in the patch energy interaction.

compute.free_volume provides the following loggable quantities: - `hpmc_free_volume` - The free volume estimate in the simulation box obtained by MC sampling (in volume units)

update.boxmc provides the following loggable quantities:

- `hpmc_boxmc_trial_count` - Number of box changes attempted since the start of the boxmc updater
- `hpmc_boxmc_volume_acceptance` - Fraction of volume/length change trials accepted (averaged from the start of the last run)
- `hpmc_boxmc_ln_volume_acceptance` - Fraction of log(volume) change trials accepted (averaged from the start of the last run)
- `hpmc_boxmc_shear_acceptance` - Fraction of shear trials accepted (averaged from the start of the last run)
- `hpmc_boxmc_aspect_acceptance` - Fraction of aspect trials accepted (averaged from the start of the last run)
- `hpmc_boxmc_betaP` Current value of the βp value of the boxmc updater

update.muvt provides the following loggable quantities.

- `hpmc_muvt_insert_acceptance` - Fraction of particle insertions accepted (averaged from start of run)

- `hpmc_muvt_remove_acceptance` - Fraction of particle removals accepted (averaged from start of run)

- `hpmc_muvt_volume_acceptance` - Fraction of particle removals accepted (averaged from start of run)

update.clusters() provides the following loggable quantities.

- `hpmc_clusters_moves` - Fraction of cluster moves divided by the number of particles

- `hpmc_clusters_pivot_acceptance` - Fraction of pivot moves accepted

- `hpmc_clusters_reflection_acceptance` - Fraction of reflection moves accepted

- `hpmc_clusters_swap_acceptance` - Fraction of swap moves accepted

- `hpmc_clusters_avg_size` - Average cluster size

Timestep definition

HOOMD-blue started as an MD code where **timestep** has a clear meaning. MC simulations are run for timesteps. In exact terms, this means different things on the CPU and GPU and something slightly different when using MPI. The behavior is approximately normalized so that user scripts do not need to drastically change run() lengths when switching from one execution resource to another.

In the GPU implementation, one trial move is applied to a number of randomly chosen particles in each cell during one timestep. The number of selected particles is `nselect*ceil(avg particles per cell)` where *nselect* is a user-chosen parameter. The default value of *nselect* is 4, which achieves optimal performance for a wide variety of benchmarks. Detailed balance is obeyed at the level of a timestep. In short: One timestep **is NOT equal** to one sweep, but is approximately *nselect* sweeps, which is an overestimation.

In the single-threaded CPU implementation, one trial move is applied *nselect* times to each of the *N* particles during one timestep. In parallel MPI runs, one trial moves is applied *nselect* times to each particle in the active region. There is a small strip of inactive region near the boundaries between MPI ranks in the domain decomposition. The trial moves are performed in a shuffled order so detailed balance is obeyed at the level of a timestep. In short: One timestep **is approximately** *nselect* sweeps (*N* trial moves). In single-threaded runs, the approximation is exact, but it is slightly underestimated in MPI parallel runs.

To approximate a fair comparison of dynamics between CPU and GPU timesteps, log the `hpmc_sweep` quantity to get the number sweeps completed so far at each logged timestep.

See J. A. Anderson et. al. 2016 for design and implementation details.

Stability

hoomd.hpmc is **stable**. When upgrading from version 2.x to 2.y (y > x), existing job scripts that follow *documented* interfaces for functions and classes will not require any modifications. **Maintainer:** Joshua A. Anderson

Modules

2.15.1 hpmc.analyze

Overview

hpmc.analyze.sdf

Details

Compute properties of hard particle configurations.

class hoomd.hpmc.analyze.**sdf**(*mc*, *filename*, *xmax*, *dx*, *navg*, *period*, *overwrite=False*, *phase=0*)
Compute the scale distribution function.

> **Parameters**
>
> - **mc** (*hoomd.hpmc.integrate*) – MC integrator.
> - **filename** (*str*) – Output file name.
> - **xmax** (*float*) – Maximum *x* value at the right hand side of the rightmost bin (distance units).
> - **dx** (*float*) – Bin width (distance units).
> - **navg** (*int*) – Number of times to average before writing the histogram to the file.
> - **period** (*int*) – Number of timesteps between histogram evaluations.
> - **overwrite** (*bool*) – Set to True to overwrite *filename* instead of appending to it.
> - **phase** (*int*) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0*.

sdf computes a distribution function of scale parameters x. For each particle, it finds the smallest scale factor $1 + x$ that would cause the particle to touch one of its neighbors and records that in the histogram $s(x)$. The histogram is discrete and $s(x_i) = s[i]$ where $x_i = i \cdot dx + dx/2$.

In an NVT simulation, the extrapolation of $s(x)$ to $x = 0$, $s(0+)$ is related to the pressure.

$$\frac{P}{kT} = \rho \left(1 + \frac{s(0+)}{2d} \right)$$

where d is the dimensionality of the system and ρ is the number density.

Extrapolating $s(0+)$ is not trivial. Here are some suggested parameters, but they may not work in all cases.

- *xmax* = 0.02
- *dx* = 1e-4
- Polynomial curve fit of degree 5.

In systems near densest packings, dx=1e-5 may be needed along with either a smaller xmax or a smaller region to fit. A good rule of thumb might be to fit a region where numpy.sum(s[0:n]*dx) ~ 0.5 - but this needs further testing to confirm.

sdf averages *navg* histograms together before writing them out to a text file in a plain format: "timestep bin_0 bin_1 bin_2 .... bin_n".

sdf works well with restartable jobs. Ensure that navg*period is an integer fraction $1/k$ of the restart period. Then *sdf* will have written the final output to its file just before the restart gets written. The new data needed for the next line of values is entirely collected after the restart.

> **Warning:** *sdf* does not compute correct pressures for simulations with concave particles.

Numpy extrapolation code:

```
def extrapolate(s, dx, xmax, degree=5):
    # determine the number of values to fit
    n_fit = int(math.ceil(xmax/dx));
    s_fit = s[0:n_fit];
    # construct the x coordinates
    x_fit = numpy.arange(0,xmax,dx)
    x_fit += dx/2;
    # perform the fit and extrapolation
    p = numpy.polyfit(x_fit, s_fit, degree);
    return numpy.polyval(p, 0.0);
```

Examples:

```
mc = hpmc.integrate.sphere(seed=415236)
analyze.sdf(mc=mc, filename='sdf.dat', xmax=0.02, dx=1e-4, navg=100, period=100)
analyze.sdf(mc=mc, filename='sdf.dat', xmax=0.002, dx=1e-5, navg=100, period=100)
```

disable()
> Disable the analyzer.
>
> Examples:
>
> ```
> my_analyzer.disable()
> ```
>
> Executing the disable command will remove the analyzer from the system. Any *hoomd.run()* command executed after disabling an analyzer will not use that analyzer during the simulation. A disabled analyzer can be re-enabled with *enable()*.

enable()
> Enables the analyzer
>
> Examples:
>
> ```
> my_analyzer.enable()
> ```
>
> See *disable()*.

restore_state()
> Restore the state information from the file used to initialize the simulations

set_period(*period*)
> Changes the period between analyzer executions
>
> > **Parameters** **period** (*int*) – New period to set (in time steps)
>
> Examples:
>
> ```
> analyzer.set_period(100)
> analyzer.set_period(1)
> ```
>
> While the simulation is running (*hoomd.run()*, the action of each analyzer is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

2.15.2 hpmc.compute

Overview

hpmc.compute.free_volume	Compute the free volume available to a test particle by stochastic integration.

Details

Compute properties of hard particle configurations.

class hoomd.hpmc.compute.**free_volume**(*mc*, *seed*, *suffix=''*, *test_type=None*, *nsample=None*)

Compute the free volume available to a test particle by stochastic integration.

> **Parameters**
>
> - **mc** (*hoomd.hpmc.integrate*) – MC integrator.
> - **seed** (*int*) – Random seed for MC integration.
> - **type** (*str*) – Type of particle to use for integration
> - **nsample** (*int*) – Number of samples to use in MC integration
> - **suffix** (*str*) – Suffix to use for log quantity

:py:class'free_volume' computes the free volume of a particle assembly using stochastic integration with a test particle type. It works together with an HPMC integrator, which defines the particle types used in the simulation. As parameters it requires the number of MC integration samples (*nsample*), and the type of particle (*test_type*) to use for the integration.

Once initialized, the compute provides a log quantity called **hpmc_free_volume**, that can be logged via *hoomd.analyze.log*. If a suffix is specified, the log quantities name will be **hpmc_free_volume_suffix**.

Examples:

```
mc = hpmc.integrate.sphere(seed=415236)
compute.free_volume(mc=mc, seed=123, test_type='B', nsample=1000)
log = analyze.log(quantities=['hpmc_free_volume'], period=100, filename='log.dat',
↪ overwrite=True)
```

disable()

Disables the compute.

Examples:

```
c.disable()
```

Executing the disable command will remove the compute from the system. Any *hoomd.run()* command executed after disabling a compute will not be able to log computed values with *hoomd.analyze.log*.

A disabled compute can be re-enabled with *enable()*.

enable()

Enables the compute.

Examples:

```
c.enable()
```

See *disable()*.

restore_state()

Restore the state information from the file used to initialize the simulations

2.15.3 hpmc.data

Overview

hpmc.data.param_dict	Manage shape parameters.

Details

Shape data structures.

class hoomd.hpmc.data.**param_dict**(*mc*)
> Manage shape parameters.

> The parameters for all hpmc integrator shapes (*hoomd.hpmc.integrate*) are specified using this class. Parameters are specified per particle type. Every HPMC integrator has a member shape_param that can read and set parameters of the shapes.

> *param_dict* can be used as a dictionary to access parameters by type. You can read individual parameters or set parameters with *set()*.

> Example:

```
mc = hpmc.integrate.sphere();
mc.shape_param['A'].set(diameter=2.0)
mc.shape_param['B'].set(diameter=0.1)
dA = mc.shape_param['A'].diameter
dB = mc.shape_param['B'].diameter
```

> **set**(*types*, ***params*)
>> Sets parameters for particle type(s).

>> **Parameters**

>>> • **type** (*str*) – Particle type (string) or list of types

>>> • **params** – Named parameters (see specific integrator for required parameters - *hoomd. hpmc.integrate*)

>> Calling set() results in one or more parameters being set for a shape. Types are identified by name, and parameters are also added by name. Which parameters you need to specify depends on the hpmc integrator you are setting these coefficients for, see the corresponding documentation.

>> All possible particle types types defined in the simulation box must be specified before executing *hoomd. run()*. You will receive an error if you fail to do so. It is an error to specify coefficients for particle types that do not exist in the simulation.

>> To set the same parameters for many particle types, provide a list of type names instead of a single one. All types in the list will be set to the same parameters. A convenient wildcard that lists all types of particles in the simulation can be gotten from a saved *sysdef* from the init command.

>> Examples:

```
mc.shape_param.set('A', diameter=1.0)
mc.shape_param.set('B', diameter=2.0)
mc.shape_param.set(['A', 'B'], diameter=2.0)
```

Note: Single parameters can not be updated. If both *diameter* and *length* are required for a particle type, then executing coeff.set('A', diameter=1.5) will fail one must call coeff.set('A', diameter=1.5, length=2.0)

2.15.4 hpmc.field

Overview

hpmc.field.callback	Use a python-defined energy function in MC integration
hpmc.field.external_field_composite	Manage multiple external fields.
hpmc.field.frenkel_ladd_energy	Compute the Frenkel-Ladd Energy of a crystal.
hpmc.field.lattice_field	Restrain particles on a lattice
hpmc.field.wall	Manage walls (an external field type).

Details

Apply external fields to HPMC simulations.

class hoomd.hpmc.field.**callback**(*mc*, *energy_function*, *composite=False*)

Use a python-defined energy function in MC integration

> **Parameters**
>
> - **mc** (*hoomd.hpmc.integrate*) – MC integrator.
>
> - **callback** (*callable*) – A python function to evaluate the energy of a configuration
>
> - **composite** (*bool*) – True if this evaluator is part of a composite external field

Example:

```
def energy(snapshot):
    # evaluate the energy in a linear potential gradient along the x-axis
    gradient = (5,0,0)
    e = 0
    for p in snap.particles.position:
        e -= numpy.dot(gradient,p)
    return e

mc = hpmc.integrate.sphere(seed=415236);
mc.shape_param.set('A',diameter=1.0)
hpmc.field.callback(mc=mc, energy_function=energy);
run(100)
```

disable()

Disables the compute.

Examples:

```
c.disable()
```

Executing the disable command will remove the compute from the system. Any *hoomd.run()* command executed after disabling a compute will not be able to log computed values with *hoomd.analyze.log*.

A disabled compute can be re-enabled with *enable()*.

---

enable ()
> Enables the compute.
>
> Examples:
>
> ```
> c.enable()
> ```
>
> See *disable()*.

restore_state ()
> Restore the state information from the file used to initialize the simulations

class hoomd.hpmc.field.**external_field_composite**(*mc*, *fields=None*)
> Manage multiple external fields.
>
> > **Parameters**
> >
> > - **mc** (*hoomd.hpmc.integrate*) – MC integrator (don't specify a new integrator later, external_field_composite will continue to use the old one)
> >
> > - **fields** (*list*) – List of external fields to combine together.
>
> *external_field_composite* allows the user to create and compute multiple external fields. Once created use *add_field()* to add a new field.
>
> Once initialized, the compute provides a log quantities that other external fields create. See those external fields to find the quantities.
>
> Examples:
>
> ```
> mc = hpmc.integrate.shape(...);
> walls = hpmc.field.walls(...)
> lattice = hpmc.field.lattice(...)
> composite_field = hpmc.field.external_field_composite(mc, fields=[walls, lattice])
> ```
>
> **add_field** (*fields*)
> > Add an external field to the ensemble.
> >
> > > **Parameters fields** (*list*) – list of fields to add
> >
> > Example:
> >
> > ```
> > mc = hpmc.integrate.shape(...);
> > composite_field = hpmc.compute.external_field_composite(mc)
> > walls = hpmc.compute.walls(..., setup=False)
> > lattice = hpmc.compute.lattice(..., setup=False)
> > composite_field.add_field(fields=[walls, lattice])
> > ```
>
> **disable** ()
> > Disables the compute.
> >
> > Examples:
> >
> > ```
> > c.disable()
> > ```
> >
> > Executing the disable command will remove the compute from the system. Any *hoomd.run()* command executed after disabling a compute will not be able to log computed values with *hoomd.analyze.log*.
> >
> > A disabled compute can be re-enabled with *enable()*.
>
> **enable** ()
> > Enables the compute.

Examples:

```
c.enable()
```

See *disable()*.

restore_state()
    Restore the state information from the file used to initialize the simulations

class hoomd.hpmc.field.**frenkel_ladd_energy**(*mc*, *ln_gamma*, *q_factor*, *r0*, *q0*, *drift_period*,
                                                symmetry=[])
    Compute the Frenkel-Ladd Energy of a crystal.

    Parameters

- **ln_gamma** (*float*) – log of the translational spring constant

- **q_factor** (*float*) – scale factor between the translational spring constant and rotational spring constant

- **r0** (*list*) – reference lattice positions

- **q0** (*list*) – reference lattice orientations

- **drift_period** (*int*) – period call the remove drift updater

frenkel_ladd_energy interacts with *lattice_field* and *hoomd.hpmc.update.remove_drift*.

Once initialized, the compute provides the log quantities from the *lattice_field*.

> **Warning:** The lattice energies and standard deviations logged by *lattice_field* are multiplied by the spring constant. As a result, when computing the free energies from *frenkel_ladd_energy* class, instead of integrating the free energy over the spring constants, you should integrate over the natural log of the spring constants.

Example:

```
mc = hpmc.integrate.convex_polyhedron(seed=seed);
mc.shape_param.set("A", vertices=verts)
mc.set_params(d=0.005, a=0.005)
#set the FL parameters
fl = hpmc.compute.frenkel_ladd_energy(mc=mc, ln_gamma=0.0, q_factor=10.0, r0=rs,
→q0=qs, drift_period=1000)
```

disable()
    Disables the compute.

    Examples:

```
c.disable()
```

Executing the disable command will remove the compute from the system. Any *hoomd.run()* command executed after disabling a compute will not be able to log computed values with *hoomd.analyze.log*.

A disabled compute can be re-enabled with *enable()*.

enable()
    Enables the compute.

    Examples:

```
c.enable()
```

See *disable()*.

reset_statistics()
> Reset the statistics counters.

> Example:

```
mc = hpmc.integrate.sphere(seed=415236);
fl = hpmc.compute.frenkel_ladd_energy(mc=mc, ln_gamma=0.0, q_factor=10.0,
↪r0=rs, q0=qs, drift_period=1000)
ks = np.linspace(1000, 0.01, 100);
for k in ks:
  fl.set_params(ln_gamma=math.log(k), q_factor=10.0);
  fl.reset_statistics();
  run(1000)
```

restore_state()
> Restore the state information from the file used to initialize the simulations

set_params(*ln_gamma=None*, *q_factor=None*)
> Set the Frenkel-Ladd parameters.

> **Parameters**

> > - **ln_gamma** (*float*) – log of the translational spring constant

> > - **q_factor** (*float*) – scale factor between the translational spring constant and rotational spring constant

> Example:

```
mc = hpmc.integrate.sphere(seed=415236);
fl = hpmc.compute.frenkel_ladd_energy(mc=mc, ln_gamma=0.0, q_factor=10.0,
↪r0=rs, q0=qs, drift_period=1000)
ks = np.linspace(1000, 0.01, 100);
for k in ks:
  fl.set_params(ln_gamma=math.log(k), q_factor=10.0);
  fl.reset_statistics();
  run(1000)
```

class hoomd.hpmc.field.**lattice_field**(*mc*, *position=[]*, *orientation=[]*, *k=0.0*, *q=0.0*, *symmetry=[]*, *composite=False*)
> Restrain particles on a lattice

> **Parameters**

> > - **mc** (*hoomd.hpmc.integrate*) – MC integrator.

> > - **position** (*list*) – list of positions to restrain each particle (distance units).

> > - **orientation** (*list*) – list of orientations to restrain each particle (quaternions).

> > - **k** (*float*) – translational spring constant.

> > - **q** (*float*) – rotational spring constant.

> > - **symmetry** (*list*) – list of equivalent quaternions for the shape.

> > - **composite** (*bool*) – Set this to True when this field is part of a *external_field_composite*.

---

lattice_field specifies that a harmonic spring is added to every particle:

$$V_i(r) = k_r * (r_i - r_{oi})^2$$
$$V_i(q) = k_q * (q_i - q_{oi})^2$$

Note: 1/2 is not included in the formulas, specify your spring constants accordingly.

- k_r - translational spring constant.
- r_o - lattice positions (in distance units).
- k_q - rotational spring constant.
- q_o - lattice orientations (quaternion)

Once initialized, the compute provides the following log quantities that can be logged via analyze.log:

- **lattice_energy** – total lattice energy
- **lattice_energy_pp_avg** – average lattice energy per particle multiplied by the spring constant
- **lattice_energy_pp_sigma** – standard deviation of the lattice energy per particle multiplied by the spring constant
- **lattice_translational_spring_constant** – translational spring constant
- **lattice_rotational_spring_constant** – rotational spring constant
- **lattice_num_samples** – number of samples used to compute the average and standard deviation

---

Warning: The lattice energies and standard deviations logged by this class are multiplied by the spring constant.

Example:

```
mc = hpmc.integrate.sphere(seed=415236);
hpmc.field.lattice_field(mc=mc, position=fcc_lattice, k=1000.0);
log = analyze.log(quantities=['lattice_energy'], period=100, filename='log.dat',
→overwrite=True);
```

disable()
> Disables the compute.

> Examples:

> ```
> c.disable()
> ```

> Executing the disable command will remove the compute from the system. Any *hoomd.run()* command executed after disabling a compute will not be able to log computed values with *hoomd.analyze.log*.

> A disabled compute can be re-enabled with *enable()*.

enable()
> Enables the compute.

> Examples:

```
c.enable()
```

See [*disable()*](#).

get_average_energy()

> **Get the average energy per particle of the lattice field.** This is a collective call and must be called on all ranks.
>
> **Example::** mc = hpmc.integrate.sphere(seed=415236); lattice = hpmc.field.lattice_field(mc=mc, position=fcc_lattice, k=exp(15)); run(20000) avg_eng = lattice.get_average_energy() // should be about 1.5kT

get_energy()

> **Get the current energy of the lattice field.** This is a collective call and must be called on all ranks.
>
> **Example::** mc = hpmc.integrate.sphere(seed=415236); lattice = hpmc.field.lattice_field(mc=mc, position=fcc_lattice, k=1000.0); run(20000) eng = lattice.get_energy()

get_sigma_energy()

> **Gives the standard deviation of the average energy per particle of the lattice field.** This is a collective call and must be called on all ranks.
>
> **Example::** mc = hpmc.integrate.sphere(seed=415236); lattice = hpmc.field.lattice_field(mc=mc, position=fcc_lattice, k=exp(15)); run(20000) sig_eng = lattice.get_sigma_energy()

reset (*timestep=None*)
> Reset the statistics counters.
>
> > **Parameters timestep** ([*int*](#)) – the timestep to pass into the reset function.
>
> Example:

```
mc = hpmc.integrate.sphere(seed=415236);
lattice = hpmc.field.lattice_field(mc=mc, position=fcc_lattice, k=1000.0);
ks = np.linspace(1000, 0.01, 100);
for k in ks:
  lattice.set_params(k=k, q=0.0);
  lattice.reset();
  run(1000)
```

restore_state()
> Restore the state information from the file used to initialize the simulations

set_params (*k*, *q*)
> Set the translational and rotational spring constants.
>
> > **Parameters**
> >
> > - **k** ([*float*](#)) – translational spring constant.
> > - **q** ([*float*](#)) – rotational spring constant.
>
> Example:

```
mc = hpmc.integrate.sphere(seed=415236);
lattice = hpmc.field.lattice_field(mc=mc, position=fcc_lattice, k=1000.0);
ks = np.linspace(1000, 0.01, 100);
for k in ks:
  lattice.set_params(k=k, q=0.0);
  run(1000)
```

set_references (*position=[]*, *orientation=[]*)
    Reset the reference positions or reference orientations.

    Parameters

    - **position** (*list*) – list of positions to restrain each particle.

    - **orientation** (*list*) – list of orientations to restrain each particle.

    Example:

```
mc = hpmc.integrate.sphere(seed=415236);
lattice = hpmc.field.lattice_field(mc=mc, position=fcc_lattice, k=1000.0);
lattice.set_references(position=bcc_lattice)
```

class hoomd.hpmc.field.**wall** (*mc*, *composite=False*)
    Manage walls (an external field type).

    Parameters

    - **mc** (*hoomd.hpmc.integrate*) – MC integrator.

    - **composite** (*bool*) – Set this to True when this field is part of a *external_field_composite*.

wall allows the user to implement one or more walls. If multiple walls are added, then particles are confined by the INTERSECTION of all of these walls. In other words, particles are confined by all walls if they independently satisfy the confinement condition associated with each separate wall. Once you've created an instance of this class, use *add_sphere_wall()* to add a new spherical wall, *add_cylinder_wall()* to add a new cylindrical wall, or *add_plane_wall()* to add a new plane wall.

Specialized overlap checks have been written for supported combinations of wall types and particle shapes. These combinations are: * Sphere particles: sphere walls, cylinder walls, plane walls * Convex polyhedron particles: sphere walls, cylinder walls, plane walls * Convex spheropolyhedron particles: sphere walls

Once initialized, the compute provides the following log quantities that can be logged via *hoomd.analyze.log*:

- **hpmc_wall_volume** : the volume associated with the intersection of implemented walls. This number is only meaningful if the user has initially provided it through *set_volume()*. It will subsequently change when the box is resized and walls are scaled appropriately.

- **hpmc_wall_sph_rsq-i** : the squared radius of the spherical wall indexed by i, beginning at 0 in the order the sphere walls were added to the system.

- **hpmc_wall_cyl_rsq-i** : the squared radius of the cylindrical wall indexed by i, beginning at 0 in the order the cylinder walls were added to the system.

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
ext_wall.set_volume(4./3.*np.pi);
log = analyze.log(quantities=['hpmc_wall_volume','hpmc_wall_sph_rsq-0'],
→period=100, filename='log.dat', overwrite=True);
```

add_cylinder_wall (*radius*, *origin*, *orientation*, *inside=True*)
    Add a cylindrical wall to the simulation.

    Parameters

    - **radius** (*float*) – radius of cylindrical wall

- **origin** (`tuple`) – origin (center) of cylindrical wall

- **orientation** (`tuple`) – vector that defines the direction of the long axis of the cylinder. will be normalized automatically by hpmc.

- **inside** (`bool`) – When True, then particles are CONFINED by the wall if they exist entirely inside the cylinder (in the portion of connected space that contains the origin). When False, then particles are CONFINED by the wall if they exist entirely outside the cylinder (in the portion of connected space that does not contain the origin). DEFAULTS to True.

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_cylinder_wall(radius = 1.0, origin = [0, 0, 0], orientation = [0,
→ 0, 1], inside = True);
```

add_plane_wall(*normal*, *origin*)
Add a plane wall to the simulation.

Parameters

- **normal** (`tuple`) – vector normal to the plane. this, in combination with a point on the plane, defines the plane entirely. It will be normalized automatically by hpmc. The direction of the normal vector defines the confinement condition associated with the plane wall. If every part of a particle exists in the halfspace into which the normal points, then that particle is CONFINED by the plane wall.

- **origin** (`tuple`) – a point on the plane wall. this, in combination with the normal vector, defines the plane entirely.

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_plane_wall(normal = [0, 0, 1], origin = [0, 0, 0]);
```

add_sphere_wall(*radius*, *origin*, *inside=True*)
Add a spherical wall to the simulation.

Parameters

- **radius** (`float`) – radius of spherical wall

- **origin** (`tuple`) – origin (center) of spherical wall.

- **inside** (`bool`) – When True, particles are CONFINED by the wall if they exist entirely inside the sphere (in the portion of connected space that contains the origin). When False, then particles are CONFINED by the wall if they exist entirely outside the sphere (in the portion of connected space that does not contain the origin).

Quick Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
```

count_overlaps(*exit_early=False*)
Count the overlaps associated with the walls.

> **Parameters exit_early** (*bool*) – When True, stop counting overlaps after the first one is found.
>
> **Returns** The number of overlaps associated with the walls

A particle "overlaps" with a wall if it fails to meet the confinement condition associated with the wall.

Example

mc = hpmc.integrate.sphere(seed = 415236); ext_wall = hpmc.compute.wall(mc); ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True); run(100) num_overlaps = ext_wall.count_overlaps();

disable()
> Disables the compute.
>
> Examples:

```
c.disable()
```

> Executing the disable command will remove the compute from the system. Any *hoomd.run()* command executed after disabling a compute will not be able to log computed values with *hoomd.analyze.log*.
>
> A disabled compute can be re-enabled with *enable()*.

enable()
> Enables the compute.
>
> Examples:

```
c.enable()
```

> See *disable()*.

get_curr_box()
> Get the simulation box that the wall class is currently storing.
>
> **Returns** The boxdim object that the wall class is currently storing.
>
> Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
ext_wall.set_volume(4./3.*np.pi);
run(100)
curr_box = ext_wall.get_curr_box();
```

get_cylinder_wall_param(*index*, *param*)
> Access a parameter associated with a particular cylinder wall.
>
> **Parameters**
>
> - **index** (*int*) – index of the cylinder wall to be accessed. indices begin at 0 in the order the cylinder walls were added to the system.
>
> - **param** (*str*) – name of parameter to be accessed. options are "rsq" (squared radius of cylinder wall), "origin" (origin of cylinder wall), "orientation" (orientation of cylinder wall), and "inside" (confinement condition associated with cylinder wall).
>
> **Returns** Value of queried parameter.

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_cylinder_wall(radius = 1.0, origin = [0, 0, 0], orientation = [0,
↪ 0, 1], inside = True);
rsq = ext_wall.get_cylinder_wall_param(index = 0, param = "rsq");
```

get_num_cylinder_walls()
> Get the current number of cylinder walls in the simulation.

>> **Returns** The current number of cylinder walls in the simulation.

> Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_cylinder_wall(radius = 1.0, origin = [0, 0, 0], orientation = [0,
↪ 0, 1], inside = True);
num_cyl_walls = ext_wall.get_num_cylinder_walls();
```

get_num_plane_walls()
> Get the current number of plane walls in the simulation.

>> **Returns** The current number of plane walls in the simulation.

> Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_plane_wall(normal = [0, 0, 1], origin = [0, 0, 0]);
num_plane_walls = ext_wall.get_num_plane_walls();
```

get_num_sphere_walls()
> Get the current number of sphere walls in the simulation.

> Returns: the current number of sphere walls in the simulation

> Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
num_sph_walls = ext_wall.get_num_sphere_walls();
```

get_plane_wall_param(*index*, *param*)
> Access a parameter associated with a particular plane wall.

>> **Parameters**

>> - **index** (`int`) – index of the plane wall to be accessed. indices begin at 0 in the order the plane walls were added to the system.

>> - **param** (`str`) – name of parameter to be accessed. options are "normal" (vector normal to the plane wall), and "origin" (point on the plane wall)

>> **Returns** Value of queried parameter.

> Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_plane_wall(normal = [0, 0, 1], origin = [0, 0, 0]);
n = ext_wall.get_plane_wall_param(index = 0, param = "normal");
```

get_sphere_wall_param(*index*, *param*)

Access a parameter associated with a particular sphere wall.

Parameters

- **index** (*int*) – index of the sphere wall to be accessed. indices begin at 0 in the order the sphere walls were added to the system.

- **param** (*str*) – name of parameter to be accessed. options are "rsq" (squared radius of sphere wall), "origin" (origin of sphere wall), and "inside" (confinement condition associated with sphere wall)

Returns Value of queried parameter.

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
rsq = ext_wall.get_sphere_wall_param(index = 0, param = "rsq");
```

get_volume()

Get the current volume associated with the intersection of all walls in the system.

If this quantity has not previously been set by the user, this returns a meaningless value.

Returns The current volume associated with the intersection of all walls in the system.

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
ext_wall.set_volume(4./3.*np.pi);
run(100)
curr_vol = ext_wall.get_volume();
```

remove_cylinder_wall(*index*)

Remove a particular cylinder wall from the simulation.

Parameters index (*int*) – index of the cylinder wall to be removed. indices begin at 0 in the order the cylinder walls were added to the system.

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_cylinder_wall(radius = 1.0, origin = [0, 0, 0], orientation = [0,
↪ 0, 1], inside = True);
ext_wall.remove_cylinder_wall(index = 0);
```

remove_plane_wall(*index*)

Remove a particular plane wall from the simulation.

Parameters index (*int*) – index of the plane wall to be removed. indices begin at 0 in the order the plane walls were added to the system.

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_plane_wall(normal = [0, 0, 1], origin = [0, 0, 0]);
ext_wall.remove_plane_wall(index = 0);
```

remove_sphere_wall(*index*)

Remove a particular sphere wall from the simulation.

> **Parameters index** ([*int*](https://docs.python.org/3/library/functions.html#int)) – index of the sphere wall to be removed. indices begin at 0 in the order the sphere walls were added to the system.

Quick Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
ext_wall.remove_sphere_wall(index = 0);
```

restore_state()

Restore the state information from the file used to initialize the simulations

set_curr_box(*Lx=None*, *Ly=None*, *Lz=None*, *xy=None*, *xz=None*, *yz=None*)

Set the simulation box that the wall class is currently storing.

You may want to set this independently so that you can cleverly control whether or not the walls actually scale in case you manually resize your simulation box. The walls scale automatically when they get the signal that the global box, associated with the system definition, has scaled. They do so, however, with a scale factor associated with the ratio of the volume of the global box to the volume of the box that the walls class is currently storing. (After the scaling the box that the walls class is currently storing is updated appropriately.) If you want to change the simulation box WITHOUT scaling the walls, then, you must first update the simulation box that the walls class is storing, THEN update the global box associated with the system definition.

Example:

```
init_box = hoomd.data.boxdim(L=10, dimensions=3);
snap = hoomd.data.make_snapshot(N=1, box=init_box, particle_types=['A']);
system = hoomd.init.read_snapshot(snap);
system.particles[0].position = [0,0,0];
system.particles[0].type = 'A';
mc = hpmc.integrate.sphere(seed = 415236);
mc.shape_param.set('A', diameter = 2.0);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 3.0, origin = [0, 0, 0], inside = True);
ext_wall.set_curr_box(Lx=2.0*init_box.Lx, Ly=2.0*init_box.Ly, Lz=2.0*init_box.
↪Lz, xy=init_box.xy, xz=init_box.xz, yz=init_box.yz);
system.sysdef.getParticleData().setGlobalBox(ext_wall.get_curr_box()._
↪getBoxDim())
```

set_cylinder_wall(*index*, *radius*, *origin*, *orientation*, *inside=True*)

Change the parameters associated with a particular cylinder wall.

> **Parameters**
>
> - **index** ([*int*](https://docs.python.org/3/library/functions.html#int)) – index of the cylinder wall to be modified. indices begin at 0 in the order the cylinder walls were added to the system.
> - **radius** ([*float*](https://docs.python.org/3/library/functions.html#float)) – New radius of cylindrical wall

- **origin** (`tuple`) – New origin (center) of cylindrical wall

- **orientation** (`tuple`) – New vector that defines the direction of the long axis of the cylinder. will be normalized automatically by hpmc.

- **inside** (`bool`) – New confinement condition. When True, then particles are CONFINED by the wall if they exist entirely inside the cylinder (in the portion of connected space that contains the origin). When False, then particles are CONFINED by the wall if they exist entirely outside the cylinder (in the portion of connected space that does not contain the origin). DEFAULTS to True.

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_cylinder_wall(radius = 1.0, origin = [0, 0, 0], orientation = [0,
↪ 0, 1], inside = True);
ext_wall.set_cylinder_wall(index = 0, radius = 3.0, origin = [0, 0, 0],␣
↪orientation = [0, 0, 1], inside = True);
```

set_plane_wall (*index*, *normal*, *origin*)
    Change the parameters associated with a particular plane wall.

    Parameters

- **index** (`int`) – index of the plane wall to be modified. indices begin at 0 in the order the plane walls were added to the system.

- **normal** (`tuple`) – new vector normal to the plane. this, in combination with a point on the plane, defines the plane entirely. It will be normalized automatically by hpmc. The direction of the normal vector defines the confinement condition associated with the plane wall. If every part of a particle exists in the halfspace into which the normal points, then that particle is CONFINED by the plane wall.

- **origin** (`tuple`) – new point on the plane wall. this, in combination with the normal vector, defines the plane entirely.

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_plane_wall(normal = [0, 0, 1], origin = [0, 0, 0]);
ext_wall.set_plane_wall(index = 0, normal = [0, 0, 1], origin = [0, 0, 1]);
```

set_sphere_wall (*index*, *radius*, *origin*, *inside=True*)
    Change the parameters associated with a particular sphere wall.

    Parameters

- **index** (`int`) – index of the sphere wall to be modified. indices begin at 0 in the order the sphere walls were added to the system.

- **radius** (`float`) – New radius of spherical wall

- **origin** (`tuple`) – New origin (center) of spherical wall.

- **inside** (`bool`) – New confinement condition. When True, particles are CONFINED by the wall if they exist entirely inside the sphere (in the portion of connected space that contains the origin). When False, then particles are CONFINED by the wall if they exist entirely outside the sphere (in the portion of connected space that does not contain the origin).

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
ext_wall.set_sphere_wall(index = 0, radius = 3.0, origin = [0, 0, 0], inside
→= True);
```

set_volume(*volume*)

> Set the volume associated with the intersection of all walls in the system.
>
> This number will subsequently change when the box is resized and walls are scaled appropriately.
>
> Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
ext_wall.set_volume(4./3.*np.pi);
```

2.15.5 hpmc.integrate

Overview

hpmc.integrate.convex_polygon	HPMC integration for convex polygons (2D).
hpmc.integrate.convex_polyhedron	HPMC integration for convex polyhedra (3D).
hpmc.integrate.convex_polyhedron_union	HPMC integration for unions of convex polyhedra (3D).
hpmc.integrate.convex_spheropolygon	HPMC integration for convex spheropolygons (2D).
hpmc.integrate.convex_spheropolyhedron	HPMC integration for spheropolyhedra (3D).
hpmc.integrate.convex_spheropolyhedron_union	HPMC integration for unions of convex polyhedra (3D).
hpmc.integrate.ellipsoid	HPMC integration for ellipsoids (2D/3D).
hpmc.integrate.faceted_sphere	HPMC integration for faceted spheres (3D).
hpmc.integrate.interaction_matrix	Define pairwise interaction matrix
hpmc.integrate.mode_hpmc	Base class HPMC integrator.
hpmc.integrate.polyhedron	HPMC integration for general polyhedra (3D).
hpmc.integrate.simple_polygon	HPMC integration for simple polygons (2D).
hpmc.integrate.sphere	HPMC integration for spheres (2D/3D).
hpmc.integrate.sphere_union	HPMC integration for unions of spheres (3D).
hpmc.integrate.sphinx	HPMC integration for sphinx particles (3D).

Details

class hoomd.hpmc.integrate.**convex_polygon**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *restore_state=False*)

> HPMC integration for convex polygons (2D).
>
> **Parameters**
>
> - **seed** (*int*) – Random number seed
>
> - **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
>
> - **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **move_ratio** (`float`) – Ratio of translation moves to rotation moves.

- **nselect** (`int`) – The number of trial moves to perform in each cell.

- **restore_state** (`bool`) – Restore internal state from initialization file when True. See
  `mode_hpmc` for a description of what state data restored. (added in version 2.2)

Note: For concave polygons, use `simple_polygon`.

Convex polygon parameters:

- *vertices* (**required**) - vertices of the polygon as is a list of (x,y) tuples of numbers (distance units)

    – Vertices **MUST** be specified in a *counter-clockwise* order.

    – The origin **MUST** be contained within the vertices.

    – Points inside the polygon **MUST NOT** be included.

    – The origin centered circle that encloses all vertices should be of minimal size for optimal performance
      (e.g. don't put the origin right next to an edge).

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with
  ignore_overlaps=True

    – Deprecated since version 2.1: Replaced by `interaction_matrix`.

Warning: HPMC does not check that all requirements are met. Undefined behavior will result if they are
violated.

Examples:

```
mc = hpmc.integrate.convex_polygon(seed=415236, d=0.3, a=0.4)
mc.shape_param.set('A', vertices=[(-0.5, -0.5), (0.5, -0.5), (0.5, 0.5), (-0.5, 0.
↪5)]);
print('vertices = ', mc.shape_param['A'].vertices)
```

get_type_shapes()
    Get all the types of shapes in the current simulation.

Example

```
>>> mc.get_type_shapes()
[{'type': 'Polygon', 'rounding_radius': 0,
  'vertices': [[-0.5, -0.5], [0.5, -0.5], [0.5, 0.5], [-0.5, 0.5]]}]
```

> **Returns** A list of dictionaries, one for each particle type in the system.

class hoomd.hpmc.integrate.**convex_polyhedron**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*,
                                                        nselect=4, *implicit=False*, *de-*
                                                        pletant_mode='circumsphere',
                                                        max_verts=None, *restore_state=False*)
    HPMC integration for convex polyhedra (3D).

    Parameters

- **seed** (`int`) – Random number seed.

- **d** (`float`) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **a** (`float`) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **move_ratio** (`float`) – Ratio of translation moves to rotation moves.

- **nselect** (`int`) – (Override the automatic choice for the number of trial moves to perform in each cell.

- **implicit** (`bool`) – Flag to enable implicit depletants.

- **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)

- **max_verts** (`int`) – Set the maximum number of vertices in a polyhedron. (deprecated in version 2.2)

- **restore_state** (`bool`) – Restore internal state from initialization file when True. See *mode_hpmc* for a description of what state data restored. (added in version 2.2)

Convex polyhedron parameters:

- *vertices* (**required**) - vertices of the polyhedron as is a list of (x,y,z) tuples of numbers (distance units)

  - The origin **MUST** be contained within the vertices.

  - The origin centered circle that encloses all vertices should be of minimal size for optimal performance (e.g. don't put the origin right next to a face).

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

  - Deprecated since version 2.1: Replaced by *interaction_matrix*.

> **Warning:** HPMC does not check that all requirements are met. Undefined behavior will result if they are violated.

Example:

```
mc = hpmc.integrate.convex_polyhedron(seed=415236, d=0.3, a=0.4)
mc.shape_param.set('A', vertices=[(0.5, 0.5, 0.5), (0.5, -0.5, -0.5), (-0.5, 0.5,
↪-0.5), (-0.5, -0.5, 0.5)]);
print('vertices = ', mc.shape_param['A'].vertices)
```

Depletants Example:

```
mc = hpmc.integrate.convex_polyhedron(seed=415236, d=0.3, a=0.4, implicit=True,
↪depletant_mode='circumsphere')
mc.set_params(nselect=1,nR=3,depletant_type='B')
mc.shape_param.set('A', vertices=[(0.5, 0.5, 0.5), (0.5, -0.5, -0.5), (-0.5, 0.5,
↪-0.5), (-0.5, -0.5, 0.5)]);
mc.shape_param.set('B', vertices=[(0.05, 0.05, 0.05), (0.05, -0.05, -0.05), (-0.
↪05, 0.05, -0.05), (-0.05, -0.05, 0.05)]);
```

get_type_shapes()
> Get all the types of shapes in the current simulation.

Example

```
>>> mc.get_type_shapes()
[{'type': 'ConvexPolyhedron', 'rounding_radius': 0,
  'vertices': [[0.5, 0.5, 0.5], [0.5, -0.5, -0.5],
               [-0.5, 0.5, -0.5], [-0.5, -0.5, 0.5]]}]
```

> **Returns** A list of dictionaries, one for each particle type in the system.

class hoomd.hpmc.integrate.**convex_polyhedron_union**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *implicit=False*, *depletant_mode='circumsphere'*)

HPMC integration for unions of convex polyhedra (3D).

> Deprecated since version 2.4: Replaced by *convex_spheropolyhedron_union*. This class stays in place for compatibility with older scripts.

> **Parameters**
>
> - **seed** (*int*) – Random number seed.
> - **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
> - **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.
> - **move_ratio** (*float*) – Ratio of translation moves to rotation moves.
> - **nselect** (*int*) – The number of trial moves to perform in each cell.
> - **implicit** (*bool*) – Flag to enable implicit depletants.
> - **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)
> - **max_members** (*int*) – Set the maximum number of members in the convex polyhedron union
> - **capacity** (*int*) – Set to the number of constituent convex polyhedra per leaf node

New in version 2.2.

Convex polyhedron union parameters:

- *vertices* (**required**) - list of vertex lists of the polyhedra in particle coordinates.
- *centers* (**required**) - list of centers of constituent polyhedra in particle coordinates.
- *orientations* (**required**) - list of orientations of constituent polyhedra.
- *overlap* (**default: 1 for all particles**) - only check overlap between constituent particles for which *overlap [i] & overlap[j]* is !=0, where '&' is the bitwise AND operator.
- *sweep_radii* (**default: 0 for all particle**) - radii of spheres sweeping out each constituent polyhedron
  - New in version 2.4.
- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking.
- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

– Deprecated since version 2.1: Replaced by *interaction_matrix*.

Example:

```
mc = hpmc.integrate.convex_polyhedron_union(seed=27, d=0.3, a=0.4)
cube_verts = [[-1,-1,-1],[-1,-1,1],[-1,1,1],[-1,1,-1],
              [1,-1,-1],[1,-1,1],[1,1,1],[1,1,-1]]
mc.shape_param.set('A', vertices=[cube_verts, cube_verts],
                        centers=[[-1,0,0],[1,0,0]],orientations=[[1,0,0,0],[1,0,0,
↪0]]);
print('vertices of the first cube = ', mc.shape_param['A'].members[0].vertices)
print('center of the first cube = ', mc.shape_param['A'].centers[0])
print('orientation of the first cube = ', mc.shape_param['A'].orientations[0])
```

class hoomd.hpmc.integrate.**convex_spheropolygon**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *restore_state=False*)

    HPMC integration for convex spheropolygons (2D).

> **Parameters**
>
> - **seed** (*int*) – Random number seed.
>
> - **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
>
> - **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.
>
> - **move_ratio** (*float*) – Ratio of translation moves to rotation moves.
>
> - **nselect** (*int*) – The number of trial moves to perform in each cell.
>
> - **restore_state** (*bool*) – Restore internal state from initialization file when True. See *mode_hpmc* for a description of what state data restored. (added in version 2.2)

Spheropolygon parameters:

- *vertices* (**required**) - vertices of the polygon as is a list of (x,y) tuples of numbers (distance units)

  – The origin **MUST** be contained within the shape.

  – The origin centered circle that encloses all vertices should be of minimal size for optimal performance (e.g. don't put the origin right next to an edge).

- *sweep_radius* (**default: 0.0**) - the radius of the sphere swept around the edges of the polygon (distance units) - **optional**

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

  – Deprecated since version 2.1: Replaced by *interaction_matrix*.

Useful cases:

- A 1-vertex spheropolygon is a disk.

- A 2-vertex spheropolygon is a spherocylinder.

> **Warning:** HPMC does not check that all requirements are met. Undefined behavior will result if they are violated.

Examples:

```
mc = hpmc.integrate.convex_spheropolygon(seed=415236, d=0.3, a=0.4)
mc.shape_param.set('A', vertices=[(-0.5, -0.5), (0.5, -0.5), (0.5, 0.5), (-0.5, 0.
→5)], sweep_radius=0.1, ignore_statistics=False);
mc.shape_param.set('A', vertices=[(0,0)], sweep_radius=0.5, ignore_
→statistics=True);
print('vertices = ', mc.shape_param['A'].vertices)
```

get_type_shapes ()
> Get all the types of shapes in the current simulation.

Example

```
>>> mc.get_type_shapes()
[{'type': 'Polygon', 'rounding_radius': 0.1,
  'vertices': [[-0.5, -0.5], [0.5, -0.5], [0.5, 0.5], [-0.5, 0.5]]}]
```

> **Returns** A list of dictionaries, one for each particle type in the system.

class hoomd.hpmc.integrate.**convex_spheropolyhedron** (*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *implicit=False*, *depletant_mode='circumsphere'*, *max_verts=None*, *restore_state=False*)

HPMC integration for spheropolyhedra (3D).

Parameters

- **seed** (`int`) – Random number seed.

- **d** (`float`) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **a** (`float`) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **move_ratio** (`float`) – Ratio of translation moves to rotation moves.

- **nselect** (`int`) – The number of trial moves to perform in each cell.

- **implicit** (`bool`) – Flag to enable implicit depletants.

- **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)

- **max_verts** (`int`) – Set the maximum number of vertices in a polyhedron. (deprecated in version 2.2)

- **restore_state** (`bool`) – Restore internal state from initialization file when True. See *mode_hpmc* for a description of what state data restored. (added in version 2.2)

A spheropolyhedron can also represent spheres (0 or 1 vertices), and spherocylinders (2 vertices).

Spheropolyhedron parameters:

- *vertices* (**required**) - vertices of the polyhedron as is a list of (x,y,z) tuples of numbers (distance units)

  – The origin **MUST** be contained within the vertices.

- **–** The origin centered sphere that encloses all vertices should be of minimal size for optimal performance (e.g. don't put the origin right next to a face).

- **–** A sphere can be represented by specifying zero vertices (i.e. vertices=[]) and a non-zero radius R

- **–** Two vertices and a non-zero radius R define a prolate spherocylinder.

- *sweep_radius* (**default: 0.0**) - the radius of the sphere swept around the edges of the polygon (distance units) - **optional**

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

   - **–** Deprecated since version 2.1: Replaced by *interaction_matrix*.

> **Warning:** HPMC does not check that all requirements are met. Undefined behavior will result if they are violated.

Example:

```
mc = hpmc.integrate.convex_spheropolyhedron(seed=415236, d=0.3, a=0.4)
mc.shape_param['tetrahedron'].set(vertices=[(0.5, 0.5, 0.5), (0.5, -0.5, -0.5), (-
→0.5, 0.5, -0.5), (-0.5, -0.5, 0.5)]);
print('vertices = ', mc.shape_param['A'].vertices)
mc.shape_param['SphericalDepletant'].set(vertices=[], sweep_radius=0.1, ignore_
→statistics=True);
```

Depletants example:

```
mc = hpmc.integrate.convex_spheropolyhedron(seed=415236, d=0.3, a=0.4,␣
→implicit=True, depletant_mode='circumsphere')
mc.set_params(nR=3,depletant_type='SphericalDepletant')
mc.shape_param['tetrahedron'].set(vertices=[(0.5, 0.5, 0.5), (0.5, -0.5, -0.5), (-
→0.5, 0.5, -0.5), (-0.5, -0.5, 0.5)]);
mc.shape_param['SphericalDepletant'].set(vertices=[], sweep_radius=0.1);
```

get_type_shapes()

> Get all the types of shapes in the current simulation.

> ### Example

> ```
> >>> mc.get_type_shapes()
> [{'type': 'ConvexPolyhedron', 'rounding_radius': 0.1,
>   'vertices': [[0.5, 0.5, 0.5], [0.5, -0.5, -0.5],
>               [-0.5, 0.5, -0.5], [-0.5, -0.5, 0.5]]}]
> ```

> **Returns** A list of dictionaries, one for each particle type in the system.

class hoomd.hpmc.integrate.**convex_spheropolyhedron_union**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *implicit=False*, *depletant_mode='circumsphere'*)

HPMC integration for unions of convex polyhedra (3D).

Parameters

- **seed** (*int*) – Random number seed.

- **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **move_ratio** (*float*) – Ratio of translation moves to rotation moves.

- **nselect** (*int*) – The number of trial moves to perform in each cell.

- **implicit** (*bool*) – Flag to enable implicit depletants.

- **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)

- **max_members** (*int*) – Set the maximum number of members in the convex polyhedron union

- **capacity** (*int*) – Set to the number of constituent convex polyhedra per leaf node

New in version 2.2.

Convex polyhedron union parameters:

- *vertices* (**required**) - list of vertex lists of the polyhedra in particle coordinates.

- *centers* (**required**) - list of centers of constituent polyhedra in particle coordinates.

- *orientations* (**required**) - list of orientations of constituent polyhedra.

- *overlap* (**default: 1 for all particles**) - only check overlap between constituent particles for which *overlap [i] & overlap[j]* is !=0, where '&' is the bitwise AND operator.

- *sweep_radii* (**default: 0 for all particle**) - radii of spheres sweeping out each constituent polyhedron

    – New in version 2.4.

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking.

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

    – Deprecated since version 2.1: Replaced by *interaction_matrix*.

Example:

```
mc = hpmc.integrate.convex_spheropolyhedron_union(seed=27, d=0.3, a=0.4)
cube_verts = [[-1,-1,-1],[-1,-1,1],[-1,1,1],[-1,1,-1],
              [1,-1,-1],[1,-1,1],[1,1,1],[1,1,-1]]
mc.shape_param.set('A', vertices=[cube_verts, cube_verts],
                   centers=[[-1,0,0],[1,0,0]],orientations=[[1,0,0,0],[1,0,0,
→0]]);
print('vertices of the first cube = ', mc.shape_param['A'].members[0].vertices)
print('center of the first cube = ', mc.shape_param['A'].centers[0])
print('orientation of the first cube = ', mc.shape_param['A'].orientations[0])
```

class hoomd.hpmc.integrate.**ellipsoid**(*seed, d=0.1, a=0.1, move_ratio=0.5, nselect=4, implicit=False, depletant_mode='circumsphere', restore_state=False*)

HPMC integration for ellipsoids (2D/3D).

Parameters

- **seed** (*int*) – Random number seed.
- **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
- **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.
- **move_ratio** (*float*) – Ratio of translation moves to rotation moves.
- **nselect** (*int*) – The number of trial moves to perform in each cell.
- **implicit** (*bool*) – Flag to enable implicit depletants.
- **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)
- **restore_state** (*bool*) – Restore internal state from initialization file when True. See *mode_hpmc* for a description of what state data restored. (added in version 2.2)

Ellipsoid parameters:

- *a* (**required**) - principle axis a of the ellipsoid (radius in the x direction) (distance units)
- *b* (**required**) - principle axis b of the ellipsoid (radius in the y direction) (distance units)
- *c* (**required**) - principle axis c of the ellipsoid (radius in the z direction) (distance units)
- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking
- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

    - Deprecated since version 2.1: Replaced by *interaction_matrix*.

Example:

```
mc = hpmc.integrate.ellipsoid(seed=415236, d=0.3, a=0.4)
mc.shape_param.set('A', a=0.5, b=0.25, c=0.125);
print('ellipsoids parameters (a,b,c) = ', mc.shape_param['A'].a, mc.shape_param['A
↪'].b, mc.shape_param['A'].c)
```

Depletants Example:

```
mc = hpmc.integrate.ellipsoid(seed=415236, d=0.3, a=0.4, implicit=True, depletant_
↪mode='circumsphere')
mc.set_params(nselect=1,nR=50,depletant_type='B')
mc.shape_param.set('A', a=0.5, b=0.25, c=0.125);
mc.shape_param.set('B', a=0.05, b=0.05, c=0.05);
```

get_type_shapes()
> Get all the types of shapes in the current simulation.

Example

```
>>> mc.get_type_shapes()
[{'type': 'Ellipsoid', 'a': 1.0, 'b': 1.5, 'c': 1}]
```

> **Returns** A list of dictionaries, one for each particle type in the system.

class hoomd.hpmc.integrate.**faceted_ellipsoid**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *implicit=False*, *deple-tant_mode='circumsphere'*, *re-store_state=False*)

HPMC integration for faceted ellipsoids (3D).

> **Parameters**
>
> - **seed** (*int*) – Random number seed.
>
> - **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
>
> - **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.
>
> - **move_ratio** (*float*) – Ratio of translation moves to rotation moves.
>
> - **nselect** (*int*) – The number of trial moves to perform in each cell.
>
> - **implicit** (*bool*) – Flag to enable implicit depletants.
>
> - **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)
>
> - **restore_state** (*bool*) – Restore internal state from initialization file when True. See *mode_hpmc* for a description of what state data restored. (added in version 2.2)

A faceted ellipsoid is an ellipsoid intersected with a convex polyhedron defined through halfspaces. The equation defining each halfspace is given by:

$$n_i \cdot r + b_i \leq 0$$

where n_i is the face normal, and b_i is the offset.

> **Warning:** The origin must be chosen so as to lie **inside the shape**, or the overlap check will not work. This condition is not checked.

Faceted ellipsoid parameters:

- *normals* (**required**) - list of (x,y,z) tuples defining the facet normals (distance units)

- *offsets* (**required**) - list of offsets (distance unit^2)

- *a* (**required**) - first half axis of ellipsoid

- *b* (**required**) - second half axis of ellipsoid

- *c* (**required**) - third half axis of ellipsoid

- *vertices* (**required**) - list of vertices for intersection polyhedron

- *origin* (**required**) - origin vector

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

  - Deprecated since version 2.1: Replaced by *interaction_matrix*.

> **Warning:** Planes must not be coplanar.

> **Note:** The half-space intersection of the normals has to match the convex polyhedron defined by the vertices (if non-empty), currently the half-space intersection is **not** calculated automatically. For simple intersections with planes that do not intersect within the sphere, the vertices list can be left empty.

Example:

```
mc = hpmc.integrate.faceted_ellipsoid(seed=415236, d=0.3, a=0.4)

# half-space intersection
slab_normals = [(-1,0,0),(1,0,0),(0,-1,0),(0,1,0),(0,0,-1),(0,0,1)]
slab_offsets = [-0.1,-1,-.5,-.5,-.5,-.5)

# polyedron vertices
slab_verts = [[-.1,-.5,-.5],[-.1,-.5,.5],[-.1,.5,.5],[-.1,.5,-.5], [1,-.5,-.5],[1,
→-.5,.5],[1,.5,.5],[1,.5,-.5]]

mc.shape_param.set('A', normals=slab_normals, offsets=slab_offsets, vertices=slab_
→verts,a=1.0, b=0.5, c=0.5);
print('a = {}, b = {}, c = {}', mc.shape_param['A'].a,mc.shape_param['A'].b,mc.
→shape_param['A'].c)
```

Depletants Example:

```
mc = hpmc.integrate.faceted_ellipsoid(seed=415236, d=0.3, a=0.4, implicit=True,
→depletant_mode='circumsphere')
mc.set_params(nselect=1,nR=3,depletant_type='B')
mc.shape_param.set('A', normals=[(-1,0,0),(1,0,0),(0,-1,0),(0,1,0),(0,0,-1),(0,0,
→1)],a=1.0, b=0.5, c=0.25);
# depletant sphere
mc.shape_param.set('B', normals=[],a=0.1,b=0.1,c=0.1);
```

class hoomd.hpmc.integrate.**faceted_ellipsoid_union**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *implicit=False*, *depletant_mode='circumsphere'*)

HPMC integration for unions of faceted ellipsoids (3D).

Parameters

- **seed** (*int*) – Random number seed.
- **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
- **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.
- **move_ratio** (*float*) – Ratio of translation moves to rotation moves.
- **nselect** (*int*) – The number of trial moves to perform in each cell.
- **implicit** (*bool*) – Flag to enable implicit depletants.
- **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)

- **max_members** (*int*) – Set the maximum number of members in the convex polyhedron union

- **capacity** (*int*) – Set to the number of constituent convex polyhedra per leaf node

New in version 2.5.

See *faceted_ellipsoid* for a detailed explanation of the constituent particle parameters.

Faceted ellipsiod union parameters:

- *normals* (**required**) - list of list of (x,y,z) tuples defining the facet normals (distance units)

- *offsets* (**required**) - list of list of offsets (distance unit^2)

- *axes* (**required**) - list of half axes, tuple of three per constituent ellipsoid

- *vertices* (**required**) - list of list list of vertices for intersection polyhedron

- *origin* (**required**) - list of origin vectors

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking.

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

    - Deprecated since version 2.1: Replaced by *interaction_matrix*.

Example:

```
mc = hpmc.integrate.faceted_ellipsoid_union(seed=27, d=0.3, a=0.4)

# make a prolate Janus ellipsoid
# cut away -x halfspace
normals = [(-1,0,0)]
offsets = [0]

mc.shape_param.set('A', normals=[normals, normals],
                        offsets=[offsets, offsets],
                        vertices=[[], []],
                        axes=[(.5,.5,2),(.5,.5,2)],
                        centers=[[0,0,0],[0,0,0]],
                        orientations=[[1,0,0,0],[0,0,0,-1]]);

print('offsets of the first faceted ellipsoid = ', mc.shape_param['A'].members[0].
↪normals)
print('normals of the first faceted ellispoid = ', mc.shape_param['A'].members[0].
↪offsets)
print('vertices of the first faceted ellipsoid = ', mc.shape_param['A'].
↪members[0].vertices)
```

class hoomd.hpmc.integrate.**faceted_sphere**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *implicit=False*, *depletant_mode='circumsphere'*, *restore_state=False*)

HPMC integration for faceted spheres (3D).

Parameters

- **seed** (*int*) – Random number seed.

- **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **move_ratio** (*float*) – Ratio of translation moves to rotation moves.

- **nselect** (*int*) – The number of trial moves to perform in each cell.

- **implicit** (*bool*) – Flag to enable implicit depletants.

- **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)

- **restore_state** (*bool*) – Restore internal state from initialization file when True. See *mode_hpmc* for a description of what state data restored. (added in version 2.2)

A faceted sphere is a sphere intersected with halfspaces. The equation defining each halfspace is given by:

$$n_i \cdot r + b_i \leq 0$$

where n_i is the face normal, and b_i is the offset.

> **Warning:** The origin must be chosen so as to lie **inside the shape**, or the overlap check will not work. This condition is not checked.

Faceted sphere parameters:

- *normals* (**required**) - list of (x,y,z) tuples defining the facet normals (distance units)

- *offsets* (**required**) - list of offsets (distance unit^2)

- *diameter* (**required**) - diameter of sphere

- *vertices* (**required**) - list of vertices for intersection polyhedron

- *origin* (**required**) - origin vector

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

    – Deprecated since version 2.1: Replaced by *interaction_matrix*.

> **Warning:** Planes must not be coplanar.

> **Note:** The half-space intersection of the normals has to match the convex polyhedron defined by the vertices (if non-empty), currently the half-space intersection is **not** calculated automatically. For simple intersections with planes that do not intersect within the sphere, the vertices list can be left empty.

Example:: # half-space intersection slab_normals = [(-1,0,0),(1,0,0),(0,-1,0),(0,1,0),(0,0,-1),(0,0,1)] slab_offsets = [-0.1,-1,-.5,-.5,-.5,-.5)

polyedron vertices slab_verts = [[-.1,-.5,-.5],[-.1,-.5,.5],[-.1,.5,.5],[-.1,.5,-.5], [.5,-.5,-.5],[.5,-.5,.5],[.5,.5,.5],[.5,.5,-.5]]

mc = hpmc.integrate.faceted_sphere(seed=415236, d=0.3, a=0.4) mc.shape_param.set('A', normals=slab_normals,offsets=slab_offsets, vertices=slab_verts,diameter=1.0); print('diameter = ', mc.shape_param['A'].diameter)

Depletants Example:

```
mc = hpmc.integrate.faceted_sphere(seed=415236, d=0.3, a=0.4, implicit=True,
↪depletant_mode='circumsphere')
mc.set_params(nselect=1,nR=3,depletant_type='B')
mc.shape_param.set('A', normals=[(-1,0,0),(1,0,0),(0,-1,0),(0,1,0),(0,0,-1),(0,0,
↪1)],diameter=1.0);
mc.shape_param.set('B', normals=[],diameter=0.1);
```

class hoomd.hpmc.integrate.**interaction_matrix**

Define pairwise interaction matrix

All shapes use *interaction_matrix* to define the interaction matrix between different pairs of particles indexed by type. The set of pair coefficients is a symmetric matrix defined over all possible pairs of particle types.

By default, all elements of the interaction matrix are 1, that means that overlaps are checked between all pairs of types. To disable overlap checking for a specific type pair, set the coefficient for that pair to 0.

Access the interaction matrix with a saved integrator object like so:

```
from hoomd import hpmc

mc = hpmc.integrate.some_shape(arguments...)
mv.overlap_checks.set('A', 'A', enable=False)
mc.overlap_checks.set('A', 'B', enable=True)
mc.overlap_checks.set('B', 'B', enable=False)
```

New in version 2.1.

set (*a*, *b*, *enable*)

Sets parameters for one type pair.

Parameters

- **a** (*str*) – First particle type in the pair (or a list of type names)
- **b** (*str*) – Second particle type in the pair (or a list of type names)
- **enable** – Set to True to enable overlap checks for this pair, False otherwise

By default, all interaction matrix elements are set to 'True'.

It is not an error, to specify matrix elements for particle types that do not exist in the simulation.

There is no need to specify matrix elements for both pairs 'A', 'B' and 'B', 'A'. Specifying only one is sufficient.

To set the same elements between many particle types, provide a list of type names instead of a single one. All pairs between the two lists will be set to the same parameters.

Examples:

```
mc.overlap_checks.set('A', 'A', False);
mc.overlap_checks.set('B', 'B', False);
mc.overlap_checks.set('A', 'B', True);
mc.overlap_checks.set(['A', 'B', 'C', 'D'], 'F', True);
mc.overlap_checks.set(['A', 'B', 'C', 'D'], ['A', 'B', 'C', 'D'], False);
```

class hoomd.hpmc.integrate.**mode_hpmc** (*implicit*, *depletant_mode=None*)

Base class HPMC integrator.

mode_hpmc is the base class for all HPMC integrators. It provides common interface elements. Users should not instantiate this class directly. Methods documented here are available to all hpmc integrators.

State data

HPMC integrators can save and restore the following state information to gsd files:

- Maximum trial move displacement *d*
- Maximum trial rotation move *a*
- Shape parameters for all types.

State data are *not* written by default. You must explicitly request that state data for an mc integrator is written to a gsd file (see *hoomd.dump.gsd.dump_state()*).

```
mc = hoomd.hpmc.shape(...)
gsd = hoomd.dump.gsd(...)
gsd.dump_state(mc)
```

State data are *not* restored by default. You must explicitly request that state data be restored when initializing the integrator.

```
init.read_gsd(...)
mc = hoomd.hpmc.shape(..., restore_state=True)
```

See the *State data* section of the HOOMD GSD schema for details on GSD data chunk names and how the data are stored.

Depletants

HPMC supports integration with depletants. An ideal gas of depletants is generated 'on-the-fly' and and used in the Metropolis acceptance criterion for the 'colloid' particles. Depletants are of arbitrary shape, however they are assumed to be 'hard' only with respect to the colloids, and mutually interpenetrable. The main idea is described in See J. Glaser et. al. 2015 .

As of version 2.2, hoomd.hpmc supports a new acceptance rule for depletants which is enabled with the **depletant_mode='overlap_regions'** argument. The new mode results in free diffusion of colloids that do not share any overlap volume with other colloids. This speeds up equilibration of dilute systems of colloids in a dense depletant bath. Both modes yield the same equilibrium statistics, but different dynamics (Glaser, to be published).

count_overlaps()
    Count the number of overlaps.

        Returns The number of overlaps in the current system configuration

    Example:

```
mc = hpmc.integrate.shape(..);
mc.shape_param.set(....);
run(100)
num_overlaps = mc.count_overlaps();
```

get_a(*type=None*)
    Get the maximum trial rotation.

        Parameters **type** (*str*) – Type name to query.

> **Returns** The current value of the 'a' parameter of the integrator.

get_configurational_bias_ratio()
>   Get the average ratio of configurational bias attempts to depletant insertion moves.
>
>   Only supported with **depletant_mode=='circumsphere'**.
>
> > **Returns** The average configurational bias ratio during the last *hoomd.run()*.
>
>   Example:

```
mc = hpmc.integrate.shape(..,implicit=True);
mc.shape_param.set(....);
run(100)
cb_ratio = mc.get_configurational_bias_ratio();
```

get_counters()
>   Get all trial move counters.
>
> > **Returns** A dictionary containing all trial moves counted during the last *hoomd.run()*.
>
>   The dictionary contains the entries:
>
>   - *translate_accept_count* - count of the number of accepted translate moves
>   - *translate_reject_count* - count of the number of rejected translate moves
>   - *rotate_accept_count* - count of the number of accepted rotate moves
>   - *rotate_reject_count* - count of the number of rejected rotate moves
>   - *overlap_checks* - estimate of the number of overlap checks performed
>   - *translate_acceptance* - Average translate acceptance ratio over the run
>   - *rotate_acceptance* - Average rotate acceptance ratio over the run
>   - *move_count* - Count of the number of trial moves during the run

get_d(*type=None*)
>   Get the maximum trial displacement.
>
> > **Parameters** **type** (*str*) – Type name to query.
>
> > **Returns** The current value of the 'd' parameter of the integrator.

get_depletant_type()
>   Get the depletant type
>
> > **Returns** The type of particle used as depletant (the 'depletant_type' argument of the integrator).

get_move_ratio()
>   Get the current probability of attempting translation moves.
>
>   Returns: The current value of the 'move_ratio' parameter of the integrator.

get_mps()
>   Get the number of trial moves per second.
>
> > **Returns** The number of trial moves per second performed during the last *hoomd.run()*.

get_nR()
>   Get depletant density
>
> > **Returns** The current value of the 'nR' parameter of the integrator.

get_nselect()
> Get nselect parameter.

>> **Returns** The current value of the 'nselect' parameter of the integrator.

get_ntrial()
> Get ntrial parameter.

>> **Returns** The current value of the 'ntrial' parameter of the integrator.

get_rotate_acceptance()
> Get the average acceptance ratio for rotate moves.

>> **Returns** The average rotate accept ratio during the last *hoomd.run()*.

> Example:

```
mc = hpmc.integrate.shape(..);
mc.shape_param.set(....);
run(100)
t_accept = mc.get_rotate_acceptance();
```

get_translate_acceptance()
> Get the average acceptance ratio for translate moves.

>> **Returns** The average translate accept ratio during the last *hoomd.run()*.

> Example:

```
mc = hpmc.integrate.shape(..);
mc.shape_param.set(....);
run(100)
t_accept = mc.get_translate_acceptance();
```

get_type_shapes()
> Get all the types of shapes in the current simulation.

> Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

map_overlaps()
> Build an overlap map of the system

>> **Returns** List of tuples. True/false value of the i,j entry indicates overlap/non-overlap of the ith and jth particles (by tag)

> **Note:** *map_overlaps()* does not support MPI parallel simulations.

> ### Example

> mc = hpmc.integrate.shape(...) mc.shape_param.set(...) overlap_map = np.asarray(mc.map_overlaps())

restore_state()
> Restore the state information from the file used to initialize the simulations

set_params(*d=None*, *a=None*, *move_ratio=None*, *nselect=None*, *nR=None*, *depletant_type=None*, *ntrial=None*, *deterministic=None*)
> Changes parameters of an existing integration mode.

>> **Parameters**

- **d** (*float*) – (if set) Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **a** (*float*) – (if set) Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.

- **move_ratio** (*float*) – (if set) New value for the move ratio.

- **nselect** (*int*) – (if set) New value for the number of particles to select for trial moves in one cell.

- **nR** (*int*) – (if set) **Implicit depletants only**: Number density of implicit depletants in free volume.

- **depletant_type** (*str*) – (if set) **Implicit depletants only**: Particle type to use as implicit depletant.

- **ntrial** (*int*) – (if set) **Implicit depletants only**: Number of re-insertion attempts per overlapping depletant. (Only supported with **depletant_mode='circumsphere'**)

- **deterministic** (*bool*) – (if set) Make HPMC integration deterministic on the GPU by sorting the cell list.

Note: Simulations are only deterministic with respect to the same execution configuration (CPU or GPU) and number of MPI ranks. Simulation output will not be identical if either of these is changed.

---

setup_pos_writer(*pos*, *colors={}*)

Set pos_writer definitions for specified shape parameters.

> **Parameters**
>
> - **pos** (*hoomd.deprecated.dump.pos*) – pos writer to setup
>
> - **colors** (*dict*) – dictionary of type name to color mappings

setup_pos_writer() uses the shape_param settings to specify the shape definitions (via set_def) to the provided pos file writer. This overrides any previous values specified to *hoomd.deprecated.dump.pos.set_def()*.

colors allows you to set per-type colors for particles. Specify colors as strings in the injavis format. When colors is not specified for a type, all colors default to `005984FF`.

Examples:

```
mc = hpmc.integrate.shape(...);
mc.shape_param.set(....);
pos = pos_writer.dumpy.pos("dump.pos", period=100);
mc.setup_pos_writer(pos, colors=dict(A='005984FF'));
```

test_overlap(*type_i*, *type_j*, *rij*, *qi*, *qj*, *use_images=True*, *exclude_self=False*)

Test overlap between two particles.

> **Parameters**
>
> - **type_i** (*str*) – Type of first particle
>
> - **type_j** (*str*) – Type of second particle
>
> - **rij** (*tuple*) – Separation vector **rj**-**ri** between the particle centers
>
> - **qi** (*tuple*) – Orientation quaternion of first particle
>
> - **qj** (*tuple*) – Orientation quaternion of second particle

- **use_images** (*bool*) – If True, check for overlap between the periodic images of the particles by adding the image vector to the separation vector

- **exclude_self** (*bool*) – If both **use_images** and **exclude_self** are true, exclude the primary image

For two-dimensional shapes, pass the third dimension of **rij** as zero.

>   **Returns** True if the particles overlap.

class hoomd.hpmc.integrate.**polyhedron**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *implicit=False*, *depletant_mode='circumsphere'*, *restore_state=False*)

HPMC integration for general polyhedra (3D).

This shape uses an internal OBB tree for fast collision queries. Depending on the number of constituent spheres in the tree, different values of the number of spheres per leaf node may yield different optimal performance. The capacity of leaf nodes is configurable.

Only triangle meshes and spheres are supported. The mesh must be free of self-intersections.

>   **Parameters**
>
>   - **seed** (*int*) – Random number seed.
>
>   - **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
>
>   - **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.
>
>   - **move_ratio** (*float*) – Ratio of translation moves to rotation moves.
>
>   - **nselect** (*int*) – The number of trial moves to perform in each cell.
>
>   - **implicit** (*bool*) – Flag to enable implicit depletants.
>
>   - **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)
>
>   - **restore_state** (*bool*) – Restore internal state from initialization file when True. See *mode_hpmc* for a description of what state data restored. (added in version 2.2)

Polyhedron parameters:

- *vertices* (**required**) - vertices of the polyhedron as is a list of (x,y,z) tuples of numbers (distance units)

  - The origin **MUST** strictly be contained in the generally nonconvex volume defined by the vertices and faces

  - The (0,0,0) centered sphere that encloses all vertices should be of minimal size for optimal performance (e.g. don't translate the shape such that (0,0,0) right next to a face).

- *faces* (**required**) - a list of vertex indices for every face

  - For visualization purposes, the faces **MUST** be defined with a counterclockwise winding order to produce an outward normal.

- *sweep_radius* (**default: 0.0**) - rounding radius applied to polyhedron

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

  - Deprecated since version 2.1: Replaced by *interaction_matrix*.

- *capacity* (**default: 4**) - set to the maximum number of particles per leaf node for better performance
  - New in version 2.2.
- *origin* (**default: (0,0,0)**) - a point strictly inside the shape, needed for correctness of overlap checks
  - New in version 2.2.
- *hull_only* (**default: True**) - if True, only consider intersections between hull polygons
  - New in version 2.2.

> **Warning:** HPMC does not check that all requirements are met. Undefined behavior will result if they are violated.

Example:

```
mc = hpmc.integrate.polyhedron(seed=415236, d=0.3, a=0.4)
mc.shape_param.set('A', vertices=[(-0.5, -0.5, -0.5), (-0.5, -0.5, 0.5), (-0.5, 0.
↪5, -0.5), (-0.5, 0.5, 0.5), \
        (0.5, -0.5, -0.5), (0.5, -0.5, 0.5), (0.5, 0.5, -0.5), (0.5, 0.5, 0.5)], \
faces = [[0, 2, 6], [6, 4, 0], [5, 0, 4], [5,1,0], [5,4,6], [5,6,7], [3,2,0], [3,
↪0,1], [3,6,2], \
        [3,7,6], [3,1,5], [3,5,7]]
print('vertices = ', mc.shape_param['A'].vertices)
print('faces = ', mc.shape_param['A'].faces)
```

Depletants Example:

```
mc = hpmc.integrate.polyhedron(seed=415236, d=0.3, a=0.4, implicit=True,␣
↪depletant_mode='circumsphere')
mc.set_param(nselect=1,nR=3,depletant_type='B')
cube_verts = [(-0.5, -0.5, -0.5), (-0.5, -0.5, 0.5), (-0.5, 0.5, -0.5), (-0.5, 0.
↪5, 0.5), \
            (0.5, -0.5, -0.5), (0.5, -0.5, 0.5), (0.5, 0.5, -0.5), (0.5, 0.5, 0.
↪5)];
cube_faces = [[0, 2, 6], [6, 4, 0], [5, 0, 4], [5,1,0], [5,4,6], [5,6,7], [3,2,0],
↪ [3,0,1], [3,6,2], \
            [3,7,6], [3,1,5], [3,5,7]]
tetra_verts = [(0.5, 0.5, 0.5), (0.5, -0.5, -0.5), (-0.5, 0.5, -0.5), (-0.5, -0.5,
↪ 0.5)];
tetra_faces = [[0, 1, 2], [3, 0, 2], [3, 2, 1], [3,1,0]];
mc.shape_param.set('A', vertices = cube_verts, faces = cube_faces);
mc.shape_param.set('B', vertices = tetra_verts, faces = tetra_faces, origin = (0,
↪0,0));
```

`get_type_shapes`()
Get all the types of shapes in the current simulation.

Example

```
>>> mc.get_type_shapes()
[{'type': 'Mesh', 'vertices': [[0.5, 0.5, 0.5], [0.5, -0.5, -0.5], [-0.5, 0.5,
↪ -0.5], [-0.5, -0.5, 0.5]],
  'indices': [[0, 1, 2], [0, 3, 1], [0, 2, 3], [1, 3, 2]]}]
```

Returns A list of dictionaries, one for each particle type in the system.

class hoomd.hpmc.integrate.**simple_polygon**(*seed, d=0.1, a=0.1, move_ratio=0.5, nselect=4, restore_state=False*)

> HPMC integration for simple polygons (2D).
>
> > **Parameters**
> >
> > - **seed** (*int*) – Random number seed.
> >
> > - **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
> >
> > - **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.
> >
> > - **move_ratio** (*float*) – Ratio of translation moves to rotation moves.
> >
> > - **nselect** (*int*) – The number of trial moves to perform in each cell.
> >
> > - **restore_state** (*bool*) – Restore internal state from initialization file when True. See *mode_hpmc* for a description of what state data restored. (added in version 2.2)

> **Note:** For simple polygons that are not concave, use *convex_polygon*, it will execute much faster than *simple_polygon*.

> Simple polygon parameters:
>
> - *vertices* (**required**) - vertices of the polygon as is a list of (x,y) tuples of numbers (distance units)
>
>   - Vertices **MUST** be specified in a *counter-clockwise* order.
>
>   - The polygon may be concave, but edges must not cross.
>
>   - The origin doesn't necessarily need to be inside the shape.
>
>   - The origin centered circle that encloses all vertices should be of minimal size for optimal performance.
>
> - *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking
>
> - *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*
>
>   - Deprecated since version 2.1: Replaced by *interaction_matrix*.

> **Warning:** HPMC does not check that all requirements are met. Undefined behavior will result if they are violated.

> Examples:

```
mc = hpmc.integrate.simple_polygon(seed=415236, d=0.3, a=0.4)
mc.shape_param.set('A', vertices=[(0, 0.5), (-0.5, -0.5), (0, 0), (0.5, -0.5)]);
print('vertices = ', mc.shape_param['A'].vertices)
```

> **get_type_shapes**()
>
> > Get all the types of shapes in the current simulation.
> >
> > **Example**

```
>>> mc.get_type_shapes()
[{'type': 'Polygon', 'rounding_radius': 0,
  'vertices': [[-0.5, -0.5], [0.5, -0.5], [0.5, 0.5], [-0.5, 0.5]]}]
```

> **Returns** A list of dictionaries, one for each particle type in the system.

class hoomd.hpmc.integrate.**sphere**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *implicit=False*, *depletant_mode='circumsphere'*, *restore_state=False*)

HPMC integration for spheres (2D/3D).

> **Parameters**
>
> - **seed** (*int*) – Random number seed
>
> - **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
>
> - **a** (float, only with **orientable=True**) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type. (added in version 2.3)
>
> - **move_ratio** (float, only used with **orientable=True**) – Ratio of translation moves to rotation moves. (added in version 2.3)
>
> - **nselect** (*int*) – The number of trial moves to perform in each cell.
>
> - **implicit** (*bool*) – Flag to enable implicit depletants.
>
> - **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)
>
> - **restore_state** (*bool*) – Restore internal state from initialization file when True. See *mode_hpmc* for a description of what state data restored. (added in version 2.2)

Hard particle Monte Carlo integration method for spheres.

Sphere parameters:

- *diameter* (**required**) - diameter of the sphere (distance units)

- *orientable* (**default: False**) - set to True for spheres with orientation (added in version 2.3)

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

    - Deprecated since version 2.1: Replaced by *interaction_matrix*.

Examples:

```
mc = hpmc.integrate.sphere(seed=415236, d=0.3)
mc.shape_param.set('A', diameter=1.0)
mc.shape_param.set('B', diameter=2.0)
mc.shape_param.set('C', diameter=1.0, orientable=True)
print('diameter = ', mc.shape_param['A'].diameter)
```

Depletants Example:

```
mc = hpmc.integrate.sphere(seed=415236, d=0.3, a=0.4, implicit=True, depletant_
↪mode='circumsphere')
mc.set_params(nselect=8,nR=3,depletant_type='B')
```

(continues on next page)

```
mc.shape_param.set('A', diameter=1.0)
mc.shape_param.set('B', diameter=.1)
```

get_type_shapes()
>   Get all the types of shapes in the current simulation.

Examples

The types will be 'Sphere' regardless of dimensionality.

```
>>> mc.get_type_shapes()
[{'type': 'Sphere', 'diameter': 1}, {'type': 'Sphere', 'diameter': 2}]
```

>   **Returns** A list of dictionaries, one for each particle type in the system.

class hoomd.hpmc.integrate.**sphere_union**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *implicit=False*, *depletant_mode='circumsphere'*, *max_members=None*, *restore_state=False*)
>   HPMC integration for unions of spheres (3D).

>   This shape uses an internal OBB tree for fast collision queries. Depending on the number of constituent spheres in the tree, different values of the number of spheres per leaf node may yield different optimal performance. The capacity of leaf nodes is configurable.

>   **Parameters**

>   - **seed** (*int*) – Random number seed.
>   - **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
>   - **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.
>   - **move_ratio** (*float*) – Ratio of translation moves to rotation moves.
>   - **nselect** (*int*) – The number of trial moves to perform in each cell.
>   - **implicit** (*bool*) – Flag to enable implicit depletants.
>   - **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)
>   - **max_members** (*int*) – Set the maximum number of members in the sphere union * .. deprecated:: 2.2
>   - **capacity** (*int*) – Set to the number of constituent spheres per leaf node. (added in version 2.2)
>   - **restore_state** (*bool*) – Restore internal state from initialization file when True. See *mode_hpmc* for a description of what state data restored. (added in version 2.2)

>   Sphere union parameters:

>   - *diameters* (**required**) - list of diameters of the spheres (distance units).
>   - *centers* (**required**) - list of centers of constituent spheres in particle coordinates.
>   - *overlap* (**default: 1 for all spheres**) - only check overlap between constituent particles for which *overlap [i] & overlap[j]* is !=0, where '&' is the bitwise AND operator.

- New in version 2.1.

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking.

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

  - Deprecated since version 2.1: Replaced by `interaction_matrix`.

- *capacity* (**default: 4) - set to the maximum number of particles per leaf node for better performance**

  - New in version 2.2.

Example:

```
mc = hpmc.integrate.sphere_union(seed=415236, d=0.3, a=0.4)
mc.shape_param.set('A', diameters=[1.0, 1.0], centers=[(-0.25, 0.0, 0.0), (0.25,
→0.0, 0.0)]);
print('diameter of the first sphere = ', mc.shape_param['A'].members[0].diameter)
print('center of the first sphere = ', mc.shape_param['A'].centers[0])
```

Depletants Example:

```
mc = hpmc.integrate.sphere_union(seed=415236, d=0.3, a=0.4, implicit=True,
→depletant_mode='circumsphere')
mc.set_params(nselect=1,nR=50,depletant_type='B')
mc.shape_param.set('A', diameters=[1.0, 1.0], centers=[(-0.25, 0.0, 0.0), (0.25,
→0.0, 0.0)]);
mc.shape_param.set('B', diameters=[0.05], centers=[(0.0, 0.0, 0.0)]);
```

class hoomd.hpmc.integrate.**sphinx**(*seed*, *d=0.1*, *a=0.1*, *move_ratio=0.5*, *nselect=4*, *implicit=False*, *depletant_mode='circumsphere'*, *restore_state=False*)

HPMC integration for sphinx particles (3D).

> **Parameters**
>
> - **seed** (*int*) – Random number seed.
>
> - **d** (*float*) – Maximum move displacement, Scalar to set for all types, or a dict containing {type:size} to set by type.
>
> - **a** (*float*) – Maximum rotation move, Scalar to set for all types, or a dict containing {type:size} to set by type.
>
> - **move_ratio** (*float*) – Ratio of translation moves to rotation moves.
>
> - **nselect** (*int*) – The number of trial moves to perform in each cell.
>
> - **implicit** (*bool*) – Flag to enable implicit depletants.
>
> - **depletant_mode** (string, only with **implicit=True**) – Where to place random depletants, either 'circumsphere' or 'overlap_regions' (added in version 2.2)
>
> - **restore_state** (*bool*) – Restore internal state from initialization file when True. See `mode_hpmc` for a description of what state data restored. (added in version 2.2)

Sphinx particles are dimpled spheres (spheres with 'positive' and 'negative' volumes).

Sphinx parameters:

- *diameters* - diameters of spheres (positive OR negative real numbers)

- *centers* - centers of spheres in local coordinate frame

- *ignore_statistics* (**default: False**) - set to True to disable ignore for statistics tracking

- *ignore_overlaps* (**default: False**) - set to True to disable overlap checks between this and other types with *ignore_overlaps=True*

    – Deprecated since version 2.1: Replaced by *interaction_matrix*.

Quick Example:

```
mc = hpmc.integrate.sphinx(seed=415236, d=0.3, a=0.4)
mc.shape_param.set('A', centers=[(0,0,0),(1,0,0)], diameters=[1,.25])
print('diameters = ', mc.shape_param['A'].diameters)
```

Depletants Example:

```
mc = hpmc.integrate.sphinx(seed=415236, d=0.3, a=0.4, implicit=True, depletant_
→mode='circumsphere')
mc.set_params(nselect=1,nR=3,depletant_type='B')
mc.shape_param.set('A', centers=[(0,0,0),(1,0,0)], diameters=[1,-.25])
mc.shape_param.set('B', centers=[(0,0,0)], diameters=[.15])
```

2.15.6 hpmc.update

Overview

hpmc.update.boxmc	Apply box updates to sample isobaric and related ensembles.
hpmc.update.clusters	Equilibrate the system according to the geometric cluster algorithm (GCA).
hpmc.update.muvt	Insert and remove particles in the muVT ensemble.
hpmc.update.remove_drift	Remove the center of mass drift from a system restrained on a lattice.
hpmc.update.wall	Apply wall updates with a user-provided python callback.

Details

HPMC updaters.

class hoomd.hpmc.update.**boxmc**(*mc*, *betaP*, *seed*)
    Apply box updates to sample isobaric and related ensembles.

> **Parameters**
>
> - **mc** (*hoomd.hpmc.integrate*) – HPMC integrator object for system on which to apply box updates
>
> - **betaP** (*float* or *hoomd.variant*) – $\frac{p}{k_{\mathrm{B}}T}$. (units of inverse area in 2D or inverse volume in 3D) Apply your chosen reduced pressure convention externally.
>
> - **seed** (*int*) – random number seed for MC box changes

One or more Monte Carlo move types are applied to evolve the simulation box. By default, no moves are applied. Activate desired move types using the following methods with a non-zero weight:

- *aspect()* - box aspect ratio moves

- *length()* - change box lengths independently

- *shear()* - shear the box

- *volume()* - scale the box lengths uniformly

- *ln_volume()* - scale the box lengths uniformly with logarithmic increments

Pressure inputs to update.boxmc are defined as βP. Conversions from a specific definition of reduced pressure P^* are left for the user to perform.

Note: All *delta* and *weight* values for all move types default to 0.

Example:

```
mc = hpmc.integrate.sphere(seed=415236, d=0.3)
boxMC = hpmc.update.boxmc(mc, betaP=1.0, seed=9876)
boxMC.set_betap(2.0)
boxMC.ln_volume(delta=0.01, weight=2.0)
boxMC.length(delta=(0.1,0.1,0.1), weight=4.0)
run(30) # perform approximately 10 volume moves and 20 length moves
```

aspect (*delta=None*, *weight=None*)
> Enable/disable aspect ratio move and set parameters.

> > **Parameters**

> > > - **delta** (*float*) – maximum relative change of aspect ratio

> > > - **weight** (*float*) – relative weight of this box move type relative to other box move types. 0 disables this move type.

> Rescale aspect ratio along a randomly chosen dimension.

Note: When an argument is None, the value is left unchanged from its current state.

Example:

```
box_update.aspect(delta=0.01)
box_update.aspect(delta=0.01, weight=2)
box_update.aspect(delta=0.01, weight=0.15)
```

> > **Returns** A *dict* with the current values of *delta*, and *weight*.

disable ()
> Disables the updater.

> Examples:

```
updater.disable()
```

> Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable ()
> Enables the updater.

> Example:

```
box_updater.set_params(isotropic=True)
run(1e5)
box_updater.disable()
update.box_resize(dLy = 10)
box_updater.enable()
run(1e5)
```

See updater base class documentation for more information

get_aspect_acceptance()
    Get the average acceptance ratio for aspect changing moves.

        Returns The average aspect change acceptance for the last run

    Example:

```
mc = hpmc.integrate.shape(..);
mc_shape_param[name].set(....);
box_update = hpmc.update.boxmc(mc, betaP=10, seed=1)
run(100)
a_accept = box_update.get_aspect_acceptance()
```

get_ln_volume_acceptance()
    Get the average acceptance ratio for log(V) changing moves.

        Returns The average volume change acceptance for the last run

    Example:

```
mc = hpmc.integrate.shape(..);
mc.shape_param[name].set(....);
box_update = hpmc.update.boxmc(mc, betaP=10, seed=1)
run(100)
v_accept = box_update.get_ln_volume_acceptance()
```

get_shear_acceptance()
    Get the average acceptance ratio for shear changing moves.

        Returns The average shear change acceptance for the last run

    Example:

```
mc = hpmc.integrate.shape(..);
mc.shape_param[name].set(....);
box_update = hpmc.update.boxmc(mc, betaP=10, seed=1)
run(100)
s_accept = box_update.get_shear_acceptance()
```

get_volume_acceptance()
    Get the average acceptance ratio for volume changing moves.

        Returns The average volume change acceptance for the last run

    Example:

```
mc = hpmc.integrate.shape(..);
mc.shape_param[name].set(....);
box_update = hpmc.update.boxmc(mc, betaP=10, seed=1)
run(100)
v_accept = box_update.get_volume_acceptance()
```

2.15. hpmc   **191**

length (*delta=None*, *weight=None*)

    Enable/disable isobaric box dimension move and set parameters.

        Parameters

- **delta** (`float` or `tuple`) – maximum change of the box thickness for each pair of parallel planes connected by the corresponding box edges. I.e. maximum change of HOOMD-blue box parameters Lx, Ly, Lz. A single float x is equivalent to (x, x, x).

- **weight** (`float`) – relative weight of this box move type relative to other box move types. 0 disables this move type.

    Sample the isobaric distribution of box dimensions by rescaling the plane-to-plane distance of box faces, Lx, Ly, Lz (see *Periodic boundary conditions*).

Note: When an argument is None, the value is left unchanged from its current state.

    Example:

```
box_update.length(delta=(0.01, 0.01, 0.0)) # 2D box changes
box_update.length(delta=(0.01, 0.01, 0.01), weight=2)
box_update.length(delta=0.01, weight=2)
box_update.length(delta=(0.10, 0.01, 0.01), weight=0.15) # sample Lx more
→aggressively
```

        Returns A `dict` with the current values of *delta* and *weight*.

ln_volume (*delta=None*, *weight=None*)

    Enable/disable isobaric volume move and set parameters.

        Parameters

- **delta** (`float`) – maximum change of **ln(V)** (where V is box area (2D) or volume (3D)).

- **weight** (`float`) – relative weight of this box move type relative to other box move types. 0 disables this move type.

    Sample the isobaric distribution of box volumes by rescaling the box.

Note: When an argument is None, the value is left unchanged from its current state.

    Example:

```
box_update.ln_volume(delta=0.001)
box_update.ln_volume(delta=0.001, weight=2)
box_update.ln_volume(delta=0.001, weight=0.15)
```

        Returns A `dict` with the current values of *delta* and *weight*.

restore_state ()

    Restore the state information from the file used to initialize the simulations

set_betap (*betaP*)

    Update the pressure set point for Metropolis Monte Carlo volume updates.

        Parameters **betaP** (float) or (`hoomd.variant`) – $\frac{p}{k_{\mathrm{B}}T}$. (units of inverse area in 2D or inverse volume in 3D) Apply your chosen reduced pressure convention externally.

---

set_period(*period*)

Changes the updater period.

> **Parameters period** (*int*) – New period to set.

Examples:

```
updater.set_period(100);
updater.set_period(1);
```

While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

shear(*delta=None*, *weight=None*, *reduce=None*)

Enable/disable box shear moves and set parameters.

> **Parameters**
>
> - **delta** (*tuple*) – maximum change of the box tilt factor xy, xz, yz.
>
> - **reduce** (*float*) – Maximum number of lattice vectors of shear to allow before applying lattice reduction. Shear of +/- 0.5 cannot be lattice reduced, so set to a value < 0.5 to disable (default 0) Note that due to precision errors, lattice reduction may introduce small overlaps which can be resolved, but which temporarily break detailed balance.
>
> - **weight** (*float*) – relative weight of this box move type relative to other box move types. 0 disables this move type.

Sample the distribution of box shear by adjusting the HOOMD-blue tilt factor parameters xy, xz, and yz. (see *Periodic boundary conditions*).

Note: When an argument is None, the value is left unchanged from its current state.

Example:

```
box_update.shear(delta=(0.01, 0.00, 0.0)) # 2D box changes
box_update.shear(delta=(0.01, 0.01, 0.01), weight=2)
box_update.shear(delta=(0.10, 0.01, 0.01), weight=0.15) # sample xy more
↪aggressively
```

> **Returns** A *dict* with the current values of *delta*, *weight*, and *reduce*.

volume(*delta=None*, *weight=None*)

Enable/disable isobaric volume move and set parameters.

> **Parameters**
>
> - **delta** (*float*) – maximum change of the box area (2D) or volume (3D).
>
> - **weight** (*float*) – relative weight of this box move type relative to other box move types. 0 disables this move type.

Sample the isobaric distribution of box volumes by rescaling the box.

Note: When an argument is None, the value is left unchanged from its current state.

Example:

```
box_update.volume(delta=0.01)
box_update.volume(delta=0.01, weight=2)
box_update.volume(delta=0.01, weight=0.15)
```

> **Returns** A `dict` with the current values of *delta* and *weight*.

class hoomd.hpmc.update.**clusters**(*mc*, *seed*, *period=1*)

Equilibrate the system according to the geometric cluster algorithm (GCA).

The GCA as described in Liu and Lujten (2004), http://doi.org/10.1103/PhysRevLett.92.035504 is used for hard shape, patch interactions and depletants.

With depletants, Clusters are defined by a simple distance cut-off criterion. Two particles belong to the same cluster if the circumspheres of the depletant-excluded volumes overlap.

Supported moves include pivot moves (point reflection), line reflections (pi rotation around an axis), and type swaps. Only the pivot move is rejection free. With anisotropic particles, the pivot move cannot be used because it would create a chiral mirror image of the particle, and only line reflections are employed. Line reflections are not rejection free because of periodic boundary conditions, as discussed in Sinkovits et al. (2012), http://doi.org/10.1063/1.3694271 .

The type swap move works between two types of spherical particles and exchanges their identities.

The *clusters* updater support TBB execution on multiple CPU cores. See *Installing binaries* for more information on how to compile HOOMD with TBB support.

> **Parameters**
>
> - **mc** (*hoomd.hpmc.integrate*) – MC integrator.
> - **seed** (*int*) – The seed of the pseudo-random number generator (Needs to be the same across partitions of the same Gibbs ensemble)
> - **period** (*int*) – Number of timesteps between histogram evaluations.

Example:

```
mc = hpmc.integrate.sphere(seed=415236)
hpmc.update.clusters(mc=mc, seed=123)
```

disable()

Disables the updater.

Examples:

```
updater.disable()
```

Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()

Enables the updater.

Examples:

```
updater.enable()
```

See also:

disable()

get_pivot_acceptance()
>   Get the average acceptance ratio for pivot moves

>>   **Returns** The average acceptance rate for pivot moves during the last run

get_reflection_acceptance()
>   Get the average acceptance ratio for reflection moves

>>   **Returns** The average acceptance rate for reflection moves during the last run

get_swap_acceptance()
>   Get the average acceptance ratio for swap moves

>>   **Returns** The average acceptance rate for type swap moves during the last run

restore_state()
>   Restore the state information from the file used to initialize the simulations

set_params(*move_ratio=None*, *flip_probability=None*, *swap_move_ratio=None*, *delta_mu=None*, *swap_types=None*)
>   Set options for the clusters moves.

>>   **Parameters**
>>
>>   - **move_ratio** (*float*) – Set the ratio between pivot and reflection moves (default 0.5)
>>
>>   - **flip_probability** (*float*) – Set the probability for transforming an individual cluster (default 0.5)
>>
>>   - **swap_move_ratio** (*float*) – Set the ratio between type swap moves and geometric moves (default 0.5)
>>
>>   - **delta_mu** (*float*) – The chemical potential difference between types to be swapped
>>
>>   - **swap_types** (*list*) – A pair of two types whose identities are swapped

>>   **Note:** When an argument is None, the value is left unchanged from its current state.

>>   Example:

```
clusters = hpmc.update.clusters(mc, seed=123)
clusters.set_params(move_ratio = 1.0)
clusters.set_params(swap_types=['A','B'], delta_mu = -0.001)
```

set_period(*period*)
>   Changes the updater period.

>>   **Parameters period** (*int*) – New period to set.

>   Examples:

```
updater.set_period(100);
updater.set_period(1);
```

>   While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.hpmc.update.**muvt**(*mc*, *seed*, *period=1*, *transfer_types=None*, *ngibbs=1*)
>   Insert and remove particles in the muVT ensemble.

>>   **Parameters**
>>
>>   - **mc** (*hoomd.hpmc.integrate*) – MC integrator.

- **seed** (*int*) – The seed of the pseudo-random number generator (Needs to be the same across partitions of the same Gibbs ensemble)

- **period** (*int*) – Number of timesteps between histogram evaluations.

- **transfer_types** (*list*) – List of type names that are being transferred from/to the reservoir or between boxes (if *None*, all types)

- **ngibbs** (*int*) – The number of partitions to use in Gibbs ensemble simulations (if == 1, perform grand canonical muVT)

The muVT (or grand-canonical) ensemble simulates a system at constant fugacity.

Gibbs ensemble simulations are also supported, where particles and volume are swapped between two or more boxes. Every box correspond to one MPI partition, and can therefore run on multiple ranks. See *hoomd.comm* and the –nrank command line option for how to split a MPI task into partitions.

Note: Multiple Gibbs ensembles are also supported in a single parallel job, with the ngibbs option to update.muvt(), where the number of partitions can be a multiple of ngibbs.

Example:

```
mc = hpmc.integrate.sphere(seed=415236)
update.muvt(mc=mc, period)
```

disable()
    Disables the updater.

    Examples:

    ```
    updater.disable()
    ```

    Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()
    Enables the updater.

    Examples:

    ```
    updater.enable()
    ```

    See also:

    disable()

restore_state()
    Restore the state information from the file used to initialize the simulations

set_fugacity(*type*, *fugacity*)
    Change muVT fugacities.

        Parameters

            - **type** (*str*) – Particle type to set parameters for

            - **fugacity** (*float*) – Fugacity of this particle type (dimension of volume^-1)

    Example:

```
muvt = hpmc.update.muvt(mc, period=10)
muvt.set_fugacity(type='A', fugacity=1.23)
variant = hoomd.variant.linear_interp(points=[(0,1e1), (1e5, 4.56)])
muvt.set_fugacity(type='A', fugacity=variant)
```

set_params (*dV=None*, *move_ratio=None*, *transfer_ratio=None*)
    Set muVT parameters.

       Parameters

- **dV** (*float*) – (if set) Set volume rescaling factor (dimensionless)

- **move_ratio** (*float*) – (if set) Set the ratio between volume and exchange/transfer moves (applies to Gibbs ensemble)

- **transfer_ratio** (*float*) – (if set) Set the ratio between transfer and exchange moves

    Example:

```
muvt = hpmc.update.muvt(mc, period = 10)
muvt.set_params(dV=0.1)
muvt.set_params(n_trial=2)
muvt.set_params(move_ratio=0.05)
```

set_period (*period*)
    Changes the updater period.

       Parameters period (*int*) – New period to set.

    Examples:

```
updater.set_period(100);
updater.set_period(1);
```

    While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.hpmc.update.**remove_drift** (*mc*, *external_lattice*, *period=1*)
    Remove the center of mass drift from a system restrained on a lattice.

       Parameters

- **mc** (*hoomd.hpmc.integrate*) – MC integrator.

- **external_lattice** (*hoomd.hpmc.field.lattice_field*) – lattice field where the lattice is defined.

- **period** (*int*) – the period to call the updater

The command hpmc.update.remove_drift sets up an updater that removes the center of mass drift of a system every period timesteps,

Example:

```
mc = hpmc.integrate.convex_polyhedron(seed=seed);
mc.shape_param.set("A", vertices=verts)
mc.set_params(d=0.005, a=0.005)
lattice = hpmc.compute.lattice_field(mc=mc, position=fcc_lattice, k=1000.0);
remove_drift = update.remove_drift(mc=mc, external_lattice=lattice, period=1000);
```

disable()
    Disables the updater.

Examples:

```
updater.disable()
```

Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()
 Enables the updater.

 Examples:

```
updater.enable()
```

 See also:

 disable()

restore_state()
 Restore the state information from the file used to initialize the simulations

set_period(*period*)
 Changes the updater period.

   Parameters period (*int*) – New period to set.

 Examples:

```
updater.set_period(100);
updater.set_period(1);
```

 While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.hpmc.update.**wall**(*mc*, *walls*, *py_updater*, *move_ratio*, *seed*, *period=1*)
 Apply wall updates with a user-provided python callback.

  Parameters

   • **mc** (*hoomd.hpmc.integrate*) – MC integrator.

   • **walls** (*hoomd.hpmc.field.wall*) – the wall class instance to be updated

   • **py_updater** (*callable*) – the python callback that performs the update moves. This must be a python method that is a function of the timestep of the simulation. It must actually update the *hoomd.hpmc.field.wall*) managed object.

   • **move_ratio** (*float*) – the probability with which an update move is attempted

   • **seed** (*int*) – the seed of the pseudo-random number generator that determines whether or not an update move is attempted

   • **period** (*int*) – the number of timesteps between update move attempt attempts Every *period* steps, a walls update move is tried with probability *move_ratio*. This update move is provided by the *py_updater* callback. Then, update.wall only accepts an update move provided by the python callback if it maintains confinement conditions associated with all walls. Otherwise, it reverts back to a non-updated copy of the walls.

 Once initialized, the update provides the following log quantities that can be logged via *hoomd.analyze.log*:

  • **hpmc_wall_acceptance_ratio** - the acceptance ratio for wall update moves

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
def perturb(timestep):
  r = np.sqrt(ext_wall.get_sphere_wall_param(index = 0, param = "rsq"));
  ext_wall.set_sphere_wall(index = 0, radius = 1.5*r, origin = [0, 0, 0], inside
↪= True);
wall_updater = hpmc.update.wall(mc, ext_wall, perturb, move_ratio = 0.5, seed =
↪27, period = 50);
log = analyze.log(quantities=['hpmc_wall_acceptance_ratio'], period=100, filename=
↪'log.dat', overwrite=True);
```

Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
def perturb(timestep):
  r = np.sqrt(ext_wall.get_sphere_wall_param(index = 0, param = "rsq"));
  ext_wall.set_sphere_wall(index = 0, radius = 1.5*r, origin = [0, 0, 0], inside
↪= True);
wall_updater = hpmc.update.wall(mc, ext_wall, perturb, move_ratio = 0.5, seed =
↪27, period = 50);
```

disable()
> Disables the updater.
>
> Examples:
>
> ```
> updater.disable()
> ```
>
> Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()
> Enables the updater.
>
> Examples:
>
> ```
> updater.enable()
> ```
>
> See also:
>
> *disable()*

get_accepted_count(*mode=0*)
> Get the number of accepted wall update moves.
>
> > **Parameters mode** (*int*) – specify the type of count to return. If mode!=0, return absolute quantities. If mode=0, return quantities relative to the start of the run. DEFAULTS to 0.
>
> > **Returns** the number of accepted wall update moves
>
> Example:
>
> ```
> mc = hpmc.integrate.sphere(seed = 415236);
> ext_wall = hpmc.compute.wall(mc);
> ```
> (continues on next page)

```
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
def perturb(timestep):
  r = np.sqrt(ext_wall.get_sphere_wall_param(index = 0, param = "rsq"));
  ext_wall.set_sphere_wall(index = 0, radius = 1.5*r, origin = [0, 0, 0],
→inside = True);
wall_updater = hpmc.update.wall(mc, ext_wall, perturb, move_ratio = 0.5, seed
→= 27, period = 50);
run(100);
acc_count = wall_updater.get_accepted_count(mode = 0);
```

get_total_count(*mode=0*)

> Get the number of attempted wall update moves.

> > **Parameters mode** (*int*) – specify the type of count to return. If mode!=0, return absolute
> > quantities. If mode=0, return quantities relative to the start of the run. DEFAULTS to 0.

> > **Returns** the number of attempted wall update moves

> Example:

```
mc = hpmc.integrate.sphere(seed = 415236);
ext_wall = hpmc.compute.wall(mc);
ext_wall.add_sphere_wall(radius = 1.0, origin = [0, 0, 0], inside = True);
def perturb(timestep):
  r = np.sqrt(ext_wall.get_sphere_wall_param(index = 0, param = "rsq"));
  ext_wall.set_sphere_wall(index = 0, radius = 1.5*r, origin = [0, 0, 0],
→inside = True);
wall_updater = hpmc.update.wall(mc, ext_wall, perturb, move_ratio = 0.5, seed
→= 27, period = 50);
run(100);
tot_count = wall_updater.get_total_count(mode = 0);
```

restore_state()

> Restore the state information from the file used to initialize the simulations

set_period(*period*)

> Changes the updater period.

> > **Parameters period** (*int*) – New period to set.

> Examples:

```
updater.set_period(100);
updater.set_period(1);
```

> While the simulation is running, the action of each updater is executed every *period* time steps. Changing
> the period does not change the phase set when the analyzer was first created.

2.15.7 hpmc.util

Overview

hpmc.util.tune	Tune mc parameters.
hpmc.util.tune_npt	Tune the HPMC *hoomd.hpmc.update.boxmc* using *tune*.

Details

HPMC utilities

class hoomd.hpmc.util.**tune**(*obj=None*, *tunables=[]*, *max_val=[]*, *target=0.2*, *max_scale=2.0*, *gamma=2.0*, *type=None*, *tunable_map=None*, **args*, ***kwargs*)

   Tune mc parameters.

   hoomd.hpmc.util.tune provides a general tool to observe Monte Carlo move acceptance rates and adjust the move sizes when called by a user script. By default, it understands how to read and adjust the trial move domain for translation moves and rotation moves for an hpmc.integrate instance. Other move types for integrators or updaters can be handled with a customized tunable map passed when creating the tuner or in a subclass definition. E.g. see use an implementation of *tune_npt*

   Parameters

   - **obj** – HPMC Integrator or Updater instance
   - **tunables** (*list*) – list of strings naming parameters to tune. By default, allowed element values are 'd' and 'a'.
   - **max_val** (*list*) – maximum allowed values for corresponding tunables
   - **target** (*float*) – desired acceptance rate
   - **max_scale** (*float*) – maximum amount to scale a parameter in a single update
   - **gamma** (*float*) – damping factor (>= 0.0) to keep from scaling parameter values too fast
   - **type** (*str*) – Name of a single hoomd particle type for which to tune move sizes. If None (default), all types are tuned with the same statistics.
   - **tunable_map** (*dict*) – For each tunable, provide a dictionary of values and methods to be used by the tuner (see below)
   - **args** – Additional positional arguments
   - **kwargs** – Additional keyword arguments

   Example:

   ```
   mc = hpmc.integrate.convex_polyhedron()
   mc.set_params(d=0.01, a=0.01, move_ratio=0.5)
   tuner = hpmc.util.tune(mc, tunables=['d', 'a'], target=0.2, gamma=0.5)
   for i in range(10):
       run(1e4)
       tuner.update()
   ```

   Note: You should run enough steps to get good statistics for the acceptance ratios. 10,000 trial moves seems like a good number. E.g. for 10,000 or more particles, tuning after a single timestep should be fine. For npt moves made once per timestep, tuning as frequently as 1,000 timesteps could get a rough convergence of acceptance ratios, which is probably good enough since we don't really know the optimal acceptance ratio, anyway.

   Warning: There are some sanity checks that are not performed. For example, you shouldn't try to scale 'd' in a single particle simulation.

   Details:

If `gamma == 0`, each call to *update()* rescales the current value of the tunable(s) by the ratio of the observed acceptance rate to the target value. For `gamma > 0`, the scale factor is the reciprocal of a weighted mean of the above ratio with 1, according to

> scale = (1.0 + gamma) / (target/acceptance + gamma)

The names in `tunables` must match one of the keys in `tunable_map`, which in turn correspond to the keyword parameters of the MC object being updated.

`tunable_map` is a `dict` of `dict`. The keys of the outer `dict` are strings that can be specified in the `tunables` parameter. The value of this outer `dict` is another `dict` with the following four keys: 'get', 'acceptance', 'set', and 'maximum'.

A default `tunable_map` is provided but can be modified or extended by setting the following dictionary key/value pairs in the entry for tunable.

- get (`callable`): function called by tuner (no arguments) to retrieve current tunable value

- acceptance (`callable`): function called by tuner (no arguments) to get relevant acceptance rate

- set (`callable`): function to call to set new value (optional). Must take one argument (the new value). If not provided, `obj.set_params(tunable=x)` will be called to set the new value.

- maximum (`float`): maximum value the tuner may set for the tunable parameter

The default `tunable_map` defines the `callable` for 'set' to call *hoomd.hpmc.integrate. mode_hpmc.set_params()* with `tunable={type:  newval}` instead of `tunable=newval` if the `type` argument is given when creating the `tune` object.

update()
> Calculate and set tunable parameters using statistics from the run just completed.

class hoomd.hpmc.util.**tune_npt**(*obj=None, tunables=[], max_val=[], target=0.2, max_scale=2.0, gamma=2.0, type=None, tunable_map=None, *args, **kwargs*)
Tune the HPMC *hoomd.hpmc.update.boxmc* using *tune*.

This is a thin wrapper to `tune` that simply defines an alternative `tunable_map` dictionary. In this case, the `obj` argument must be an instance of *hoomd.hpmc.update.boxmc*. Several tunables are defined.

'dLx', 'dLy', and 'dLz' use the acceptance rate of volume moves to set `delta[0]`, `delta[1]`, and `delta[2]`, respectively in a call to *hoomd.hpmc.update.boxmc.length()*.

'dV' uses the volume acceptance to call *hoomd.hpmc.update.boxmc.volume()*.

'dlnV' uses the ln_volume acceptance to call *hoomd.hpmc.update.boxmc.ln_volume()*.

'dxy', 'dxz', and 'dyz' tunables use the shear acceptance to set `delta[0]`, `delta[1]`, and `delta[2]`, respectively in a call to *hoomd.hpmc.update.boxmc.shear()*.

Refer to the documentation for *hoomd.hpmc.update.boxmc* for information on how these parameters are used, since they are not all applicable for a given use of `boxmc`.

Note: A bigger damping factor gamma may be appropriate for tuning box volume changes because there may be multiple parameters affecting each acceptance rate.

Example:

```
mc = hpmc.integrate.convex_polyhedron()
mc.set_params(d=0.01, a=0.01, move_ratio=0.5)
updater = hpmc.update.boxmc(mc, betaP=10)
```

<div align="right">(continues on next page)</div>

```
updater.length(0.1, weight=1)
tuner = hpmc.util.tune_npt(updater, tunables=['dLx', 'dLy', 'dLz'], target=0.3,
↪gamma=1.0)
for i in range(10):
    run(1e4)
    tuner.update()
```

update()
> Calculate and set tunable parameters using statistics from the run just completed.

2.16 md

Details

Molecular Dynamics

Perform Molecular Dynamics simulations with HOOMD-blue.

Stability

hoomd.md is **stable**. When upgrading from version 2.x to 2.y (y > x), existing job scripts that follow *documented* interfaces for functions and classes will not require any modifications. **Maintainer:** Joshua A. Anderson

Modules

2.16.1 md.angle

Overview

md.angle.harmonic	Harmonic angle potential.
md.angle.cosinesq	Cosine squared angle potential.
md.angle.table	Tabulated angle potential.

Details

Angle potentials.

Angles add forces between specified triplets of particles and are typically used to model chemical angles between two bonds.

By themselves, angles that have been specified in an initial configuration do nothing. Only when you specify an angle force (i.e. angle.harmonic), are forces actually calculated between the listed particles.

class hoomd.md.angle.**coeff**
> Define angle coefficients.

> The coefficients for all angle force are specified using this class. Coefficients are specified per angle type.

> There are two ways to set the coefficients for a particular angle potential. The first way is to save the angle potential in a variable and call *set()* directly. See below for an example of this.

> The second method is to build the coeff class first and then assign it to the angle potential. There are some

---

advantages to this method in that you could specify a complicated set of angle potential coefficients in a separate python file and import it into your job script.

Example:

```
my_coeffs = hoomd.md.angle.coeff();
my_angle_force.angle_coeff.set('polymer', k=330.0, r=0.84)
my_angle_force.angle_coeff.set('backbone', k=330.0, r=0.84)
```

set (*type*, ***coeffs*)
    Sets parameters for angle types.

Parameters

- **type** (*str*) – Type of angle (or a list of type names)
- **coeffs** – Named coefficients (see below for examples)

Calling *set ()* results in one or more parameters being set for a angle type. Types are identified by name, and parameters are also added by name. Which parameters you need to specify depends on the angle potential you are setting these coefficients for, see the corresponding documentation.

All possible angle types as defined in the simulation box must be specified before executing run(). You will receive an error if you fail to do so. It is not an error, however, to specify coefficients for angle types that do not exist in the simulation. This can be useful in defining a potential field for many different types of angles even when some simulations only include a subset.

Examples:

```
my_angle_force.angle_coeff.set('polymer', k=330.0, r0=0.84)
my_angle_force.angle_coeff.set('backbone', k=1000.0, r0=1.0)
my_angle_force.angle_coeff.set(['angleA','angleB'], k=100, r0=0.0)
```

Note: Single parameters can be updated. If both `k` and `r0` have already been set for a particle type, then executing `coeff.set('polymer', r0=1.0)` will update the value of `r0` and leave the other parameters as they were previously set.

class hoomd.md.angle.**cosinesq**
    Cosine squared angle potential.

The command angle.cosinesq specifies a cosine squared potential energy between every triplet of particles with an angle specified between them.

$$V(\theta) = \frac{1}{2}k\left(\cos\theta - \cos\theta_0\right)^2$$

where θ is the angle between the triplet of particles. This angle style is also known as g96, since they were used in the gromos96 force field. These are also the types of angles used with the coarse-grained MARTINI force field.

Coefficients:

- θ_0 - rest angle `t0` (in radians)
- k - potential constant `k` (in units of energy)

Coefficients k and θ_0 must be set for each type of angle in the simulation using the method *angle_coeff. set ()*. Note that the value of k for this angle potential is not comparable to the value of k for harmonic angles, as they have different units.

Examples:

```
cosinesq = angle.cosinesq()
cosinesq.angle_coeff.set('polymer', k=3.0, t0=0.7851)
cosinesq.angle_coeff.set('backbone', k=100.0, t0=1.0)
```

disable(*log=False*)

Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)

Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

> g = group.all() virial = force.get_net_virial(g)

class hoomd.md.angle.**harmonic**

> Harmonic angle potential.
>
> The command angle.harmonic specifies a harmonic potential energy between every triplet of particles with an angle specified between them.
>
> $$V(\theta) = \frac{1}{2} k (\theta - \theta_0)^2$$
>
> where θ is the angle between the triplet of particles.
>
> Coefficients:
>
> - θ_0 - rest angle t0 (in radians)
>
> - k - potential constant k (in units of energy/radians^2)
>
> Coefficients k and θ_0 must be set for each type of angle in the simulation using the method *angle_coeff. set()*.
>
> Examples:
>
> ```
> harmonic = angle.harmonic()
> harmonic.angle_coeff.set('polymer', k=3.0, t0=0.7851)
> harmonic.angle_coeff.set('backbone', k=100.0, t0=1.0)
> ```
>
> **disable** (*log=False*)
>
> > Disable the force.
> >
> > > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.
> >
> > Examples:
> >
> > ```
> > force.disable()
> > force.disable(log=True)
> > ```
> >
> > Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.
> >
> > By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.
>
> **enable** ()
>
> > Enable the force.
> >
> > Examples:
> >
> > ```
> > force.enable()
> > ```
> >
> > See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

>> **Parameters group** (`hoomd.group`) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

>> **Parameters group** (`hoomd.group`) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

>> **Parameters group** (`hoomd.group`) – The particle group to query the virial for.

>> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.angle.**table**(*width*, *name=None*)
> Tabulated angle potential.

>> **Parameters**

>>> • **width** (`int`) – Number of points to use to interpolate V and F (see documentation above)

>>> • **name** (`str`) – Name of the force instance

`table` specifies that a tabulated angle potential should be added to every bonded triple of particles in the simulation.

The torque T is (in units of force * distance) and the potential $V(\theta)$ is (in energy units):

$$T(\theta) = T_{\mathrm{user}}(\theta)$$
$$V(\theta) = V_{\mathrm{user}}(\theta)$$

where θ is the angle from A-B to B-C in the triple.

$T_{\mathrm{user}}(\theta)$ and $V_{\mathrm{user}}(\theta)$ are evaluated on *width* grid points between 0 and π. Values are interpolated linearly between grid points. For correctness, you must specify: $T = -\frac{\partial V}{\partial \theta}$

Parameters:

• $T_{\mathrm{user}}(\theta)$ and $V_{\mathrm{user}}(\theta)$ - evaluated by *func* (see example)

• coefficients passed to *func* - *coeff* (see example)

The table *width* is set once when `table` is specified. There are two ways to specify the other parameters.

Set table from a given function

When you have a functional form for T and F, you can enter that directly into python. `table` will evaluate the given function over *width* points between 0 and π and use the resulting values in the table:

```python
def harmonic(theta, kappa, theta_0):
    V = 0.5 * kappa * (theta-theta_0)**2;
    T = -kappa*(theta-theta_0);
    return (V, T)

btable = angle.table(width=1000)
btable.angle_coeff.set('angle1', func=harmonic, coeff=dict(kappa=330, theta_0=0))
btable.angle_coeff.set('angle2', func=harmonic,coeff=dict(kappa=30, theta_0=0.1))
```

Set a table from a file

When you have no function for for *T* or *F*, or you otherwise have the data listed in a file, `table` can use the given values directly. You must first specify the number of rows in your tables when initializing `table`. Then use `set_from_file()` to read the file:

```python
btable = angle.table(width=1000)
btable.set_from_file('polymer', 'angle.dat')
```

disable(*log=False*)

> Disable the force.

>> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

```python
force.disable()
force.disable(log=True)
```

> Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

> Enable the force.

> Examples:

```python
force.enable()
```

> See `disable()`.

get_energy(*group*)

> Get the energy of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

set_from_file(*anglename*, *filename*)

Set a angle pair interaction from a file.

> **Parameters**
>
> - **anglename** (`str`) – Name of angle
> - **filename** (`str`) – Name of the file to read

The provided file specifies V and F at equally spaced theta values:

```
#t   V    T
0.0 2.0 -3.0
1.5707 3.0 -4.0
3.1414 2.0 -3.0
```

> **Warning:** The theta values are not used by the code. It is assumed that a table that has N rows will start at 0, end at π and that $\delta\theta = \pi/(N-1)$. The table is read directly into the grid points used to evaluate $T_{\mathrm{user}}(\theta)$ and $V_{\mathrm{user}}(\theta)$.

2.16.2 md.bond

Overview

`md.bond.fene`	FENE bond potential.
`md.bond.harmonic`	Harmonic bond potential.
`md.bond.table`	Tabulated bond potential.

Details

Bond potentials.

Bonds add forces between specified pairs of particles and are typically used to model chemical bonds between two particles.

By themselves, bonds that have been specified in an initial configuration do nothing. Only when you specify an bond force (i.e. bond.harmonic), are forces actually calculated between the listed particles.

class `hoomd.md.bond.`**`coeff`**
>   Define bond coefficients.
>
>   The coefficients for all bond potentials are specified using this class. Coefficients are specified per bond type.
>
>   There are two ways to set the coefficients for a particular bond potential. The first way is to save the bond potential in a variable and call `set()` directly. See below for an example of this.
>
>   The second method is to build the coeff class first and then assign it to the bond potential. There are some advantages to this method in that you could specify a complicated set of bond potential coefficients in a separate python file and import it into your job script.
>
>   Example:

```
my_coeffs = hoomd.md.bond.coeff();
my_bond_force.bond_coeff.set('polymer', k=330.0, r=0.84)
my_bond_force.bond_coeff.set('backbone', k=330.0, r=0.84)
```

>   **set** (*type*, ***coeffs*)
>   >   Sets parameters for bond types.
>   >
>   >   **Parameters**
>   >   >   • **type** (`str`) – Type of bond (or a list of type names)
>   >   >   • **coeffs** – Named coefficients (see below for examples)
>   >
>   >   Calling `set()` results in one or more parameters being set for a bond type. Types are identified by name, and parameters are also added by name. Which parameters you need to specify depends on the bond potential you are setting these coefficients for, see the corresponding documentation.
>   >
>   >   All possible bond types as defined in the simulation box must be specified before executing run(). You will receive an error if you fail to do so. It is not an error, however, to specify coefficients for bond types that do not exist in the simulation. This can be useful in defining a potential field for many different types of bonds even when some simulations only include a subset.
>   >
>   >   Examples:

```
my_bond_force.bond_coeff.set('polymer', k=330.0, r0=0.84)
my_bond_force.bond_coeff.set('backbone', k=1000.0, r0=1.0)
my_bond_force.bond_coeff.set(['bondA','bondB'], k=100, r0=0.0)
```

>   >   **Note:**   Single parameters can be updated. If both `k` and `r0` have already been set for a particle type, then executing `coeff.set('polymer', r0=1.0)` will update the value of `r0` and leave the other parameters as they were previously set.

class `hoomd.md.bond.`**`fene`** (*name=None*)
>   FENE bond potential.
>
>   **Parameters** **name** (`str`) – Name of the bond instance.

`fene` specifies a FENE potential energy between the two particles in each defined bond.

$$V(r) = -\frac{1}{2}kr_0^2 \ln\left(1 - \left(\frac{r - \Delta}{r_0}\right)^2\right) + V_{\mathrm{WCA}}(r)$$

where $\vec{r}$ is the vector pointing from one particle to the other in the bond, $\Delta = (d_i + d_j)/2 - 1$, d_i is the diameter of particle i, and

$$
\begin{aligned}
V_{\mathrm{WCA}}(r) = \quad & 4\varepsilon\left[\left(\frac{\sigma}{r-\Delta}\right)^{12} - \left(\frac{\sigma}{r-\Delta}\right)^{6}\right] + \varepsilon \quad && r - \Delta < 2^{\frac{1}{6}}\sigma \\
= \quad & 0 && r - \Delta \geq 2^{\frac{1}{6}}\sigma
\end{aligned}
$$

Coefficients:

- k - attractive force strength `k` (in units of energy/distance^2)

- r_0 - size parameter `r0` (in distance units)

- ε - repulsive force strength `epsilon` (in energy units)

- σ - repulsive force interaction distance `sigma` (in distance units)

Examples:

```
fene = bond.fene()
fene.bond_coeff.set('polymer', k=30.0, r0=1.5, sigma=1.0, epsilon= 2.0)
fene.bond_coeff.set('backbone', k=100.0, r0=1.0, sigma=1.0, epsilon= 2.0)
```

disable (*log=False*)

Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable ()

Enable the force.

Examples:

```
force.enable()
```

See `disable()`.

get_energy (*group*)

Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.bond.**harmonic**(*name=None*)
> Harmonic bond potential.

> > **Parameters name** (*str*) – Name of the bond instance.

> *harmonic* specifies a harmonic potential energy between the two particles in each defined bond.

$$V(r) = \frac{1}{2} k \left(r - r_0 \right)^2$$

where $\vec{r}$ is the vector pointing from one particle to the other in the bond.

Coefficients:

- k - force constant k (in units of energy/distance^2)

- r_0 - bond rest length r0 (in distance units)

Example:

```
harmonic = bond.harmonic(name="mybond")
harmonic.bond_coeff.set('polymer', k=330.0, r0=0.84)
```

disable(*log=False*)
> Disable the force.

> > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
  Enable the force.

  Examples:

```
force.enable()
```

  See `disable()`.

get_energy(*group*)
  Get the energy of a particle group.

  Parameters group (`hoomd.group`) – The particle group to query the energy for.

  Returns The last computed energy for the members in the group.

  Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
  Get the force of a particle group.

  Parameters group (`hoomd.group`) – The particle group to query the force for.

  Returns The last computed force for the members in the group.

  Examples

  g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
  Get the virial of a particle group.

  Parameters group (`hoomd.group`) – The particle group to query the virial for.

  Returns The last computed virial for the members in the group.

  Examples

  g = group.all() virial = force.get_net_virial(g)

class hoomd.md.bond.**table**(*width*, *name=None*)
  Tabulated bond potential.

  Parameters

  • **width** (*int*) – Number of points to use to interpolate V and F

  • **name** (*str*) – Name of the potential instance

`table` specifies that a tabulated bond potential should be applied between the two particles in each defined bond.

The force $\vec{F}$ is (in force units) and the potential $V(r)$ is (in energy units):

$$
\begin{aligned}
\vec{F}(\vec{r}) &= & 0 & \quad r < r_{\min} \\
&= & F_{\text{user}}(r)\hat{r} & \quad r < r_{\max} \\
&= & 0 & \quad r \geq r_{\max}
\end{aligned}
$$

$$
\begin{aligned}
V(r) &= & 0 & \quad r < r_{\min} \\
&= & V_{\text{user}}(r) & \quad r < r_{\max} \\
&= & 0 & \quad r \geq r_{\max}
\end{aligned}
$$

where $\vec{r}$ is the vector pointing from one particle to the other in the bond. Care should be taken to define the range of the bond so that it is not possible for the distance between two bonded particles to be outside the specified range. On the CPU, this will throw an error. On the GPU, this will throw an error if GPU error checking is enabled.

$F_{\text{user}}(r)$ and $V_{\text{user}}(r)$ are evaluated on *width* grid points between $r_{\min}$ and $r_{\max}$. Values are interpolated linearly between grid points. For correctness, you must specify the force defined by: $F = -\frac{\partial V}{\partial r}$

The following coefficients must be set for each bond type:

- $F_{\text{user}}(r)$ and $V_{\text{user}}(r)$ - evaluated by `func` (see example)
- coefficients passed to *func* - `coeff` (see example)
- $r_{\min}$ - `rmin` (in distance units)
- $r_{\max}$ - `rmax` (in distance units)

The table *width* is set once when bond.table is specified. There are two ways to specify the other parameters.

Set table from a given function

When you have a functional form for V and F, you can enter that directly into python. `table` will evaluate the given function over *width* points between *rmin* and *rmax* and use the resulting values in the table:

```python
def harmonic(r, rmin, rmax, kappa, r0):
    V = 0.5 * kappa * (r-r0)**2;
    F = -kappa*(r-r0);
    return (V, F)

btable = bond.table(width=1000)
btable.bond_coeff.set('bond1', func=harmonic, rmin=0.2, rmax=5.0,
→coeff=dict(kappa=330, r0=0.84))
btable.bond_coeff.set('bond2', func=harmonic, rmin=0.2, rmax=5.0,
→coeff=dict(kappa=30, r0=1.0))
```

Set a table from a file

When you have no function for for *V* or *F*, or you otherwise have the data listed in a file, `table` can use the given values directly. You must first specify the number of rows in your tables when initializing bond.table. Then use `set_from_file()` to read the file:

```
btable = bond.table(width=1000)
btable.set_from_file('polymer', 'btable.file')
```

Note: For potentials that diverge near r=0, make sure to set `rmin` to a reasonable value. If a potential does not diverge near r=0, then a setting of `rmin=0` is valid.

Note: Ensure that `rmin` and `rmax` cover the range of possible bond lengths. When gpu error checking is on, a error will be thrown if a bond distance is outside than this range.

disable(*log=False*)
    Disable the force.

> **Parameters log** ([*bool*](#)) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any [*hoomd.run()*](#) command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with [*enable()*](#).

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
    Enable the force.

Examples:

```
force.enable()
```

See [*disable()*](#).

get_energy(*group*)
    Get the energy of a particle group.

> **Parameters group** ([*hoomd.group*](#)) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
    Get the force of a particle group.

> **Parameters group** ([*hoomd.group*](#)) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
   Get the virial of a particle group.

   > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

   > **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

set_from_file(*bondname*, *filename*)
   Set a bond pair interaction from a file.

   > **Parameters**
   >
   > - **bondname** (*str*) – Name of bond
   >
   > - **filename** (*str*) – Name of the file to read

   The provided file specifies V and F at equally spaced r values. Example:

```
#r   V     F
1.0 2.0 -3.0
1.1 3.0 -4.0
1.2 2.0 -3.0
1.3 1.0 -2.0
1.4 0.0 -1.0
1.5 -1.0 0.0
```

   The first r value sets `rmin`, the last sets `rmax`. Any line with # as the first non-whitespace character is is treated as a comment. The `r` values must monotonically increase and be equally spaced. The table is read directly into the grid points used to evaluate $F_{user}(r)$ and $V_{user}(r)$.

2.16.3 md.charge

Overview

md.charge.pppm	Long-range electrostatics computed with the PPPM method.

Details

Electrostatic potentials.

Charged interactions are usually long ranged, and for computational efficiency this is split into two parts, one part computed in real space and on in Fourier space. You don't need to worry about this implementation detail, however, as charge commands in hoomd automatically initialize and configure both the long and short range parts.

Only one method of computing charged interactions should be used at a time. Otherwise, they would add together and produce incorrect results.

class hoomd.md.charge.**pppm**(*group*, *nlist*)

Long-range electrostatics computed with the PPPM method.

> **Parameters**
>
> - **group** (`hoomd.group`) – Group on which to apply long range PPPM forces. The short range part is always applied between all particles.
>
> - **nlist** (`hoomd.md.nlist`) – Neighbor list

D. LeBard et. al. 2012 describes the PPPM implementation details in HOOMD-blue. Please cite it if you utilize the PPPM functionality in your work.

`pppm` specifies **both** the long-ranged **and** short range parts of the electrostatic force should be computed between all charged particles in the simulation. In other words, `pppm` initializes and sets all parameters for its own `hoomd.md.pair.ewald`, so do not specify an additional one.

The command supports additional screening of interactions, according to the Ewald summation for Yukawa potentials. This is useful if one wants to compute a screened interaction (i.e. a solution to the linearized Poisson-Boltzmann equation), yet the cut-off radius is so large that the computation with a purely short-ranged potential would become inefficient. In that case, the inverse Debye screening length can be supplied using `set_params()`. Also see *Salin, G and Caillol, J. 2000, <http://dx.doi.org/10.1063/1.1326477>*.

Parameters:

- Nx - Number of grid points in x direction

- Ny - Number of grid points in y direction

- Nz - Number of grid points in z direction

- order - Number of grid points in each direction to assign charges to

- r_{cut} - Cutoff for the short-ranged part of the electrostatics calculation

Parameters Nx, Ny, Nz, order, r_{cut} must be set using `set_params()` before any `hoomd.run()` can take place.

See *Units* for information on the units assigned to charges in hoomd.

Note: `pppm` takes a particle group as an option. This should be the group of all charged particles (`hoomd.group.charged()`). However, note that this group is static and determined at the time `pppm` is specified. If you are going to add charged particles at a later point in the simulation with the data access API, ensure that this group includes those particles as well.

Important: In MPI simulations, the number of grid point along every dimensions must be a power of two.

Example:

```
charged = group.charged();
pppm = charge.pppm(group=charged)
```

disable (*log=False*)

Disable the force.

> **Parameters** **log** (`bool`) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
>   Enable the force.

>   Examples:

```
force.enable()
```

>   See *disable()*.

get_energy(*group*)
>   Get the energy of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

>   Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
>   Get the force of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

Examples

>   g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
>   Get the virial of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

>> **Returns** The last computed virial for the members in the group.

Examples

>   g = group.all() virial = force.get_net_virial(g)

set_params(*Nx*, *Ny*, *Nz*, *order*, *rcut*, *alpha=0.0*)
>   Sets PPPM parameters.

>> **Parameters**

- **Nx** (*int*) – Number of grid points in x direction

- **Ny** (*int*) – Number of grid points in y direction

- **Nz** (*int*) – Number of grid points in z direction

- **order** (*int*) – Number of grid points in each direction to assign charges to

- **rcut** (*float*) – Cutoff for the short-ranged part of the electrostatics calculation

- **alpha** (float, **optional**) – Debye screening parameter (in units 1/distance) .. version-added:: 2.1

Examples:

```
pppm.set_params(Nx=64, Ny=64, Nz=64, order=6, rcut=2.0)
```

Note that the Fourier transforms are much faster for number of grid points of the form 2^N.

2.16.4 md.constrain

Overview

md.constrain.distance	Constrain pairwise particle distances.
md.constrain.rigid	Constrain particles in rigid bodies.
md.constrain.sphere	Constrain particles to the surface of a sphere.
md.constrain.oneD	Constrain particles to move along a specific direction only

Details

Constraints.

Constraint forces constrain a given set of particle to a given surface, to have some relative orientation, or impose some other type of constraint. For example, a group of particles can be constrained to the surface of a sphere with *sphere*.

As with other force commands in hoomd, multiple constrain commands can be issued to specify multiple constraints, which are additively applied.

> **Warning:** Constraints will be invalidated if two separate constraint commands apply to the same particle.

The degrees of freedom removed from the system by constraints are correctly taken into account when computing the temperature for thermostatting and logging.

class hoomd.md.constrain.**distance**

Constrain pairwise particle distances.

distance specifies that forces will be applied to all particles pairs for which constraints have been defined.

The constraint algorithm implemented is described in:

- [1] M. Yoneya, H. J. C. Berendsen, and K. Hirasawa, "A Non-Iterative Matrix Method for Constraint Molecular Dynamics Simulations," Mol. Simul., vol. 13, no. 6, pp. 395–405, 1994.

- [2] M. Yoneya, "A Generalized Non-iterative Matrix Method for Constraint Molecular Dynamics Simulations," J. Comput. Phys., vol. 172, no. 1, pp. 188–197, Sep. 2001.

In brief, the second derivative of the Lagrange multipliers with respect to time is set to zero, such that both the distance constraints and their time derivatives are conserved within the accuracy of the Velocity Verlet scheme, i.e. within Δt^2. The corresponding linear system of equations is solved. Because constraints are satisfied at $t + 2\Delta t$, the scheme is self-correcting and drifts are avoided.

> **Warning:** In MPI simulations, all particles connected through constraints will be communicated between processors as ghost particles. Therefore, it is an error when molecules defined by constraints extend over more than half the local domain size.

> **Caution:** constrain.distance() does not currently interoperate with integrate.brownian() or integrate.langevin()

Example:

```
constrain.distance()
```

disable()
>   Disable the force.
>
>   Example:

```
force.disable()
```

>   Executing the disable command removes the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`

enable()
>   Enable the force.
>
>   Example:

```
force.enable()
```

>   See `disable()`.

set_params(*rel_tol=None*)
>   Set parameters for constraint computation.
>
> > **Parameters rel_tol** (*float*) – The relative tolerance with which constraint violations are detected (**optional**).
>
>   Example:

```
dist = constrain.distance()
dist.set_params(rel_tol=0.0001)
```

class hoomd.md.constrain.**oneD**(*group, constraint_vector=[0, 0, 1]*)
>   Constrain particles to move along a specific direction only
>
> > **Parameters**
> >
> > - **group** (*hoomd.group*) – Group on which to apply the constraint.
> > - **constraint_vector** (*list*) – [x,y,z] list indicating the direction that the particles are restricted to

oneD specifies that forces will be applied to all particles in the given group to constrain them to only move along a given vector.

Example:

```
constrain.oneD(group=groupA, constraint_vector=[1,0,0])
```

New in version 2.1.

disable()
    Disable the force.

    Example:

    ```
    force.disable()
    ```

    Executing the disable command removes the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*

enable()
    Enable the force.

    Example:

    ```
    force.enable()
    ```

    See *disable()*.

class hoomd.md.constrain.**rigid**
    Constrain particles in rigid bodies.

Overview

Rigid bodies are defined by a single central particle and a number of constituent particles. All of these are particles in the HOOMD system configuration and can interact with other particles via force computes. The mass and moment of inertia of the central particle set the full mass and moment of inertia of the rigid body (constituent particle mass is ignored).

The central particle is at the center of mass of the rigid body and the orientation quaternion defines the rotation from the body space into the simulation box. In body space, the center of mass of the body is at 0,0,0 and the moment of inertia is diagonal. You specify the constituent particles to *rigid* for each type of body in body coordinates. Then, *rigid* takes control of those particles, and sets their position and orientation in the simulation box relative to the position and orientation of the central particle. *rigid* also transfers forces and torques from constituent particles to the central particle. Then, MD integrators can use these forces and torques to integrate the equations of motion of the central particles (representing the whole rigid body) forward in time.

Defining bodies

rigid accepts one local body environment per body type. The type of a body is the particle type of the central particle in that body. In this way, each particle of type *R* in the system configuration defines a body of type *R*.

As a convenience, you do not need to create placeholder entries for all of the constituent particles in your initial configuration. You only need to specify the positions and orientations of all the central particles. When you call *create_bodies()*, it will create all constituent particles that do not exist. (those that already exist e.g. in a restart file are left unchanged).

Example that creates rigid rods:

```
# Place the type R central particles
uc = hoomd.lattice.unitcell(N = 1,
                            a1 = [10.8, 0,    0],
                            a2 = [0,     1.2, 0],
                            a3 = [0,      0,   1.2],
                            dimensions = 3,
                            position = [[0,0,0]],
                            type_name = ['R'],
                            mass = [1.0],
                            moment_inertia = [[0,
                                               1/12*1.0*8**2,
                                               1/12*1.0*8**2]],
                            orientation = [[1, 0, 0, 0]]);
system = hoomd.init.create_lattice(unitcell=uc, n=[2,18,18]);

# Add constituent particles of type A and create the rods
system.particles.types.add('A');
rigid = hoomd.md.constrain.rigid();
rigid.set_param('R',
                types=['A']*8,
                positions=[(-4,0,0),(-3,0,0),(-2,0,0),(-1,0,0),
                           (1,0,0),(2,0,0),(3,0,0),(4,0,0)]);

rigid.create_bodies()
```

> **Danger:** Automatic creation of constituent particles can change particle tags. If bonds have been defined between particles in the initial configuration, or bonds connect to constituent particles, rigid bodies should be created manually.

When you create the constituent particles manually (i.e. in an input file or with snapshots), the central particle of a rigid body must have a lower tag than all of its constituent particles. Constituent particles follow in monotonically increasing tag order, corresponding to the order they were defined in the argument to `set_param()`. The order of central and contiguous particles need **not** to be contiguous. Additionally, you must set the `body` field for each of the particles in the rigid body to the tag of the central particle (for both the central and constituent particles). Set `body` to -1 for particles that do not belong to a rigid body. After setting an initial configuration that contains properly defined bodies and all their constituent particles, call `validate_bodies()` to verify that the bodies are defined and prepare the constraint.

You must call either `create_bodies()` or `validate_bodies()` prior to starting a simulation `hoomd.run()`.

Integrating bodies

Most integrators in HOOMD support the integration of rotational degrees of freedom. When there are rigid bodies present in the system, do not apply integrators to the constituent particles, only the central and non-rigid particles.

Example:

```
rigid = hoomd.group.rigid_center();
hoomd.md.integrate.langevin(group=rigid, kT=1.0, seed=42);
```

Thermodynamic quantities of bodies

HOOMD computes thermodynamic quantities (temperature, kinetic energy, etc. . .) appropriately when there are rigid bodies present in the system. When it does so, it ignores all constituent particles and computes the translational and rotational energies of the central particles, which represent the whole body. *hoomd.analyze.log* can log the translational and rotational energy terms separately.

Restarting simulations with rigid bodies.

To restart, use *hoomd.dump.gsd* to write restart files. GSD stores all of the particle data fields needed to reconstruct the state of the system, including the body tag, rotational momentum, and orientation of the body. Restarting from a gsd file is equivalent to manual constituent particle creation. You still need to specify the same local body space environment to *rigid* as you did in the earlier simulation.

create_bodies(*create=True*)
    Create copies of rigid bodies.

        Parameters create (*bool*) – When True, create rigid bodies, otherwise validate existing ones.

disable()
    Disable the force.

    Example:

```
force.disable()
```

    Executing the disable command removes the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*

enable()
    Enable the force.

    Example:

```
force.enable()
```

    See *disable()*.

set_param(*type_name*, *types*, *positions*, *orientations=None*, *charges=None*, *diameters=None*)
    Set constituent particle types and coordinates for a rigid body.

        Parameters

- **type_name** (*str*) – The type of the central particle
- **types** (*list*) – List of types of constituent particles
- **positions** (*list*) – List of relative positions of constituent particles
- **orientations** (*list*) – List of orientations of constituent particles (**optional**)
- **charge** (*list*) – List of charges of constituent particles (**optional**)
- **diameters** (*list*) – List of diameters of constituent particles (**optional**)

> **Caution:** The constituent particle type must be exist. If it does not exist, it can be created on the fly using `system.particles.types.add('A_const')` (see *hoomd.data*).

Example:

```
rigid = constrain.rigid()
rigid.set_param('A', types = ['A_const', 'A_const'], positions = [(0,0,1),(0,
↪0,-1)])
rigid.set_param('B', types = ['B_const', 'B_const'], positions = [(0,0,.5),(0,
↪0,-.5)])
```

validate_bodies()

Validate that bodies are well defined and prepare for the simulation run.

class hoomd.md.constrain.**sphere**(*group*, *P*, *r*)

Constrain particles to the surface of a sphere.

Parameters

- **group** (*hoomd.group*) – Group on which to apply the constraint.

- **P** (*tuple*) – (x,y,z) tuple indicating the position of the center of the sphere (in distance units).

- **r** (*float*) – Radius of the sphere (in distance units).

sphere specifies that forces will be applied to all particles in the given group to constrain them to a sphere. Currently does not work with Brownian or Langevin dynamics (*hoomd.md.integrate.brownian* and *hoomd.md.integrate.langevin*).

Example:

```
constrain.sphere(group=groupA, P=(0,10,2), r=10)
```

disable()

Disable the force.

Example:

```
force.disable()
```

Executing the disable command removes the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*

enable()

Enable the force.

Example:

```
force.enable()
```

See *disable()*.

2.16.5 md.dihedral

Overview

md.dihedral.harmonic	Harmonic dihedral potential.
md.dihedral.opls	OPLS dihedral force
md.dihedral.table	Tabulated dihedral potential.

Details

Dihedral potentials.

Dihedrals add forces between specified quadruplets of particles and are typically used to model rotation about chemical bonds.

By themselves, dihedrals that have been specified in an input file do nothing. Only when you specify an dihedral force (i.e. dihedral.harmonic), are forces actually calculated between the listed particles.

Important: There are multiple conventions pertaining to the dihedral angle (phi) in the literature. HOOMD utilizes the convention shown in the following figure, where vectors are defined from the central particles to the outer particles. These vectors correspond to a stretched state (phi=180 deg) when they are anti-parallel and a compact state (phi=0 deg) when they are parallel.
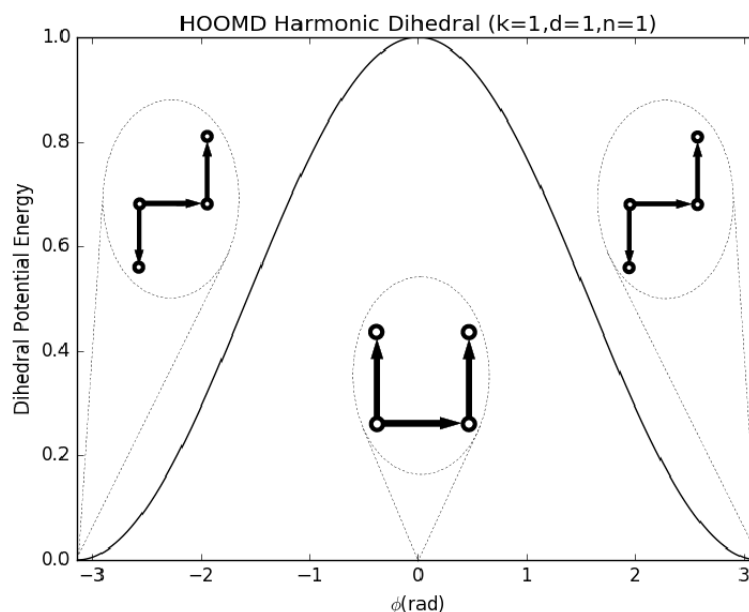
class `hoomd.md.dihedral.`**`coeff`**
    Defines dihedral coefficients.

    The coefficients for all dihedral force are specified using this class. Coefficients are specified per dihedral type.

    There are two ways to set the coefficients for a particular dihedral force. The first way is to save the dihedral force in a variable and call `set()` directly. See below for an example of this.

    The second method is to build the `coeff` class first and then assign it to the dihedral force. There are some advantages to this method in that you could specify a complicated set of dihedral force coefficients in a separate python file and import it into your job script.

    Examples:

```
my_coeffs = dihedral.coeff();
my_dihedral_force.dihedral_coeff.set('polymer', k=330.0, r=0.84)
my_dihedral_force.dihedral_coeff.set('backbone', k=330.0, r=0.84)
```

    set (*type*, ***coeffs*)
        Sets parameters for dihedral types.

        Parameters

            • **type** (*str*) – Type of dihedral, or list of types

- **coeffs** – Named coefficients (see below for examples)

Calling *set()* results in one or more parameters being set for a dihedral type. Types are identified by name, and parameters are also added by name. Which parameters you need to specify depends on the dihedral force you are setting these coefficients for, see the corresponding documentation.

All possible dihedral types as defined in the simulation box must be specified before executing run(). You will receive an error if you fail to do so. It is not an error, however, to specify coefficients for dihedral types that do not exist in the simulation. This can be useful in defining a force field for many different types of dihedrals even when some simulations only include a subset.

To set the same coefficients between many particle types, provide a list of type names instead of a single one. All types in the list will be set to the same parameters.

Examples:

```
my_dihedral_force.dihedral_coeff.set('polymer', k=330.0, r0=0.84)
my_dihedral_force.dihedral_coeff.set('backbone', k=1000.0, r0=1.0)
my_dihedral_force.dihedral_coeff.set(['dihedralA','dihedralB'], k=100, r0=0.0)
```

Note: Single parameters can be updated. If both k and r0 have already been set for a particle type, then executing coeff.set('polymer', r0=1.0) will update the value of r0 and leave the other parameters as they were previously set.

class hoomd.md.dihedral.**harmonic**

Harmonic dihedral potential.

harmonic specifies a harmonic dihedral potential energy between every defined dihedral quadruplet of particles in the simulation:

$$V(r) = \frac{1}{2}k\left(1 + d\cos\left(n * \phi(r) - \phi_0\right)\right)$$

where ϕ is angle between two sides of the dihedral.

Coefficients:

- k - strength of force (in energy units)
- d - sign factor (unitless)
- n - angle scaling factor (unitless)
- ϕ_0 - phase shift phi_0 (in radians) - *optional*: defaults to 0.0

Coefficients k, d, n must be set for each type of dihedral in the simulation using *dihedral_coeff.set()*.

Examples:

```
harmonic.dihedral_coeff.set('phi-ang', k=30.0, d=-1, n=3)
harmonic.dihedral_coeff.set('psi-ang', k=100.0, d=1, n=4, phi_0=math.pi/2)
```

disable(*log=False*)

Disable the force.

    Parameters log (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

>> **Parameters** **group** (*hoomd.group*) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

>> **Parameters** **group** (*hoomd.group*) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

>> **Parameters** **group** (*hoomd.group*) – The particle group to query the virial for.

>> **Returns** The last computed virial for the members in the group.

> ### Examples

> g = group.all() virial = force.get_net_virial(g)

class hoomd.md.dihedral.**opls**
> OPLS dihedral force

`opls` specifies an OPLS-style dihedral potential energy between every defined dihedral.

$$V(r) = \frac{1}{2}k_1\left(1 + \cos\left(\phi\right)\right) + \frac{1}{2}k_2\left(1 - \cos\left(2\phi\right)\right) + \frac{1}{2}k_3\left(1 + \cos\left(3\phi\right)\right) + \frac{1}{2}k_4\left(1 - \cos\left(4\phi\right)\right)$$

where ϕ is the angle between two sides of the dihedral and k_n are the force coefficients in the Fourier series (in energy units).

k_1, k_2, k_3, and k_4 must be set for each type of dihedral in the simulation using `dihedral_coeff.set()`.

Example:

```
opls_di.dihedral_coeff.set('dihedral1', k1=30.0, k2=15.5, k3=2.2, k4=23.8)
```

disable (*log=False*)

Disable the force.

> **Parameters log** (`bool`) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable ()

Enable the force.

Examples:

```
force.enable()
```

See `disable()`.

get_energy (*group*)

Get the energy of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force (*group*)

Get the force of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.dihedral.**table**(*width*, *name=None*)
> Tabulated dihedral potential.

> > **Parameters**

> > > • **width** (*int*) – Number of points to use to interpolate V and T (see documentation above)

> > > • **name** (*str*) – Name of the force instance

> `table` specifies that a tabulated dihedral force should be applied to every define dihedral.

> $T_{\text{user}}(\theta)$ and $V_{\text{user}}(\theta)$ are evaluated on *width* grid points between $-\pi$ and π. Values are interpolated linearly between grid points. For correctness, you must specify the derivative of the potential with respect to the dihedral angle, defined by: $T = -\frac{\partial V}{\partial \theta}$.

> Parameters:

> > • $T_{\text{user}}(\theta)$ and $V_{\text{user}}(\theta)$ - evaluated by func (see example)

> > • coefficients passed to *func - coeff* (see example)

Set table from a given function

When you have a functional form for V and T, you can enter that directly into python. `table` will evaluate the given function over *width* points between $-\pi$ and π and use the resulting values in the table:

```
def harmonic(theta, kappa, theta0):
    V = 0.5 * kappa * (theta-theta0)**2;
    F = -kappa*(theta-theta0);
    return (V, F)

dtable = dihedral.table(width=1000)
dtable.dihedral_coeff.set('dihedral1', func=harmonic, coeff=dict(kappa=330, theta_
↪0=0.0))
dtable.dihedral_coeff.set('dihedral2', func=harmonic,coeff=dict(kappa=30, theta_
↪0=1.0))
```

Set a table from a file

When you have no function for for *V* or *T*, or you otherwise have the data listed in a file, dihedral.table can use the given values directly. You must first specify the number of rows in your tables when initializing `table`. Then use `set_from_file()` to read the file.

> dtable = dihedral.table(width=1000) dtable.set_from_file('polymer', 'dihedral.dat')

---

disable(*log=False*)
> Disable the force.

>> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

> Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

>> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

set_from_file(*dihedralname*, *filename*)

Set a dihedral pair interaction from a file.

> **Parameters**
>
> - **dihedralname** (`str`) – Name of dihedral
>
> - **filename** (`str`) – Name of the file to read

The provided file specifies V and F at equally spaced theta values.

Example:

```
#t   V    T
-3.141592653589793 2.0 -3.0
-1.5707963267948966 3.0 -4.0
0.0 2.0 -3.0
1.5707963267948966 3.0 -4.0
3.141592653589793 2.0 -3.0
```

Note: The theta values are not used by the code. It is assumed that a table that has N rows will start at $-\pi$, end at π and that $\delta\theta = 2\pi/(N-1)$. The table is read directly into the grid points used to evaluate $T_{\text{user}}(\theta)$ and $V_{\text{user}}(\theta)$.

2.16.6 md.external

Overview

`md.external.periodic`	One-dimension periodic potential.
`md.external.e_field`	Electric field.

Details

External forces.

Apply an external force to all particles in the simulation. This module organizes all external forces. As an example, a force derived from a `periodic` potential can be used to induce a concentration modulation in the system.

class hoomd.md.external.**coeff**

Defines external potential coefficients.

The coefficients for all external forces are specified using this class. Coefficients are specified per particle type.

Example:

```
my_external_force.force_coeff.set('A', A=1.0, i=1, w=0.02, p=3)
my_external_force.force_coeff.set('B', A=-1.0, i=1, w=0.02, p=3)
```

set(*type*, ***coeffs*)

Sets parameters for particle types.

> **Parameters**

- **type** (*str*) – Type of particle (or list of types)
- **coeff** – Named coefficients (see below for examples)

Calling `set()` results in one or more parameters being set for a particle type. Types are identified by name, and parameters are also added by name. Which parameters you need to specify depends on the external force you are setting these coefficients for, see the corresponding documentation.

All possible particle types as defined in the simulation box must be specified before executing run(). You will receive an error if you fail to do so. It is not an error, however, to specify coefficients for particle types that do not exist in the simulation. This can be useful in defining a force field for many different types of particles even when some simulations only include a subset.

To set the same coefficients between many particle types, provide a list of type names instead of a single one. All types in the list will be set to the same parameters. A convenient wildcard that lists all types of particles in the simulation can be gotten from a saved system from the init command.

Examples:

```
coeff.set('A', A=1.0, i=1, w=0.02, p=3)
coeff.set('B', A=-1.0, i=1, w=0.02, p=3)
coeff.set(['A','B'], i=1, w=0.02, p=3)
```

Note: Single parameters can be updated. For example, executing `coeff.set('A', A=1.0)` will update the value of A and leave the other parameters as they were previously set.

class hoomd.md.external.**e_field**(*field*, *name=''*)
Electric field.

`e_field` specifies that an external force should be added to every particle in the simulation that results from an electric field.

The external potential $V(\vec{r})$ is implemented using the following formula:

$$V(\vec{r}) = -q_i \vec{E} \cdot \vec{r}$$

where q_i is the particle charge and $\vec{E}$ is the field vector

Example:

```
# Apply an electric field in the x-direction
e_field = external.e_field((1,0,0))
```

disable(*log=False*)
Disable the force.

Parameters log (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used

throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)
Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.external.**periodic**(*name=''*)
One-dimension periodic potential.

periodic specifies that an external force should be added to every particle in the simulation to induce a periodic modulation in the particle concentration. The force parameters can be set on a per particle type basis. The potential can e.g. be used to induce an ordered phase in a block-copolymer melt.

The external potential $V(\vec{r})$ is implemented using the following formula:

$$V(\vec{r}) = A * \tanh\left[\frac{1}{2\pi pw}\cos\left(p\vec{b}_i \cdot \vec{r}\right)\right]$$

where A is the ordering parameter, $\vec{b}_i$ is the reciprocal lattice vector direction $i = 0..2$, p the periodicity and w the interface width (relative to the distance $2\pi/|\mathbf{b_i}|$ between planes in the i-direction). The modulation is one-dimensional. It extends along the lattice vector $\mathbf{a}_i$ of the simulation cell.

Examples:

```
# Apply a periodic composition modulation along the first lattice vector
periodic = external.periodic()
periodic.force_coeff.set('A', A=1.0, i=0, w=0.02, p=3)
periodic.force_coeff.set('B', A=-1.0, i=0, w=0.02, p=3)
```

disable(*log=False*)

Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

Enable the force.

Examples:

```
force.enable()
```

See `disable()`.

get_energy(*group*)

Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.
>
> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

2.16.7 md.force

Overview

md.force.active	Active force.
md.force.constant	Constant force.
md.force.dipole	Treat particles as dipoles in an electric field.

Details

Apply forces to particles.

class hoomd.md.force.**active**(*seed, group, f_lst=None, t_lst=None, orientation_link=True, orientation_reverse_link=False, rotation_diff=0, constraint=None*)

> Active force.
>
> **Parameters**
>
> - **seed** (*int*) – required user-specified seed number for random number generator.
>
> - **f_list** (*list*) – An array of (x,y,z) tuples for the active force vector for each individual particle.
>
> - **t_list** (*list*) – An array of (x,y,z) tuples that indicate active torque vectors for each particle
>
> - **group** (*hoomd.group*) – Group for which the force will be set
>
> - **orientation_link** (*bool*) – if True then forces and torques are applied in the particle's reference frame. If false, then the box reference frame is used. Only relevant for non-point-like anisotropic particles.
>
> - **orientation_reverse_link** (*bool*) – When True, the particle's orientation is set to match the active force vector. Useful for for using a particle's orientation to log the active force vector. Not recommended for anisotropic particles. Quaternion rotation assumes base vector of (0,0,1).
>
> - **rotation_diff** (*float*) – rotational diffusion constant, D_r, for all particles in the group.
>
> - **constraint** (*hoomd.md.update.constraint_ellipsoid*) – such as update.constraint_ellipsoid.

active specifies that an active force should be added to all particles. Obeys $\delta \mathbf{r}_i = \delta t v_0 \hat{p}_i$, where v_0 is the active velocity. In 2D $\hat{p}_i = (\cos\theta_i, \sin\theta_i)$ is the active force vector for particle i; and the diffusion of the active force vector follows $\delta\theta/\delta t = \sqrt{2D_r/\delta t}\Gamma$, where D_r is the rotational diffusion constant, and the gamma function is a unit-variance random variable, whose components are uncorrelated in time, space, and between particles. In 3D, $\hat{p}_i$ is a unit vector in 3D space, and diffusion follows $\delta\hat{p}_i/\delta t = \sqrt{2D_r/\delta t}\Gamma(\hat{p}_i(\cos\theta - 1) + \hat{p}_r\sin\theta)$, where $\hat{p}_r$ is an uncorrelated random unit vector. The persistence length of an active particle's path is v_0/D_r.

> **Attention:** *active()* does not support MPI execution.

Examples:

```
force.active( seed=13, f_list=[tuple(3,0,0) for i in range(N)])

ellipsoid = update.constraint_ellipsoid(group=groupA, P=(0,0,0), rx=3, ry=4, rz=5)
force.active( seed=7, f_list=[tuple(1,2,3) for i in range(N)], orientation_
→link=False, rotation_diff=100, constraint=ellipsoid)
```

disable(*log=False*)
> Disable the force.

> > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

> ```
> force.disable()
> force.disable(log=True)
> ```

> Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

> ```
> force.enable()
> ```

> See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

> ```
> g = group.all()
> energy = force.get_energy(g)
> ```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial (*group*)

Get the virial of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the virial for.
>
> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.force.**constant** (*fx=None, fy=None, fz=None, fvec=None, tvec=None, group=None, callback=None*)

Constant force.

> **Parameters**
>
> - **fvec** (`tuple`) – force vector (in force units)
> - **tvec** (`tuple`) – torque vector (in torque units)
> - **fx** (`float`) – x component of force, retained for backwards compatibility
> - **fy** (`float`) – y component of force, retained for backwards compatibility
> - **fz** (`float`) – z component of force, retained for backwards compatibility
> - **group** (`hoomd.group`) – Group for which the force will be set.
> - **callback** (*callable*) – A python callback invoked every time the forces are computed

[*constant*](#) specifies that a constant force should be added to every particle in the simulation or optionally to all particles in a group.

Note: Forces are kept constant during the simulation. If a callback should re-compute particle forces every time step, it needs to overwrite the old forces of **all** particles with new values.

Note: Per-particle forces take precedence over a particle group, which takes precedence over constant forces for all particles.

Examples:

```
force.constant(fx=1.0, fy=0.5, fz=0.25)
const = force.constant(fvec=(0.4,1.0,0.5))
const = force.constant(fvec=(0.4,1.0,0.5),group=fluid)
const = force.constant(fvec=(0.4,1.0,0.5), tvec=(0,0,1) ,group=fluid)

def update_forces(timestep):
    global const
    const.set_force(tag=1, fvec=(1.0*timestep,2.0*timestep,3.0*timestep))
const = force.constant(callback=update_forces)
```

disable (*log=False*)

Disable the force.

> **Parameters log** (`bool`) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
Enable the force.

Examples:

```
force.enable()
```

See `disable()`.

get_energy(*group*)
Get the energy of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
Get the force of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
Get the virial of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.force.**dipole**(*field_x*, *field_y*, *field_z*, *p*)
  Treat particles as dipoles in an electric field.

  Parameters

  - **field_x** (*float*) – x-component of the field (units?)

  - **field_y** (*float*) – y-component of the field (units?)

  - **field_z** (*float*) – z-component of the field (units?)

  - **p** (*float*) – magnitude of the particles' dipole moment in the local z direction

  Examples:

  ```
  force.external_field_dipole(field_x=0.0, field_y=1.0 ,field_z=0.5, p=1.0)
  const_ext_f_dipole = force.external_field_dipole(field_x=0.0, field_y=1.0 ,field_
  ↪z=0.5, p=1.0)
  ```

  disable(*log=False*)
    Disable the force.

    Parameters log (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

    Examples:

    ```
    force.disable()
    force.disable(log=True)
    ```

    Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

    By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

  enable()
    Enable the force.

    Examples:

    ```
    force.enable()
    ```

    See *disable()*.

  get_energy(*group*)
    Get the energy of a particle group.

    Parameters group (*hoomd.group*) – The particle group to query the energy for.

    Returns The last computed energy for the members in the group.

    Examples:

    ```
    g = group.all()
    energy = force.get_energy(g)
    ```

  get_net_force(*group*)
    Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.
>
> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.
>
> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

set_params(*field_y*, *field_z*, *p*)
Change the constant field and dipole moment.

> **Parameters**
>
> - **field_x** (*float*) – x-component of the field (units?)
> - **field_y** (*float*) – y-component of the field (units?)
> - **field_z** (*float*) – z-component of the field (units?)
> - **p** (*float*) – magnitude of the particles' dipole moment in the local z direction

Examples:

```
const_ext_f_dipole = force.external_field_dipole(field_x=0.0, field_y=1.0 ,
↪field_z=0.5, p=1.0)
const_ext_f_dipole.setParams(field_x=0.1, field_y=0.1, field_z=0.0, p=1.0))
```

2.16.8 md.improper

Overview

md.improper.harmonic	Harmonic improper potential.

Details

Improper potentials.

Impropers add forces between specified quadruplets of particles and are typically used to model rotation about chemical bonds without having bonds to connect the atoms. Their most common use is to keep structural elements flat, i.e. model the effect of conjugated double bonds, like in benzene rings and its derivatives.

By themselves, impropers that have been specified in an input file do nothing. Only when you specify an improper force (i.e. improper.harmonic), are forces actually calculated between the listed particles.

class hoomd.md.improper.**coeff**
Define improper coefficients.

The coefficients for all improper force are specified using this class. Coefficients are specified per improper type.

Examples:

```
my_coeffs = improper.coeff();
my_improper_force.improper_coeff.set('polymer', k=330.0, r=0.84)
my_improper_force.improper_coeff.set('backbone', k=330.0, r=0.84)
```

set (*type*, ***coeffs*)
    Sets parameters for one improper type.

    Parameters

    • **type** (*str*) – Type of improper (or list of types).

    • **coeffs** – Named coefficients (see below for examples)

Calling *set()* results in one or more parameters being set for a improper type. Types are identified by name, and parameters are also added by name. Which parameters you need to specify depends on the improper force you are setting these coefficients for, see the corresponding documentation.

All possible improper types as defined in the simulation box must be specified before executing *hoomd.run()*. You will receive an error if you fail to do so. It is not an error, however, to specify coefficients for improper types that do not exist in the simulation. This can be useful in defining a force field for many different types of impropers even when some simulations only include a subset.

To set the same coefficients between many particle types, provide a list of type names instead of a single one. All types in the list will be set to the same parameters.

Examples:

```
my_improper_force.improper_coeff.set('polymer', k=330.0, r0=0.84)
my_improper_force.improper_coeff.set('backbone', k=1000.0, r0=1.0)
my_improper_force.improper_coeff.set(['improperA','improperB'], k=100, r0=0.0)
```

Note: Single parameters can be updated. If both `k` and `r0` have already been set for a particle type, then executing `coeff.set('polymer', r0=1.0)` will update the value of `r0` and leave the other parameters as they were previously set.

---

class hoomd.md.improper.**harmonic**
    Harmonic improper potential.

The command improper.harmonic specifies a harmonic improper potential energy between every quadruplet of particles in the simulation.

$$V(r) = \frac{1}{2}k\left(\chi - \chi_0\right)^2$$

where χ is angle between two sides of the improper.

Coefficients:

• k - strength of force, `k` (in energy units)

• χ_0 - equilibrium angle, `chi` (in radians)

Coefficients k and χ_0 must be set for each type of improper in the simulation using *improper_coeff.set()*.

Examples:

```
harmonic.improper_coeff.set('heme-ang', k=30.0, chi=1.57)
harmonic.improper_coeff.set('hydro-bond', k=20.0, chi=1.57)
```

disable(*log=False*)
    Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
    Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)
    Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
    Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
    Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

2.16.9 md.integrate

Overview

md.integrate.berendsen	Applies the Berendsen thermostat.
md.integrate.brownian	Brownian dynamics.
md.integrate.langevin	Langevin dynamics.
md.integrate.mode_standard	Enables a variety of standard integration methods.
md.integrate.mode_minimize_fire	Energy Minimizer (FIRE).
md.integrate.npt	NPT Integration via MTK barostat-thermostat.
md.integrate.nph	NPH Integration via MTK barostat-thermostat..
md.integrate.nve	NVE Integration via Velocity-Verlet
md.integrate.nvt	NVT Integration via the Nosé-Hoover thermostat.

Details

Integration methods.

To integrate the system forward in time, an integration mode must be set. Only one integration mode can be active at a time, and the last `integrate.mode_*` command before the *hoomd.run()* command is the one that will take effect. It is possible to set one mode, run for a certain number of steps and then switch to another mode before the next run command.

The most commonly used mode is :py:class'mode_standard'. It specifies a standard mode where, at each time step, all of the specified forces are evaluated and used in moving the system forward to the next step. :py:class'mode_standard' doesn't integrate any particles by itself, one or more compatible integration methods must be specified before the staring a *hoomd.run()*. Like commands that specify forces, integration methods are **persistent** and remain set until they are disabled.

To clarify, the following series of commands will run for 1000 time steps in the NVT ensemble and then switch to NVE for another 1000 steps:

```
all = group.all()
integrate.mode_standard(dt=0.005)
nvt = integrate.nvt(group=all, kT=1.2, tau=0.5)
run(1000)
nvt.disable()
integrate.nve(group=all)
run(1000)
```

You can change integrator parameters between runs:

```
integrator = integrate.nvt(group=all, kT=1.2, tau=0.5)
run(100)
integrator.set_params(kT=1.0)
run(100)
```

This code snippet runs the first 100 time steps with kT=1.2 and the next 100 with kT=1.0.

class hoomd.md.integrate.**berendsen**(*group*, *kT*, *tau*)
    Applies the Berendsen thermostat.

Parameters

- **group** (`hoomd.group`) – Group to which the Berendsen thermostat will be applied.

- **kT** (`hoomd.variant` or `float`) – Temperature of thermostat. (in energy units).

- **tau** (`float`) – Time constant of thermostat. (in time units)

`berendsen` rescales the velocities of all particles on each time step. The rescaling is performed so that the difference in the current temperature from the set point decays exponentially: Berendsen et. al. 1984.

$$\frac{dT_{\mathrm{cur}}}{dt} = \frac{T - T_{\mathrm{cur}}}{\tau}$$

Attention: `berendsen` does not function with MPI parallel simulations.

Attention: `berendsen` does not integrate rotational degrees of freedom.

---

disable()

Disables the integration method.

Examples:

```
method.disable()
```

Executing the disable command will remove the integration method from the simulation. Any `hoomd.run()` command executed after disabling an integration method will not apply the integration method to the particles during the simulation. A disabled integration method can be re-enabled with `enable()`.

enable()

Enables the integration method.

Examples:

```
method.enable()
```

See also:

`disable()`.

randomize_velocities(*seed*)

Assign random velocities and angular momenta to particles in the group, sampling from the Maxwell-Boltzmann distribution. This method considers the dimensionality of the system and particle anisotropy, and removes drift (the center of mass velocity).

New in version 2.3.

Parameters **seed** (`int`) – Random number seed

Note: Randomization is applied at the start of the next call to `hoomd.run()`.

Example:

```
integrator = md.integrate.berendsen(group=group.all(), kT=1.0, tau=0.5)
integrator.randomize_velocities(seed=42)
run(100)
```

class hoomd.md.integrate.**brownian**(*group*, *kT*, *seed*, *dscale=False*, *noiseless_t=False*, *noiseless_r=False*)

> Brownian dynamics.
>
> > **Parameters**
> >
> > - **group** (*hoomd.group*) – Group of particles to apply this method to.
> >
> > - **kT** (*hoomd.variant* or *float*) – Temperature of the simulation (in energy units).
> >
> > - **seed** (*int*) – Random seed to use for generating $\vec{F}_R$.
> >
> > - **dscale** (*bool*) – Control λ options. If 0 or False, use γ values set per type. If non-zero, $\gamma = \lambda d_i$.
> >
> > - **noiseless_t** (*bool*) – If set true, there will be no translational noise (random force)
> >
> > - **noiseless_r** (*bool*) – If set true, there will be no rotational noise (random torque)

brownian integrates particles forward in time according to the overdamped Langevin equations of motion, sometimes called Brownian dynamics, or the diffusive limit.

$$\frac{d\vec{x}}{dt} = \frac{\vec{F}_C + \vec{F}_R}{\gamma}$$
$$\langle \vec{F}_R \rangle = 0$$
$$\langle |\vec{F}_R|^2 \rangle = 2dkT\gamma/\delta t$$
$$\langle \vec{v}(t) \rangle = 0$$
$$\langle |\vec{v}(t)|^2 \rangle = dkT/m$$

where $\vec{F}_C$ is the force on the particle from all potentials and constraint forces, γ is the drag coefficient, $\vec{F}_R$ is a uniform random force, $\vec{v}$ is the particle's velocity, and d is the dimensionality of the system. The magnitude of the random force is chosen via the fluctuation-dissipation theorem to be consistent with the specified drag and temperature, T. When $kT = 0$, the random force $\vec{F}_R = 0$.

brownian generates random numbers by hashing together the particle tag, user seed, and current time step index. See C. L. Phillips et. al. 2011 for more information.

> **Attention:** Change the seed if you reset the simulation time step to 0. If you keep the same seed, the simulation will continue with the same sequence of random numbers used previously and may cause unphysical correlations.
>
> For MPI runs: all ranks other than 0 ignore the seed input and use the value of rank 0.

brownian uses the integrator from I. Snook, The Langevin and Generalised Langevin Approach to the Dynamics of Atomic, Polymeric and Colloidal Systems, 2007, section 6.2.5, with the exception that $\vec{F}_R$ is drawn from a uniform random number distribution.

In Brownian dynamics, particle velocities are completely decoupled from positions. At each time step, *brownian* draws a new velocity distribution consistent with the current set temperature so that *hoomd.compute.thermo* will report appropriate temperatures and pressures if logged or needed by other commands.

Brownian dynamics neglects the acceleration term in the Langevin equation. This assumption is valid when overdamped: $\frac{m}{\gamma} \ll \delta t$. Use *langevin* if your system is not overdamped.

You can specify γ in two ways:

1. Use *set_gamma()* to specify it directly, with independent values for each particle type in the system.

2. Specify λ which scales the particle diameter to $\gamma = \lambda d_i$. The units of λ are mass / distance / time.

`brownian` must be used with integrate.mode_standard.

kT can be a variant type, allowing for temperature ramps in simulation runs.

A `hoomd.compute.thermo` is automatically created and associated with *group*.

Examples:

```
all = group.all();
integrator = integrate.brownian(group=all, kT=1.0, seed=5)
integrator = integrate.brownian(group=all, kT=1.0, dscale=1.5)
typeA = group.type('A');
integrator = integrate.brownian(group=typeA, kT=hoomd.variant.linear_interp([(0,␣
↪4.0), (1e6, 1.0)]), seed=10)
```

disable()

    Disables the integration method.

    Examples:

```
method.disable()
```

    Executing the disable command will remove the integration method from the simulation. Any `hoomd.`
    `run()` command executed after disabling an integration method will not apply the integration method to
    the particles during the simulation. A disabled integration method can be re-enabled with `enable()`.

enable()

    Enables the integration method.

    Examples:

```
method.enable()
```

    See also:

    `disable()`.

set_gamma(*a*, *gamma*)

    Set gamma for a particle type.

        Parameters

            • **a** (*str*) – Particle type name

            • **gamma** (*float*) – γ for particle type a (in units of force/velocity)

    `set_gamma()` sets the coefficient γ for a single particle type, identified by name. The default is 1.0 if
    not specified for a type.

    It is not an error to specify gammas for particle types that do not exist in the simulation. This can be useful
    in defining a single simulation script for many different types of particles even when some simulations
    only include a subset.

    Examples:

```
bd.set_gamma('A', gamma=2.0)
```

set_gamma_r(*a*, *gamma_r*)

    Set gamma_r for a particle type.

        Parameters

            • **a** (*str*) – Particle type name

- **gamma_r** (*float or tuple*) – γ_r for particle type a (in units of force/velocity), optionally for all body frame directions

`set_gamma_r()` sets the coefficient γ_r for a single particle type, identified by name. The default is 1.0 if not specified for a type. It must be positive or zero, if set zero, it will have no rotational damping or random torque, but still with updates from normal net torque.

Examples:

```
bd.set_gamma_r('A', gamma_r=2.0)
bd.set_gamma_r('A', gamma_r=(1,2,3))
```

set_params(*kT=None*)
Change langevin integrator parameters.

> **Parameters kT** (*hoomd.variant* or *float*) – New temperature (if set) (in energy units).

Examples:

```
integrator.set_params(kT=2.0)
```

class hoomd.md.integrate.**langevin**(*group, kT, seed, dscale=False, tally=False, noiseless_t=False, noiseless_r=False*)
Langevin dynamics.

Parameters

- **group** (*hoomd.group*) – Group of particles to apply this method to.
- **kT** (*hoomd.variant* or *float*) – Temperature of the simulation (in energy units).
- **seed** (*int*) – Random seed to use for generating $\vec{F}_R$.
- **dscale** (*bool*) – Control λ options. If 0 or False, use γ values set per type. If non-zero, $\gamma = \lambda d_i$.
- **tally** (*bool*) – (optional) If true, the energy exchange between the thermal reservoir and the particles is tracked. Total energy conservation can then be monitored by adding `langevin_reservoir_energy_groupname` to the logged quantities.
- **noiseless_t** (*bool*) – If set true, there will be no translational noise (random force)
- **noiseless_r** (*bool*) – If set true, there will be no rotational noise (random torque)

Translational degrees of freedom

`langevin` integrates particles forward in time according to the Langevin equations of motion:

$$m\frac{d\vec{v}}{dt} = \vec{F}_C - \gamma \cdot \vec{v} + \vec{F}_R$$

$$\langle \vec{F}_R \rangle = 0$$

$$\langle |\vec{F}_R|^2 \rangle = 2dkT\gamma/\delta t$$

where $\vec{F}_C$ is the force on the particle from all potentials and constraint forces, γ is the drag coefficient, $\vec{v}$ is the particle's velocity, $\vec{F}_R$ is a uniform random force, and d is the dimensionality of the system (2 or 3). The magnitude of the random force is chosen via the fluctuation-dissipation theorem to be consistent with the specified drag and temperature, T. When $kT = 0$, the random force $\vec{F}_R = 0$.

`langevin` generates random numbers by hashing together the particle tag, user seed, and current time step index. See C. L. Phillips et. al. 2011 for more information.

> **Attention:** Change the seed if you reset the simulation time step to 0. If you keep the same seed, the simulation will continue with the same sequence of random numbers used previously and may cause unphysical correlations.
>
> For MPI runs: all ranks other than 0 ignore the seed input and use the value of rank 0.

Langevin dynamics includes the acceleration term in the Langevin equation and is useful for gently thermalizing systems using a small gamma. This assumption is valid when underdamped: $\frac{m}{\gamma} \gg \delta t$. Use `brownian` if your system is not underdamped.

`langevin` uses the same integrator as `nve` with the additional force term $-\gamma \cdot \vec{v} + \vec{F}_{\mathrm{R}}$. The random force $\vec{F}_{\mathrm{R}}$ is drawn from a uniform random number distribution.

You can specify γ in two ways:

1. Use `set_gamma()` to specify it directly, with independent values for each particle type in the system.

2. Specify λ which scales the particle diameter to $\gamma = \lambda d_i$. The units of λ are mass / distance / time.

`langevin` must be used with `mode_standard`.

kT can be a variant type, allowing for temperature ramps in simulation runs.

A `hoomd.compute.thermo` is automatically created and associated with *group*.

> **Warning:** When restarting a simulation, the energy of the reservoir will be reset to zero.

Examples:

```
all = group.all();
integrator = integrate.langevin(group=all, kT=1.0, seed=5)
integrator = integrate.langevin(group=all, kT=1.0, dscale=1.5, tally=True)
typeA = group.type('A');
integrator = integrate.langevin(group=typeA, kT=hoomd.variant.linear_interp([(0,
↪4.0), (1e6, 1.0)]), seed=10)
```

disable()
> Disables the integration method.
>
> Examples:
>
> ```
> method.disable()
> ```
>
> Executing the disable command will remove the integration method from the simulation. Any `hoomd.run()` command executed after disabling an integration method will not apply the integration method to the particles during the simulation. A disabled integration method can be re-enabled with `enable()`.

enable()
> Enables the integration method.
>
> Examples:
>
> ```
> method.enable()
> ```
>
> **See also:**
>
> `disable()`.

set_gamma(*a*, *gamma*)

Set gamma for a particle type.

Parameters

- **a** (*str*) – Particle type name
- **gamma** (*float*) – γ for particle type a (in units of force/velocity)

set_gamma() sets the coefficient γ for a single particle type, identified by name. The default is 1.0 if not specified for a type.

It is not an error to specify gammas for particle types that do not exist in the simulation. This can be useful in defining a single simulation script for many different types of particles even when some simulations only include a subset.

Examples:

```
bd.set_gamma('A', gamma=2.0)
```

set_gamma_r(*a*, *gamma_r*)

Set gamma_r for a particle type.

Parameters

- **a** (*str*) – Particle type name
- **gamma_r** (*float or tuple*) – γ_r for particle type a (in units of force/velocity), optionally for all body frame directions

set_gamma_r() sets the coefficient γ_r for a single particle type, identified by name. The default is 1.0 if not specified for a type. It must be positive or zero, if set zero, it will have no rotational damping or random torque, but still with updates from normal net torque.

Examples:

```
langevin.set_gamma_r('A', gamma_r=2.0)
langevin.set_gamma_r('A', gamma_r=(1.0,2.0,3.0))
```

set_params(*kT=None*, *tally=None*)

Change langevin integrator parameters.

Parameters

- **kT** (*hoomd.variant* or *float*) – New temperature (if set) (in energy units).
- **tally** (*bool*) – (optional) If true, the energy exchange between the thermal reservoir and the particles is tracked. Total energy conservation can then be monitored by adding `langevin_reservoir_energy_groupname` to the logged quantities.

Examples:

```
integrator.set_params(kT=2.0)
integrator.set_params(tally=False)
```

class hoomd.md.integrate.**mode_minimize_fire**(*dt*, *Nmin=5*, *finc=1.1*, *fdec=0.5*, *alpha_start=0.1*, *falpha=0.99*, *ftol=0.1*, *wtol=0.1*, *Etol=1e-05*, *min_steps=10*, *group=None*, *aniso=None*)

Energy Minimizer (FIRE).

Parameters

- **group** (*hoomd.group*) – Particle group to apply minimization to. Deprecated in version 2.2: *hoomd.md.integrate.mode_minimize_fire()* now accepts integration methods, such as *hoomd.md.integrate.nve()* and *hoomd.md.integrate.nph()*. The functions operate on user-defined groups. If **group** is defined here, automatically *hoomd.md.integrate.nve()* will be used for integration

- **dt** (*float*) – This is the maximum step size the minimizer is permitted to use. Consider the stability of the system when setting. (in time units)

- **Nmin** (*int*) – Number of steps energy change is negative before allowing α and δt to adapt.

- **finc** (*float*) – Factor to increase δt by

- **fdec** (*float*) – Factor to decrease δt by

- **alpha_start** (*float*) – Initial (and maximum) α

- **falpha** (*float*) – Factor to decrease αt by

- **ftol** (*float*) – force convergence criteria (in units of force over mass)

- **wtol** (*float*) – angular momentum convergence criteria (in units of angular momentum)

- **Etol** (*float*) – energy convergence criteria (in energy units)

- **min_steps** (*int*) – A minimum number of attempts before convergence criteria are considered

- **aniso** (*bool*) – Whether to integrate rotational degrees of freedom (bool), default None (autodetect). Added in version 2.2

New in version 2.1.

Changed in version 2.2.

mode_minimize_fire uses the Fast Inertial Relaxation Engine (FIRE) algorithm to minimize the energy for a group of particles while keeping all other particles fixed. This method is published in Bitzek, et. al., PRL, 2006.

At each time step, δt, the algorithm uses the NVE Integrator to generate a x, v, and F, and then adjusts v according to

$$\vec{v} = (1 - \alpha)\vec{v} + \alpha\hat{F}|\vec{v}|$$

where α and δt are dynamically adaptive quantities. While a current search has been lowering the energy of system for more than N_{min} steps, α is decreased by $\alpha \rightarrow \alpha f_{alpha}$ and δt is increased by $\delta t \rightarrow max(\delta t \cdot f_{inc}, \delta t_{max})$. If the energy of the system increases (or stays the same), the velocity of the particles is set to 0, $\alpha \rightarrow \alpha_{start}$ and $\delta t \rightarrow \delta t \cdot f_{dec}$. Convergence is determined by both the force per particle and the change in energy per particle dropping below *ftol* and *Etol*, respectively or

$$\frac{\sum |F|}{N * \sqrt{N_{dof}}} < ftol \ \ and \ \ \Delta \frac{\sum |E|}{N} < Etol$$

where N is the number of particles the minimization is acting over (i.e. the group size) Either of the two criterion can be effectively turned off by setting the tolerance to a large number.

If the minimization is acted over a subset of all the particles in the system, the "other" particles will be kept frozen but will still interact with the particles being moved.

Examples:

```
fire=integrate.mode_minimize_fire(dt=0.05, ftol=1e-2, Etol=1e-7)
nve=integrate.nve(group=group.all())
while not(fire.has_converged()):
    run(100)
```

Examples:

```
fire=integrate.mode_minimize_fire(dt=0.05, ftol=1e-2, Etol=1e-7)
nph=integrate.nph(group=group.all(),P=0.0,gamma=.5)
while not(fire.has_converged()):
    run(100)
```

Note: The algorithm requires a base integrator to update the particle position and velocities. Usually this will be either NVE (to minimize energy) or NPH (to minimize energy and relax the box). The quantity minimized is in any case the energy (not the enthalpy or any other quantity).

Note: As a default setting, the algorithm will start with a $\delta t = \frac{1}{10}\delta t_{max}$ and attempts at least 10 search steps. In practice, it was found that this prevents the simulation from making too aggressive a first step, but also from quitting before having found a good search direction. The minimum number of attempts can be set by the user.

get_energy()
  Returns the energy after the last iteration of the minimizer

has_converged()
  Test if the energy minimizer has converged.

  Returns True when the minimizer has converged. Otherwise, return False.

reset()
  Reset the minimizer to its initial state.

restore_state()
  Restore the state information from the file used to initialize the simulations

set_params(*aniso=None*)
  Changes parameters of an existing integration mode.

  Parameters **aniso** (*bool*) – Anisotropic integration mode (bool), default None (autodetect).

  Examples:

  ```
  integrator_mode.set_params(aniso=False)
  ```

class hoomd.md.integrate.**mode_standard**(*dt*, *aniso=None*)
  Enables a variety of standard integration methods.

  Parameters

  - **dt** (*float*) – Each time step of the simulation *hoomd.run()* will advance the real time of the system forward by *dt* (in time units).
  - **aniso** (*bool*) – Whether to integrate rotational degrees of freedom (bool), default None (autodetect).

  mode_standard performs a standard time step integration technique to move the system forward. At each time step, all of the specified forces are evaluated and used in moving the system forward to the next step.

By itself, *mode_standard* does nothing. You must specify one or more integration methods to apply to the system. Each integration method can be applied to only a specific group of particles enabling advanced simulation techniques.

The following commands can be used to specify the integration methods used by integrate.mode_standard.

- *brownian*

- *langevin*

- *nve*

- *nvt*

- *npt*

- *nph*

There can only be one integration mode active at a time. If there are more than one `integrate.mode_*` commands in a hoomd script, only the most recent before a given *hoomd.run()* will take effect.

Examples:

```
integrate.mode_standard(dt=0.005)
integrator_mode = integrate.mode_standard(dt=0.001)
```

Some integration methods (notable *nvt*, *npt* and *nph* maintain state between different *hoomd.run()* commands, to allow for restartable simulations. After adding or removing particles, however, a new *hoomd.run()* will continue from the old state and the integrator variables will re-equilibrate. To ensure equilibration from a unique reference state (such as all integrator variables set to zero), the method :py:method:reset_methods() can be use to re-initialize the variables.

reset_methods()
> (Re-)initialize the integrator variables in all integration methods

> New in version 2.2.

> Examples:

```
run(100)
# .. modify the system state, e.g. add particles ..
integrator_mode.reset_methods()
run(100)
```

restore_state()
> Restore the state information from the file used to initialize the simulations

set_params(*dt=None*, *aniso=None*)
> Changes parameters of an existing integration mode.

> **Parameters**
> - **dt** (*float*) – New time step delta (if set) (in time units).
> - **aniso** (*bool*) – Anisotropic integration mode (bool), default None (autodetect).

> Examples:

```
integrator_mode.set_params(dt=0.007)
integrator_mode.set_params(dt=0.005, aniso=False)
```

class hoomd.md.integrate.**nph**(***params*)
> NPH Integration via MTK barostat-thermostat..

Parameters

- **params** – keyword arguments passed to *npt*.

- **gamma** – (*float*, units of energy): Damping factor for the box degrees of freedom

nph performs constant pressure (NPH) simulations using a Martyna-Tobias-Klein barostat, an explicitly reversible and measure-preserving integration scheme. It allows for fully deformable simulation cells and uses the same underlying integrator as *npt* (with *nph=True*).

The available options are identical to those of *npt*, except that *kT* cannot be specified. For further information, refer to the documentation of *npt*.

Note: A time scale *tauP* for the relaxation of the barostat is required. This is defined as the relaxation time the barostat would have at an average temperature $T\_0 = 1$, and it is related to the internally used (Andersen) Barostat mass W via $W = dNT_0\tau_P^2$, where d is the dimensionality and N the number of particles.

---

nph is an integration method and must be used with *mode_standard*.

Examples:

```python
# Triclinic unit cell
nph=integrate.nph(group=all, P=2.0, tauP=1.0, couple="none", all=True)
# Cubic unit cell
nph = integrate.nph(group=all, P=2.0, tauP=1.0)
# Relax the box
nph = integrate.nph(group=all, P=0, tauP=1.0, gamma=0.1)
```

disable()
:   Disables the integration method.

    Examples:

    ```python
    method.disable()
    ```

    Executing the disable command will remove the integration method from the simulation. Any *hoomd. run()* command executed after disabling an integration method will not apply the integration method to the particles during the simulation. A disabled integration method can be re-enabled with *enable()*.

enable()
:   Enables the integration method.

    Examples:

    ```python
    method.enable()
    ```

    See also:

    disable().

randomize_velocities(*kT*, *seed*)
:   Assign random velocities and angular momenta to particles in the group, sampling from the Maxwell-Boltzmann distribution. This method considers the dimensionality of the system and particle anisotropy, and removes drift (the center of mass velocity).

    New in version 2.3.

    Starting in version 2.5, *randomize_velocities* also chooses random values for the internal integrator variables.

    Parameters

- **kT** (*float*) – Temperature (in energy units)

- **seed** (*int*) – Random number seed

Note: Randomization is applied at the start of the next call to *hoomd.run()*.

Example:

```
integrator = md.integrate.nph(group=group.all(), P=2.0, tauP=1.0)
integrator.randomize_velocities(kT=1.0, seed=42)
run(100)
```

set_params (*kT=None*, *tau=None*, *S=None*, *P=None*, *tauP=None*, *rescale_all=None*, *gamma=None*)
    Changes parameters of an existing integrator.

    Parameters

- **kT** (*hoomd.variant* or *float*) – New temperature (if set) (in energy units)

- **tau** (*float*) – New coupling constant (if set) (in time units)

- **S** (*list* of *hoomd.variant* or *float*) – New stress components set point (if set) for the barostat (in pressure units). In Voigt notation: [Sxx, Syy, Szz, Syz, Sxz, Sxy]

- **P** (*hoomd.variant* or *float*) – New isotropic pressure set point (if set) for the barostat (in pressure units). Overrides *S* if set.

- **tauP** (*float*) – New barostat coupling constant (if set) (in time units)

- **rescale_all** (*bool*) – When True, rescale all particles, not only those in the group

    Examples:

```
integrator.set_params(tau=0.6)
integrator.set_params(dt=3e-3, kT=2.0, P=1.0)
```

class hoomd.md.integrate.**npt** (*group*, *kT=None*, *tau=None*, *S=None*, *P=None*, *tauP=None*, *couple='xyz'*, *x=True*, *y=True*, *z=True*, *xy=False*, *xz=False*, *yz=False*, *all=False*, *nph=False*, *rescale_all=None*, *gamma=None*)
    NPT Integration via MTK barostat-thermostat.

    Parameters

- **group** (*hoomd.group*) – Group of particles on which to apply this method.

- **kT** (*hoomd.variant* or *float*) – Temperature set point for the thermostat, not needed if *nph=True* (in energy units).

- **tau** (*float*) – Coupling constant for the thermostat, not needed if *nph=True* (in time units).

- **S** (*list* of *hoomd.variant* or *float*) – Stress components set point for the barostat (in pressure units). In Voigt notation: [Sxx, Syy, Szz, Syz, Sxz, Sxy]

- **P** (*hoomd.variant* or *float*) – Isotropic pressure set point for the barostat (in pressure units). Overrides *S* if set.

- **tauP** (*float*) – Coupling constant for the barostat (in time units).

- **couple** (*str*) – Couplings of diagonal elements of the stress tensor, can be "none", "xy", "xz","yz", or "xyz" (default).

- **x** (*bool*) – if True, rescale *Lx* and x component of particle coordinates and velocities

---

- **y** (`bool`) – if True, rescale *Ly* and y component of particle coordinates and velocities
- **z** (`bool`) – if True, rescale *Lz* and z component of particle coordinates and velocities
- **xy** (`bool`) – if True, rescale xy tilt factor and x and y components of particle coordinates and velocities
- **xz** (`bool`) – if True, rescale xz tilt factor and x and z components of particle coordinates and velocities
- **yz** (`bool`) – if True, rescale yz tilt factor and y and z components of particle coordinates and velocities
- **all** (`bool`) – if True, rescale all lengths and tilt factors and components of particle coordinates and velocities
- **nph** (`bool`) – if True, integrate without a thermostat, i.e. in the NPH ensemble
- **rescale_all** (`bool`) – if True, rescale all particles, not only those in the group
- **gamma** – (`float`): Dimensionless damping factor for the box degrees of freedom (default: 0)

`npt` performs constant pressure, constant temperature simulations, allowing for a fully deformable simulation box.

The integration method is based on the rigorous Martyna-Tobias-Klein equations of motion for NPT. For optimal stability, the update equations leave the phase-space measure invariant and are manifestly time-reversible.

By default, `npt` performs integration in a cubic box under hydrostatic pressure by simultaneously rescaling the lengths *Lx*, *Ly* and *Lz* of the simulation box.

`npt` can also perform more advanced integration modes. The integration mode is specified by a set of couplings and by specifying the box degrees of freedom that are put under barostat control.

Couplings define which diagonal elements of the pressure tensor $P_{\alpha,\beta}$ should be averaged over, so that the corresponding box lengths are rescaled by the same amount.

Valid couplings are:

- none (all box lengths are updated independently)
- xy (*Lx* and *Ly* are coupled)
- xz (*Lx* and *Lz* are coupled)
- yz (*Ly* and *Lz* are coupled)
- xyz (*Lx* and *Ly* and *Lz* are coupled)

The default coupling is **xyz**, i.e. the ratios between all box lengths stay constant.

Degrees of freedom of the box specify which lengths and tilt factors of the box should be updated, and how particle coordinates and velocities should be rescaled.

Valid keywords for degrees of freedom are:

- x (the box length Lx is updated)
- y (the box length Ly is updated)
- z (the box length Lz is updated)
- xy (the tilt factor xy is updated)
- xz (the tilt factor xz is updated)
- yz (the tilt factor yz is updated)

- all (all elements are updated, equivalent to x, y, z, xy, xz, and yz together)

Any of the six keywords can be combined together. By default, the x, y, and z degrees of freedom are updated.

Note: If any of the diagonal x, y, z degrees of freedom is not being integrated, pressure tensor components along that direction are not considered for the remaining degrees of freedom.

For example:

- Specifying xyz couplings and x, y, and z degrees of freedom amounts to cubic symmetry (default)

- Specifying xy couplings and x, y, and z degrees of freedom amounts to tetragonal symmetry.

- Specifying no couplings and all degrees of freedom amounts to a fully deformable triclinic unit cell

`npt` Can also apply a constant stress to the simulation box. To do so, specify the symmetric stress tensor S instead of an isotropic pressure P.

Note: `npt` assumes that isotropic pressures are positive. Conventions for the stress tensor sometimes assume negative values on the diagonal. You need to set these values negative manually in HOOMD.

`npt` is an integration method. It must be used with `mode_standard`.

`npt` uses the proper number of degrees of freedom to compute the temperature and pressure of the system in both 2 and 3 dimensional systems, as long as the number of dimensions is set before the `npt` command is specified.

For the MTK equations of motion, see:

- G. J. Martyna, D. J. Tobias, M. L. Klein 1994

- M. E. Tuckerman et. al. 2006

- T. Yu et. al. 2010

- Glaser et. al (2013), to be published

Both *kT* and *P* can be variant types, allowing for temperature/pressure ramps in simulation runs.

τ is related to the Nosé mass Q by

$$\tau = \sqrt{\frac{Q}{g k_B T_0}}$$

where g is the number of degrees of freedom, and $k_B T_0$ is the set point (*kT* above).

A `hoomd.compute.thermo` is automatically specified and associated with *group*.

Examples:

```
integrate.npt(group=all, kT=1.0, tau=0.5, tauP=1.0, P=2.0)
integrator = integrate.npt(group=all, tau=1.0, kT=0.65, tauP = 1.2, P=2.0)
# orthorhombic symmetry
integrator = integrate.npt(group=all, tau=1.0, kT=0.65, tauP = 1.2, P=2.0, couple=
↪"none")
# tetragonal symmetry
integrator = integrate.npt(group=all, tau=1.0, kT=0.65, tauP = 1.2, P=2.0, couple=
↪"xy")
# triclinic symmetry
integrator = integrate.npt(group=all, tau=1.0, kT=0.65, tauP = 1.2, P=2.0, couple=
↪"none", rescale_all=True)
```

disable()
> Disables the integration method.

> Examples:

```
method.disable()
```

> Executing the disable command will remove the integration method from the simulation. Any *hoomd.* *run()* command executed after disabling an integration method will not apply the integration method to the particles during the simulation. A disabled integration method can be re-enabled with *enable()*.

enable()
> Enables the integration method.

> Examples:

```
method.enable()
```

> **See also:**

> *disable()*.

randomize_velocities(*seed*)
> Assign random velocities and angular momenta to particles in the group, sampling from the Maxwell-Boltzmann distribution. This method considers the dimensionality of the system and particle anisotropy, and removes drift (the center of mass velocity).

> New in version 2.3.

> Starting in version 2.5, *randomize_velocities* also chooses random values for the internal integrator variables.

> > **Parameters seed** (*int*) – Random number seed

> **Note:** Randomization is applied at the start of the next call to *hoomd.run()*.

> Example:

```
integrator = md.integrate.npt(group=group.all(), kT=1.0, tau=0.5, tauP=1.0,
↪P=2.0)
integrator.randomize_velocities(seed=42)
run(100)
```

set_params(*kT=None*, *tau=None*, *S=None*, *P=None*, *tauP=None*, *rescale_all=None*, *gamma=None*)
> Changes parameters of an existing integrator.

> > **Parameters**

> > - **kT** (*hoomd.variant* or *float*) – New temperature (if set) (in energy units)

> > - **tau** (*float*) – New coupling constant (if set) (in time units)

> > - **S** (*list* of *hoomd.variant* or *float*) – New stress components set point (if set) for the barostat (in pressure units). In Voigt notation: [Sxx, Syy, Szz, Syz, Sxz, Sxy]

> > - **P** (*hoomd.variant* or *float*) – New isotropic pressure set point (if set) for the barostat (in pressure units). Overrides *S* if set.

> > - **tauP** (*float*) – New barostat coupling constant (if set) (in time units)

> > - **rescale_all** (*bool*) – When True, rescale all particles, not only those in the group

Examples:

```
integrator.set_params(tau=0.6)
integrator.set_params(dt=3e-3, kT=2.0, P=1.0)
```

class hoomd.md.integrate.**nve**(*group*, *limit=None*, *zero_force=False*)

NVE Integration via Velocity-Verlet

Parameters

- **group** (*hoomd.group*) – Group of particles on which to apply this method.

- **limit** (*bool*) – (optional) Enforce that no particle moves more than a distance of a limit in a single time step

- **zero_force** (*bool*) – When set to true, particles in the a group are integrated forward in time with constant velocity and any net force on them is ignored.

nve performs constant volume, constant energy simulations using the standard Velocity-Verlet method. For poor initial conditions that include overlapping atoms, a limit can be specified to the movement a particle is allowed to make in one time step. After a few thousand time steps with the limit set, the system should be in a safe state to continue with unconstrained integration.

Another use-case for *nve* is to fix the velocity of a certain group of particles. This can be achieved by setting the velocity of those particles in the initial condition and setting the *zero_force* option to True for that group. A True value for *zero_force* causes integrate.nve to ignore any net force on each particle and integrate them forward in time with a constant velocity.

Note: With an active limit, Newton's third law is effectively **not** obeyed and the system can gain linear momentum. Activate the *hoomd.md.update.zero_momentum* updater during the limited nve run to prevent this.

---

nve is an integration method. It must be used with *mode_standard*.

A *hoomd.compute.thermo* is automatically specified and associated with *group*.

Examples:

```
all = group.all()
integrate.nve(group=all)
integrator = integrate.nve(group=all)
typeA = group.type('A')
integrate.nve(group=typeA, limit=0.01)
integrate.nve(group=typeA, zero_force=True)
```

disable()

Disables the integration method.

Examples:

```
method.disable()
```

Executing the disable command will remove the integration method from the simulation. Any *hoomd.run()* command executed after disabling an integration method will not apply the integration method to the particles during the simulation. A disabled integration method can be re-enabled with *enable()*.

enable()

Enables the integration method.

Examples:

```
method.enable()
```

See also:

[`disable()`](#).

randomize_velocities(*kT*, *seed*)

Assign random velocities and angular momenta to particles in the group, sampling from the Maxwell-Boltzmann distribution. This method considers the dimensionality of the system and particle anisotropy, and removes drift (the center of mass velocity).

New in version 2.3.

> **Parameters**
>
> - **kT** (*float*) – Temperature (in energy units)
> - **seed** (*int*) – Random number seed

Note: Randomization is applied at the start of the next call to [`hoomd.run()`](#).

Example:

```
integrator = md.integrate.nve(group=group.all())
integrator.randomize_velocities(kT=1.0, seed=42)
run(100)
```

set_params(*limit=None*, *zero_force=None*)

Changes parameters of an existing integrator.

> **Parameters**
>
> - **limit** (*bool*) – (if set) New limit value to set. Removes the limit if limit is False
> - **zero_force** (*bool*) – (if set) New value for the zero force option

Examples:

```
integrator.set_params(limit=0.01)
integrator.set_params(limit=False)
```

class hoomd.md.integrate.**nvt**(*group*, *kT*, *tau*)

NVT Integration via the Nosé-Hoover thermostat.

> **Parameters**
>
> - **group** (*hoomd.group*) – Group of particles on which to apply this method.
> - **kT** (*hoomd.variant* or *float*) – Temperature set point for the Nosé-Hoover thermostat. (in energy units).
> - **tau** (*float*) – Coupling constant for the Nosé-Hoover thermostat. (in time units).

nvt performs constant volume, constant temperature simulations using the Nosé-Hoover thermostat, using the MTK equations described in Refs. G. J. Martyna, D. J. Tobias, M. L. Klein 1994 and J. Cao, G. J. Martyna 1996.

nvt is an integration method. It must be used in connection with [`mode_standard`](#).

nvt uses the proper number of degrees of freedom to compute the temperature of the system in both 2 and 3 dimensional systems, as long as the number of dimensions is set before the integrate.nvt command is specified.

τ is related to the Nosé mass Q by

$$\tau = \sqrt{\frac{Q}{gk_BT_0}}$$

where g is the number of degrees of freedom, and k_BT_0 is the set point (*kT* above).

kT can be a variant type, allowing for temperature ramps in simulation runs.

A `hoomd.compute.thermo` is automatically specified and associated with *group*.

Examples:

```
all = group.all()
integrate.nvt(group=all, kT=1.0, tau=0.5)
integrator = integrate.nvt(group=all, tau=1.0, kT=0.65)
typeA = group.type('A')
integrator = integrate.nvt(group=typeA, tau=1.0, kT=hoomd.variant.linear_
↪interp([(0, 4.0), (1e6, 1.0)]))
```

disable()
    Disables the integration method.

    Examples:

```
method.disable()
```

Executing the disable command will remove the integration method from the simulation. Any `hoomd.run()` command executed after disabling an integration method will not apply the integration method to the particles during the simulation. A disabled integration method can be re-enabled with `enable()`.

enable()
    Enables the integration method.

    Examples:

```
method.enable()
```

See also:

`disable()`.

randomize_velocities(*seed*)
    Assign random velocities and angular momenta to particles in the group, sampling from the Maxwell-Boltzmann distribution. This method considers the dimensionality of the system and particle anisotropy, and removes drift (the center of mass velocity).

    New in version 2.3.

    Starting in version 2.5, *randomize_velocities* also chooses random values for the internal integrator variables.

        Parameters seed (*int*) – Random number seed

    Note: Randomization is applied at the start of the next call to `hoomd.run()`.

    Example:

```
integrator = md.integrate.nvt(group=group.all(), kT=1.0, tau=0.5)
integrator.randomize_velocities(seed=42)
run(100)
```

set_params (*kT=None*, *tau=None*)

Changes parameters of an existing integrator.

Parameters

- **kT** (*float*) – New temperature (if set) (in energy units)
- **tau** (*float*) – New coupling constant (if set) (in time units)

Examples:

```
integrator.set_params(tau=0.6)
integrator.set_params(tau=0.7, kT=2.0)
```

2.16.10 md.nlist

Overview

`md.nlist.cell`	Cell list based neighbor list
`md.nlist.stencil`	Cell list based neighbor list using stencils
`md.nlist.tree`	Bounding volume hierarchy based neighbor list.

Details

Neighbor list acceleration structures.

Neighbor lists accelerate pair force calculation by maintaining a list of particles within a cutoff radius. Multiple pair forces can utilize the same neighbor list. Neighbors are included using a pairwise cutoff $r_{\mathrm{cut}}(i, j)$ that is the maximum of all $r_{\mathrm{cut}}(i, j)$ set for the pair forces attached to the list.

Multiple neighbor lists can be created to accelerate simulations where there is significant disparity in $r_{\mathrm{cut}}(i, j)$ between pair potentials. If one pair force has a cutoff radius much smaller than another pair force, the pair force calculation for the short cutoff will be slowed down considerably because many particles in the neighbor list will have to be read and skipped because they lie outside the shorter cutoff.

The simplest way to build a neighbor list is $O(N^2)$: each particle loops over all other particles and only includes those within the neighbor list cutoff. This algorithm is no longer implemented in HOOMD-blue because it is slow and inefficient. Instead, three accelerated algorithms based on cell lists and bounding volume hierarchy trees are implemented. The cell list implementation is usually fastest when the cutoff radius is similar between all pair forces (smaller than 2:1 ratio). The stencil implementation is a different variant of the cell list, and its main use is when a cell list would be faster than a tree but memory demands are too big. The tree implementation is faster when there is large size disparity, but its performance has been improved to be only slightly slower than the cell list for many use cases. Because the performance of these algorithms depends on your system and hardware, you should carefully test which option is fastest for your simulation.

Particles can be excluded from the neighbor list based on certain criteria. Setting $r_{\mathrm{cut}}(i, j) \leq 0$ will exclude this cross interaction from the neighbor list on build time. Particles can also be excluded by topology or for belonging to the same rigid body (see `nlist.reset_exclusions()`). To support molecular structures, the body flag can also be used to exclude particles that are not part of a rigid structure. All particles with positive values of the body flag are considered part of a rigid body (see `hoomd.md.constrain.rigid`), while the default value of -1 indicates that a particle is free. Any other negative value of the body flag indicates that the particles are part of a floppy body; such

particles are integrated separately, but are automatically excluded from the neighbor list as well.

Examples:

```
nl_c = nlist.cell(check_period=1)
nl_t = nlist.tree(r_buff = 0.8)
lj1 = pair.lj(r_cut = 3.0, nlist=nl_c)
lj2 = pair.lj(r_cut = 10.0, nlist=nl_t)
```

class hoomd.md.nlist.**cell**(*r_buff=0.4,   check_period=1,   d_max=None,   dist_check=True,*
                                        name=None, deterministic=False)

> Cell list based neighbor list
>
> > **Parameters**
> >
> > - **r_buff** (*float*) – Buffer width.
> >
> > - **check_period** (*int*) – How often to attempt to rebuild the neighbor list.
> >
> > - **d_max** (*float*) – The maximum diameter a particle will achieve, only used in conjunction with slj diameter shifting.
> >
> > - **dist_check** (*bool*) – Flag to enable / disable distance checking.
> >
> > - **name** (*str*) – Optional name for this neighbor list instance.
> >
> > - **deterministic** (*bool*) – When True, enable deterministic runs on the GPU by sorting the cell list.
>
> *cell* creates a cell list based neighbor list object to which pair potentials can be attached for computing non-bonded pairwise interactions. Cell listing allows for *O(N)* construction of the neighbor list. Particles are first spatially sorted into cells based on the largest pairwise cutoff radius attached to this instance of the neighbor list. Particles then query their adjacent cells, and neighbors are included based on pairwise cutoffs. This method is very efficient for systems with nearly monodisperse cutoffs, but performance degrades for large cutoff radius asymmetries due to the significantly increased number of particles per cell.
>
> Use base class methods to change parameters (*set_params*), reset the exclusion list (*reset_exclusions*) or tune *r_buff* (*tune*).
>
> Examples:
>
> ```
> nl_c = nlist.cell(check_period = 1)
> nl_c.set_params(r_buff=0.5)
> nl_c.reset_exclusions([]);
> nl_c.tune()
> ```
>
> ---
>
> **Note:** *d_max* should only be set when slj diameter shifting is required by a pair potential. Currently, slj is the only pair potential requiring this shifting, and setting *d_max* for other potentials may lead to significantly degraded performance or incorrect results.
>
> ---

class hoomd.md.nlist.**nlist**

> Base class neighbor list.
>
> Methods provided by this base class are available to all subclasses.
>
> **add_exclusion**(*i, j*)
>
> > Add a specific pair of particles to the exclusion list.
> >
> > > **Parameters**
> > >
> > > - **i** (*int*) – The tag of the first particle in the pair.

- **j** (*int*) – The tag of the second particle in the pair.

Examples:

```
nl.add_exclusions(system.particles[0].tag, system.particles[1].tag)
```

query_update_period()
:   Query the maximum possible check_period.

    query_update_period() examines the counts of nlist rebuilds during the previous *hoomd.run()*.
    It returns `s-1`, where *s* is the smallest update period experienced during that time. Use it after a medium-
    length warm up run with *check_period=1* to determine what check_period to set for production runs.

    > **Warning:** If the previous *hoomd.run()* was short, insufficient sampling may cause the queried
    > update period to be large enough to result in dangerous builds during longer runs. Unless you use a
    > really long warm up run, subtract an additional 1 from this when you set check_period for additional
    > safety.

reset_exclusions(*exclusions=None*)
:   Resets all exclusions in the neighborlist.

    > **Parameters exclusions** (*list*) – Select which interactions should be excluded from the
    > pair interaction calculation.

    By default, the following are excluded from short range pair interactions"

    - Directly bonded particles.
    - Directly constrained particles.
    - Particles that are in the same body (i.e. have the same body flag). Note that these bodies need not be
      rigid.

    reset_exclusions allows the defaults to be overridden to add other exclusions or to remove the exclusion
    for bonded or constrained particles.

    Specify a list of desired types in the *exclusions* argument (or an empty list to clear all exclusions). All
    desired exclusions have to be explicitly listed, i.e. '1-3' does **not** imply '1-2'.

    Valid types are:

    - **bond** - Exclude particles that are directly bonded together.
    - **constraint** - Exclude particles that are directly constrained.
    - **angle** - Exclude the two outside particles in all defined angles.
    - **dihedral** - Exclude the two outside particles in all defined dihedrals.
    - **pair** - Exclude particles in all defined special pairs.
    - **body** - Exclude particles that belong to the same body.

    The following types are determined solely by the bond topology. Every chain of particles in the simulation
    connected by bonds (1-2-3-4) will be subject to the following exclusions, if enabled, whether or not explicit
    angles or dihedrals are defined:

    - **1-2** - Same as bond
    - **1-3** - Exclude particles connected with a sequence of two bonds.
    - **1-4** - Exclude particles connected with a sequence of three bonds.

Examples:

```
nl.reset_exclusions(exclusions = ['1-2'])
nl.reset_exclusions(exclusions = ['1-2', '1-3', '1-4'])
nl.reset_exclusions(exclusions = ['bond', 'angle'])
nl.reset_exclusions(exclusions = ['bond', 'angle','constraint'])
nl.reset_exclusions(exclusions = [])
```

set_params(*r_buff=None*, *check_period=None*, *d_max=None*, *dist_check=True*)
Change neighbor list parameters.

Parameters

- **r_buff** (*float*) – (if set) changes the buffer radius around the cutoff (in distance units)

- **check_period** (*int*) – (if set) changes the period (in time steps) between checks to see if the neighbor list needs updating

- **d_max** (*float*) – (if set) notifies the neighbor list of the maximum diameter that a particle attain over the following run() commands. (in distance units)

- **dist_check** (*bool*) – When set to False, disable the distance checking logic and always regenerate the nlist every *check_period* steps

set_params() changes one or more parameters of the neighbor list. *r_buff* and *check_period* can have a significant effect on performance. As *r_buff* is made larger, the neighbor list needs to be updated less often, but more particles are included leading to slower force computations. Smaller values of *r_buff* lead to faster force computation, but more often neighbor list updates, slowing overall performance again. The sweet spot for the best performance needs to be found by experimentation. The default of *r_buff = 0.4* works well in practice for Lennard-Jones liquid simulations.

As *r_buff* is changed, *check_period* must be changed correspondingly. The neighbor list is updated no sooner than *check_period* time steps after the last update. If *check_period* is set too high, the neighbor list may not be updated when it needs to be.

For safety, the default check_period is 1 to ensure that the neighbor list is always updated when it needs to be. Increasing this to an appropriate value for your simulation can lead to performance gains of approximately 2 percent.

check_period should be set so that no particle moves a distance more than *r_buff/2.0* during a the *check_period*. If this occurs, a *dangerous build* is counted and printed in the neighbor list statistics at the end of a *hoomd.run()*.

When using *hoomd.md.pair.slj*, *d_max* **MUST** be set to the maximum diameter that a particle will attain at any point during the following *hoomd.run()* commands (see *hoomd.md.pair.slj* for more information). When using in conjunction, *hoomd.md.pair.slj* will automatically set *d_max* for the nlist. This can be overridden (e.g. if multiple potentials using diameters are used) by using *set_params()* after the *hoomd.md.pair.slj* class has been initialized.

Caution: When **not** using *hoomd.md.pair.slj*, *d_max* **MUST** be left at the default value of 1.0 or the simulation will be incorrect if d_max is less than 1.0 and slower than necessary if d_max is greater than 1.0.

Examples:

```
nl.set_params(r_buff = 0.9)
nl.set_params(check_period = 11)
```

(continues on next page)

```
nl.set_params(r_buff = 0.7, check_period = 4)
nl.set_params(d_max = 3.0)
```

tune(*warmup=200000,   r_min=0.05,   r_max=1.0,   jumps=20,   steps=5000,   set_max_check_period=False, quiet=False*)

Make a series of short runs to determine the fastest performing r_buff setting.

Parameters

- **warmup** (`int`) – Number of time steps to run() to warm up the benchmark
- **r_min** (`float`) – Smallest value of r_buff to test
- **r_max** (`float`) – Largest value of r_buff to test
- **jumps** (`int`) – Number of different r_buff values to test
- **steps** (`int`) – Number of time steps to run() at each point
- **set_max_check_period** (`bool`) – Set to True to enable automatic setting of the maximum nlist check_period
- **quiet** (`bool`) – Quiet the individual run() calls.

`tune()` executes *warmup* time steps. Then it sets the nlist *r_buff* value to *r_min* and runs for *steps* time steps. The TPS value is recorded, and the benchmark moves on to the next *r_buff* value completing at *r_max* in *jumps* jumps. Status information is printed out to the screen, and the optimal *r_buff* value is left set for further `hoomd.run()` calls to continue at optimal settings.

Each benchmark is repeated 3 times and the median value chosen. Then, *warmup* time steps are run again at the optimal *r_buff* in order to determine the maximum value of check_period. In total, (`2*warmup + 3*jump*steps`) time steps are run.

Note: By default, the maximum check_period is **not** set for safety. If you wish to have it set when the call completes, call with the parameter *set_max_check_period=True*.

Returns (optimal_r_buff, maximum check_period)

class hoomd.md.nlist.**stencil**(*r_buff=0.4,   check_period=1,   d_max=None,   dist_check=True,   cell_width=None, name=None, deterministic=False*)

Cell list based neighbor list using stencils

Parameters

- **r_buff** (`float`) – Buffer width.
- **check_period** (`int`) – How often to attempt to rebuild the neighbor list.
- **d_max** (`float`) – The maximum diameter a particle will achieve, only used in conjunction with slj diameter shifting.
- **dist_check** (`bool`) – Flag to enable / disable distance checking.
- **cell_width** (`float`) – The underlying stencil bin width for the cell list
- **name** (`str`) – Optional name for this neighbor list instance.
- **deterministic** (`bool`) – When True, enable deterministic runs on the GPU by sorting the cell list.

stencil creates a cell list based neighbor list object to which pair potentials can be attached for computing non-bonded pairwise interactions. Cell listing allows for O(N) construction of the neighbor list. Particles are first spatially sorted into cells based on the largest pairwise cutoff radius attached to this instance of the neighbor list.

M.P. Howard et al. 2016 describes this neighbor list implementation in HOOMD-blue. Cite it if you utilize this neighbor list style in your work.

This neighbor-list style differs from `cell` based on how the adjacent cells are searched for particles. The cell list *cell_width* is set by default using the shortest active cutoff radius in the system. One *stencil* is computed per particle type based on the largest cutoff radius that type participates in, which defines the bins that the particle must search in. Distances to the bins in the stencil are precomputed so that certain particles can be quickly excluded from the neighbor list, leading to improved performance compared to `cell` when there is size disparity in the cutoff radius. The memory demands of `stencil` can also be lower than `cell` if your system is large and has many small cells in it; however, `tree` is usually a better choice for these systems.

The performance of the stencil depends strongly on the choice of *cell_width*. The best performance is obtained when the cutoff radii are multiples of the *cell_width*, and when the *cell_width* covers the simulation box with a roughly integer number of cells. The *cell_width* can be set manually, or be automatically scanning through a range of possible bin widths using *tune_cell_width()*.

Examples:

```
nl_s = nlist.stencil(check_period = 1)
nl_s.set_params(r_buff=0.5)
nl_s.reset_exclusions([]);
nl_s.tune()
nl_s.tune_cell_width(min_width=1.5, max_width=3.0)
```

Note: *d_max* should only be set when slj diameter shifting is required by a pair potential. Currently, slj is the only pair potential requiring this shifting, and setting *d_max* for other potentials may lead to significantly degraded performance or incorrect results.

---

set_cell_width(*cell_width*)
    Set the cell width

        Parameters cell_width (*float*) – New cell width.

tune_cell_width(*warmup=200000, min_width=None, max_width=None, jumps=20, steps=5000*)
    Make a series of short runs to determine the fastest performing bin width.

        Parameters

            • **warmup** (*int*) – Number of time steps to run() to warm up the benchmark

            • **min_width** (*float*) – Minimum cell bin width to try

            • **max_width** (*float*) – Maximum cell bin width to try

            • **jumps** (*int*) – Number of different bin width to test

            • **steps** (*int*) – Number of time steps to run() at each point

    tune_cell_width() executes *warmup* time steps. Then it sets the nlist *cell_width* value to *min_width* and runs for *steps* time steps. The TPS value is recorded, and the benchmark moves on to the next *cell_width* value completing at *max_width* in *jumps* jumps. Status information is printed out to the screen, and the optimal *cell_width* value is left set for further runs() to continue at optimal settings.

    Each benchmark is repeated 3 times and the median value chosen. In total, (`warmup + 3*jump*steps`) time steps are run.

> **Returns** The optimal cell width.

class hoomd.md.nlist.**tree**(*r_buff=0.4*, *check_period=1*, *d_max=None*, *dist_check=True*, *name=None*)

> Bounding volume hierarchy based neighbor list.

> **Parameters**

> - **r_buff** (*float*) – Buffer width.

> - **check_period** (*int*) – How often to attempt to rebuild the neighbor list.

> - **d_max** (*float*) – The maximum diameter a particle will achieve, only used in conjunction with slj diameter shifting.

> - **dist_check** (*bool*) – Flag to enable / disable distance checking.

> - **name** (*str*) – Optional name for this neighbor list instance.

> *tree* creates a neighbor list using bounding volume hierarchy (BVH) tree traversal. Pair potentials are attached for computing non-bonded pairwise interactions. A BVH tree of axis-aligned bounding boxes is constructed per particle type, and each particle queries each tree to determine its neighbors. This method of searching leads to significantly improved performance compared to cell lists in systems with moderate size asymmetry, but has slightly poorer performance (10% slower) for monodisperse systems. *tree* can also be slower than *cell* if there are multiple types in the system, but the cutoffs between types are identical. (This is because one BVH is created per type.) The user should carefully benchmark neighbor list build times to select the appropriate neighbor list construction type.

> M.P. Howard et al. 2016 describes the original implementation of this algorithm for HOOMD-blue. M.P. Howard et al. 2019 describes the improved algorithm that is currently implemented. Cite both if you utilize this neighbor list style in your work.

> Examples:

```
nl_t = nlist.tree(check_period = 1)
nl_t.set_params(r_buff=0.5)
nl_t.reset_exclusions([]);
nl_t.tune()
```

> **Note:** *d_max* should only be set when slj diameter shifting is required by a pair potential. Currently, slj is the only pair potential requiring this shifting, and setting *d_max* for other potentials may lead to significantly degraded performance or incorrect results.

2.16.11 md.pair

Overview

md.pair.buckingham	Buckingham pair potential.
md.pair.dipole	Screened dipole-dipole interactions.
md.pair.dpd	Dissipative Particle Dynamics.
md.pair.dpdlj	Dissipative Particle Dynamics with a LJ conservative force
md.pair.dpd_conservative	DPD Conservative pair force.
md.pair.ewald	Ewald pair potential.
md.pair.force_shifted_lj	Force-shifted Lennard-Jones pair potential.

Continued on next page

Table 36 – continued from previous page

md.pair.fourier	Fourier pair potential.
md.pair.gauss	Gaussian pair potential.
md.pair.gb	Gay-Berne anisotropic pair potential.
md.pair.lj	Lennard-Jones pair potential.
md.pair.lj1208	Lennard-Jones 12-8 pair potential.
md.pair.mie	Mie pair potential.
md.pair.morse	Morse pair potential.
md.pair.moliere	Moliere pair potential.
md.pair.pair	Common pair potential documentation.
md.pair.reaction_field	Onsager reaction field pair potential.
md.pair.slj	Shifted Lennard-Jones pair potential.
md.pair.square_density	Soft potential for simulating a van-der-Waals liquid
md.pair.table	Tabulated pair potential.
md.pair.tersoff	Tersoff Potential.
md.pair.yukawa	Yukawa pair potential.
md.pair.zbl	ZBL pair potential.

Details

Pair potentials.

Generally, pair forces are short range and are summed over all non-bonded particles within a certain cutoff radius of each particle. Any number of pair forces can be defined in a single simulation. The net force on each particle due to all types of pair forces is summed.

Pair forces require that parameters be set for each unique type pair. Coefficients are set through the aid of the *coeff* class. To set these coefficients, specify a pair force and save it in a variable:

```
my_force = pair.some_pair_force(arguments...)
```

Then the coefficients can be set using the saved variable:

```
my_force.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
my_force.pair_coeff.set('A', 'B', epsilon=1.0, sigma=2.0)
my_force.pair_coeff.set('B', 'B', epsilon=2.0, sigma=1.0)
```

This example set the parameters *epsilon* and *sigma* (which are used in *lj*). Different pair forces require that different coefficients are set. Check the documentation of each to see the definition of the coefficients.

class hoomd.md.pair.**DLVO**(*r_cut*, *nlist*, *d_max=None*, *name=None*)
  DLVO colloidal interaction

  DLVO specifies that a DLVO dispersion and electrostatic interaction should be applied between every non-excluded particle pair in the simulation.

  Parameters

  - **r_cut** (*float*) – Default cutoff radius (in distance units).
  - **nlist** (*hoomd.md.nlist*) – Neighbor list
  - **name** (*str*) – Name of the force instance.
  - **d_max** (*float*) – Maximum diameter particles in the simulation will have (in distance units)

  DLVO evaluates the forces for the pair potential .. math:

```
   V_{\mathrm{DLVO}}(r)  = & - \frac{A}{6} \left[
       \frac{2a_1a_2}{r^2 - (a_1+a_2)^2} + \frac{2a_1a_2}{r^2 - (a_1-a_2)^2}
       + \log \left( \frac{r^2 - (a_1+a_2)^2}{r^2 - (a_1+a_2)^2} \right) \right]
       + \frac{a_1 a_2}{a_1+a_2} Z e^{-\kappa(r - (a_1+a_2))} & r < (r_{\mathrm
↪{cut}} + \Delta)
       = & 0 & r \ge (r_{\mathrm{cut}} + \Delta)

where math:`a_i` is the radius of particle :math:`i`, :math:`\Delta = (d_i + d_j)/
↪2` and
:math:`d_i` is the diameter of particle :math:`i`.
```

The first term corresponds to the attractive van der Waals interaction with A being the Hamaker constant, the second term to the repulsive double-layer interaction between two spherical surfaces with Z proportional to the surface electric potential.

See Israelachvili 2011, pp. 317.

The DLVO potential does not need charge, but does need diameter. See `slj` for an explanation on how diameters are handled in the neighbor lists.

Due to the way that DLVO modifies the cutoff condition, it will not function properly with the xplor shifting mode. See `pair` for details on how forces are calculated and the available energy shifting and smoothing modes.

Use `pair_coeff.set` to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in units of energy*distance)

- κ - *kappa* (in units of 1/distance)

- r_{cut} - *r_cut* (in units of distance) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on} - *r_on* (in units of distance) - *optional*: defaults to the global r_cut specified in the pair command

New in version 2.2.

Example:

```
nl = nlist.cell()
DLVO.pair_coeff.set('A', 'A', epsilon=1.0, kappa=1.0)
DLVO.pair_coeff.set('A', 'B', epsilon=2.0, kappa=0.5, r_cut=3.0, r_on=2.0);
DLVO.pair_coeff.set(['A', 'B'], ['C', 'D'], epsilon=0.5, kappa=3.0)
```

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \mathrm{tags1}, j \in \mathrm{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
→array(tags[1:N:2]))
```

disable(*log=False*)
> Disable the force.

> > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

> Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See `disable()`.

get_energy(*group*)
> Get the energy of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
> Get all the types of shapes in the current simulation.

> Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)
> Set parameters controlling the way forces are computed.

> > **Parameters mode** (*str*) – (if set) Set the mode with which potentials are handled at the cutoff.

> Valid values for *mode* are: "none" (the default), "shift", and "xplor":

> - **none** - No shifting is performed and potentials are abruptly cut off

> - **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff

> - **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

> See *pair* for the equations.

> Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**ai_pair**(*r_cut*, *nlist*, *name=None*)
> Generic anisotropic pair potential.

> Users should not instantiate *ai_pair* directly. It is a base class that provides common features to all anisotropic pair forces. Rather than repeating all of that documentation in a dozen different places, it is collected here.

> All anisotropic pair potential commands specify that a given potential energy, force and torque be computed on all non-excluded particle pairs in the system within a short range cutoff distance r_{cut}. The interaction energy, forces and torque depend on the inter-particle separation $\vec{r}$ and on the orientations $\vec{q_i}$, q_j, of the particles.

compute_energy(*tags1*, *tags2*)
> Compute the energy between two sets of particles.

> > **Parameters**

> > - **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

> > - **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)
   Disable the force.

   > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy
   > associated with this force.

   Examples:

   ```
   force.disable()
   force.disable(log=True)
   ```

   Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

   By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
   Enable the force.

   Examples:

   ```
   force.enable()
   ```

   See *disable()*.

get_energy(*group*)
   Get the energy of a particle group.

   > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

   > **Returns** The last computed energy for the members in the group.

   Examples:

   ```
   g = group.all()
   energy = force.get_energy(g)
   ```

get_net_force(*group*)
> Get the force of a particle group.

>> **Parameters group** (`hoomd.group`) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

>> **Parameters group** (`hoomd.group`) – The particle group to query the virial for.

>> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
> Get all the types of shapes in the current simulation.

> Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)
> Set parameters controlling the way forces are computed.

>> **Parameters mode** (`str`) – (if set) Set the mode with which potentials are handled at the cutoff

> valid values for mode are: "none" (the default) and "shift":

> - *none* - No shifting is performed and potentials are abruptly cut off
> - *shift* - A constant shift is applied to the entire potential so that it is 0 at the cutoff

> Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
```

shape
> Get or set shape parameters per type.

> In addition to any pair-specific parameters required to characterize a pair potential, individual particles that have anisotropic interactions may also have their own shapes that affect the potentials. General anisotropic pair potentials may set per-particle shapes using this method.

class hoomd.md.pair.**buckingham**(*r_cut*, *nlist*, *name=None*)
> Buckingham pair potential.

>> **Parameters**

>>> - **r_cut** (`float`) – Default cutoff radius (in distance units).
>>> - **nlist** (`hoomd.md.nlist`) – Neighbor list
>>> - **name** (`str`) – Name of the force instance.

---

buckingham specifies that a Buckingham pair potential should be applied between every non-excluded particle pair in the simulation.

$$V_{\text{Buckingham}}(r) = \quad A \exp\left(-\frac{r}{\rho}\right) - \frac{C}{r^6} \quad r < r_{\text{cut}}$$
$$= \qquad\qquad 0 \qquad\qquad r \geq r_{\text{cut}}$$

See *pair* for details on how forces are calculated and the available energy shifting and smoothing modes. Use *pair_coeff.set* to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- A - *A* (in energy units)

- ρ - *rho* (in distance units)

- C - *C* (in energy * distance**6 units)

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on} - *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

New in version 2.2.

Changed in version 2.2.

Example:

```
nl = nlist.cell()
buck = pair.buckingham(r_cut=3.0, nlist=nl)
buck.pair_coeff.set('A', 'A', A=1.0, rho=1.0, C=1.0)
buck.pair_coeff.set('A', 'B', A=2.0, rho=1.0, C=1.0, r_cut=3.0, r_on=2.0);
buck.pair_coeff.set('B', 'B', A=1.0, rho=1.0, C=1.0, r_cut=2**(1.0/6.0), r_on=2.
↪0);
buck.pair_coeff.set(['A', 'B'], ['C', 'D'], A=1.5, rho=2.0, C=1.0)
```

compute_energy (*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)

Disable the force.

>   **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy
>   associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` com-
mand executed after disabling a force will not calculate or use the force during the simulation. A disabled
force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the
simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used
throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would
be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

Enable the force.

Examples:

```
force.enable()
```

See `disable()`.

get_energy(*group*)

Get the energy of a particle group.

>   **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

>   **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

>   **Parameters group** (*hoomd.group*) – The particle group to query the force for.

>   **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

>   **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes ()
    Get all the types of shapes in the current simulation.

    Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params (*mode=None*)
    Set parameters controlling the way forces are computed.

        Parameters mode (*str*) – (if set) Set the mode with which potentials are handled at the cutoff.

    Valid values for *mode* are: "none" (the default), "shift", and "xplor":

    - **none** - No shifting is performed and potentials are abruptly cut off

    - **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff

    - **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

    See *pair* for the equations.

    Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**coeff**
    Define pair coefficients

    All pair forces use *coeff* to specify the coefficients between different pairs of particles indexed by type. The set of pair coefficients is a symmetric matrix defined over all possible pairs of particle types.

    There are two ways to set the coefficients for a particular pair force. The first way is to save the pair force in a variable and call *set()* directly.

    The second method is to build the *coeff* class first and then assign it to the pair force. There are some advantages to this method in that you could specify a complicated set of pair coefficients in a separate python file and import it into your job script.

    Example (**force_field.py**):

```
from hoomd import md
my_coeffs = md.pair.coeff();
my_force.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
my_force.pair_coeff.set('A', 'B', epsilon=1.0, sigma=2.0)
my_force.pair_coeff.set('B', 'B', epsilon=2.0, sigma=1.0)
```

    Example job script:

```
from hoomd import md
import force_field

.....
```

(continues on next page)

```
my_force = md.pair.some_pair_force(arguments...)
my_force.pair_coeff = force_field.my_coeffs
```

set (*a*, *b*, ***coeffs*)
    Sets parameters for one type pair.

        Parameters

            • **a** (*str*) – First particle type in the pair (or a list of type names)

            • **b** (*str*) – Second particle type in the pair (or a list of type names)

            • **coeffs** – Named coefficients (see below for examples)

    Calling *set()* results in one or more parameters being set for a single type pair or set of type pairs. Particle types are identified by name, and parameters are also added by name. Which parameters you need to specify depends on the pair force you are setting these coefficients for, see the corresponding documentation.

    All possible type pairs as defined in the simulation box must be specified before executing *hoomd.run()*. You will receive an error if you fail to do so. It is not an error, however, to specify coefficients for particle types that do not exist in the simulation. This can be useful in defining a force field for many different types of particles even when some simulations only include a subset.

    There is no need to specify coefficients for both pairs 'A', 'B' and 'B', 'A'. Specifying only one is sufficient.

    To set the same coefficients between many particle types, provide a list of type names instead of a single one. All pairs between the two lists will be set to the same parameters.

    Examples:

```
coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
coeff.set('B', 'B', epsilon=2.0, sigma=1.0)
coeff.set('A', 'B', epsilon=1.5, sigma=1.0)
coeff.set(['A', 'B', 'C', 'D'], 'F', epsilon=2.0)
coeff.set(['A', 'B', 'C', 'D'], ['A', 'B', 'C', 'D'], epsilon=1.0)

system = init.read_xml('init.xml')
coeff.set(system.particles.types, system.particles.types, epsilon=2.0)
coeff.set('A', system.particles.types, epsilon=1.2)
```

Note: Single parameters can be updated. If both epsilon and sigma have already been set for a type pair, then executing `coeff.set('A', 'B', epsilon=1.1)` will update the value of epsilon and leave sigma as it was previously set.

    Some pair potentials assign default values to certain parameters. If the default setting for a given coefficient (as documented in the respective pair command) is not set explicitly, the default will be used.

class hoomd.md.pair.**dipole** (*r_cut*, *nlist*, *name=None*)
    Screened dipole-dipole interactions.

        Parameters

            • **r_cut** (*float*) – Default cutoff radius (in distance units).

            • **nlist** (*hoomd.md.nlist*) – Neighbor list

            • **name** (*str*) – Name of the force instance.

dipole computes the (screened) interaction between pairs of particles with dipoles and electrostatic charges. The total energy computed is:

$$U_{dipole} = U_{dd} + U_{de} + U_{ee}$$

$$U_{dd} = Ae^{-\kappa r} \left(\frac{\vec{\mu_i} \cdot \vec{\mu_j}}{r^3} - 3\frac{(\vec{\mu_i} \cdot \vec{r_{ji}})(\vec{\mu_j} \cdot \vec{r_{ji}})}{r^5} \right)$$

$$U_{de} = Ae^{-\kappa r} \left(\frac{(\vec{\mu_j} \cdot \vec{r_{ji}})q_i}{r^3} - \frac{(\vec{\mu_i} \cdot \vec{r_{ji}})q_j}{r^3} \right)$$

$$U_{ee} = Ae^{-\kappa r} \frac{q_i q_j}{r}$$

Use *pair_coeff.set* to set potential coefficients. *dipole* does not implement and energy shift / smoothing modes due to the function of the force.

The following coefficients must be set per unique pair of particle types:

- mu - magnitude of $\vec{\mu} = \mu(1, 0, 0)$ in the particle local reference frame

- A - electrostatic energy scale A (default value 1.0)

- kappa - inverse screening length κ

Example:

```
# A/A interact only with screened electrostatics
dipole.pair_coeff.set('A', 'A', mu=0.0, A=1.0, kappa=1.0)
dipole.pair_coeff.set('A', 'B', mu=0.5, kappa=1.0)
```

compute_energy (*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
→array(tags[1:N:2]))
```

disable (*log=False*)

Disable the force.

Parameters **log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
    Enable the force.

    Examples:

```
force.enable()
```

    See `disable()`.

get_energy(*group*)
    Get the energy of a particle group.

> **Parameters** **group** (`hoomd.group`) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

    Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
    Get the force of a particle group.

> **Parameters** **group** (`hoomd.group`) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
    Get the virial of a particle group.

> **Parameters** **group** (`hoomd.group`) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
    Get all the types of shapes in the current simulation.

Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params (**args*, ***kwargs*)
    dipole has no energy shift modes

shape
    Get or set shape parameters per type.

    In addition to any pair-specific parameters required to characterize a pair potential, individual particles that have anisotropic interactions may also have their own shapes that affect the potentials. General anisotropic pair potentials may set per-particle shapes using this method.

class hoomd.md.pair.**dpd**(*r_cut*, *nlist*, *kT*, *seed*, *name=None*)
    Dissipative Particle Dynamics.

> **Parameters**
>
> - **r_cut** (*float*) – Default cutoff radius (in distance units).
> - **nlist** (*hoomd.md.nlist*) – Neighbor list
> - **kT** (*hoomd.variant* or *float*) – Temperature of thermostat (in energy units).
> - **seed** (*int*) – seed for the PRNG in the DPD thermostat.
> - **name** (*str*) – Name of the force instance.

dpd specifies that a DPD pair force should be applied between every non-excluded particle pair in the simulation, including an interaction potential, pairwise drag force, and pairwise random force. See Groot and Warren 1997.

$$F = F_C(r) + F_{R,ij}(r_{ij}) + F_{D,ij}(v_{ij})$$

$$
\begin{aligned}
F_C(r) &= A \cdot w(r_{ij}) \\
F_{R,ij}(r_{ij}) &= -\theta_{ij}\sqrt{3}\sqrt{\frac{2k_b\gamma T}{\Delta t}} \cdot w(r_{ij}) \\
F_{D,ij}(r_{ij}) &= -\gamma w^2(r_{ij})\left(\hat{r}_{ij} \circ v_{ij}\right)
\end{aligned}
$$

$$
\begin{aligned}
w(r_{ij}) &= (1 - r/r_{\text{cut}}) & r < r_{\text{cut}} \\
&= 0 & r \geq r_{\text{cut}}
\end{aligned}
$$

where $\hat{r}_{ij}$ is a normalized vector from particle i to particle j, $v_{ij} = v_i - v_j$, and θ_{ij} is a uniformly distributed random number in the range [-1, 1].

dpd generates random numbers by hashing together the particle tags in the pair, the user seed, and the current time step index.

> **Attention:** Change the seed if you reset the simulation time step to 0. If you keep the same seed, the simulation will continue with the same sequence of random numbers used previously and may cause unphysical correlations.
>
> For MPI runs: all ranks other than 0 ignore the seed input and use the value of rank 0.

C. L. Phillips et. al. 2011 describes the DPD implementation details in HOOMD-blue. Cite it if you utilize the DPD functionality in your work.

`dpd` does not implement and energy shift / smoothing modes due to the function of the force. Use `pair_coeff.set` to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- A - *A* (in force units)

- γ - *gamma* (in units of force/velocity)

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

To use the DPD thermostat, an `hoomd.md.integrate.nve` integrator must be applied to the system and the user must specify a temperature. Use of the dpd thermostat pair force with other integrators will result in unphysical behavior. To use pair.dpd with a different conservative potential than F_C, set A to zero and define the conservative pair potential separately. Note that DPD thermostats are often defined in terms of σ where $\sigma = \sqrt{2k_b\gamma T}$.

Example:

```
nl = nlist.cell()
dpd = pair.dpd(r_cut=1.0, nlist=nl, kT=1.0, seed=0)
dpd.pair_coeff.set('A', 'A', A=25.0, gamma = 4.5)
dpd.pair_coeff.set('A', 'B', A=40.0, gamma = 4.5)
dpd.pair_coeff.set('B', 'B', A=25.0, gamma = 4.5)
dpd.pair_coeff.set(['A', 'B'], ['C', 'D'], A=12.0, gamma = 1.2)
dpd.set_params(kT = 1.0)
integrate.mode_standard(dt=0.02)
integrate.nve(group=group.all())
```

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

> **Parameters**
>
> - **tags1** (`ndarray<int32>`) – a numpy array of particle tags in the first group
>
> - **tags2** (`ndarray<int32>`) – a numpy array of particle tags in the second group
>
> $$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$
>
> where $V_{ij}(r)$ is the pairwise energy between two particles i and j.
>
> Assumed properties of the sets *tags1* and *tags2* are:
>
> - *tags1* and *tags2* are disjoint
>
> - all elements in *tags1* and *tags2* are unique
>
> - *tags1* and *tags2* are contiguous numpy arrays of dtype int32
>
> None of these properties are validated.
>
> Examples:
>
> ```
> tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
> # computes the energy between even and odd particles
> U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
> →array(tags[1:N:2]))
> ```

disable(*log=False*)

Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

> ### Examples

> g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
>   Get all the types of shapes in the current simulation.
>
>   Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*kT=None*)
>   Changes parameters.
>
>>   **Parameters kT** (*hoomd.variant* or *float*) – Temperature of thermostat (in energy units).
>
>   Example:

```
dpd.set_params(kT=2.0)
```

class hoomd.md.pair.**dpd_conservative**(*r_cut*, *nlist*, *name=None*)
>   DPD Conservative pair force.
>
>>   **Parameters**
>>
>>   • **r_cut** (*float*) – Default cutoff radius (in distance units).
>>
>>   • **nlist** (*hoomd.md.nlist*) – Neighbor list
>>
>>   • **name** (*str*) – Name of the force instance.
>
>   *dpd_conservative* specifies the conservative part of the DPD pair potential should be applied between every non-excluded particle pair in the simulation. No thermostat (e.g. Drag Force and Random Force) is applied, as is in *dpd*.

$$V_{\mathrm{DPD-C}}(r) = \quad A \cdot (r_{\mathrm{cut}} - r) - \tfrac{1}{2} \cdot \frac{A}{r_{\mathrm{cut}}} \cdot \left(r_{\mathrm{cut}}^2 - r^2 \right) \quad r < r_{\mathrm{cut}}$$
$$= \qquad\qquad\qquad 0 \qquad\qquad\qquad r \geq r_{\mathrm{cut}}$$

>   *dpd_conservative* does not implement and energy shift / smoothing modes due to the function of the force. Use *pair_coeff.set* to set potential coefficients.
>
>   The following coefficients must be set per unique pair of particle types:
>
>   • *A* - *A* (in force units)
>
>   • r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command
>
>   Example:

```
nl = nlist.cell()
dpdc = pair.dpd_conservative(r_cut=3.0, nlist=nl)
dpdc.pair_coeff.set('A', 'A', A=1.0)
dpdc.pair_coeff.set('A', 'B', A=2.0, r_cut = 1.0)
dpdc.pair_coeff.set('B', 'B', A=1.0)
dpdc.pair_coeff.set(['A', 'B'], ['C', 'D'], A=5.0)
```

compute_energy(*tags1*, *tags2*)
>   Compute the energy between two sets of particles.
>
>>   **Parameters**
>>
>>   • **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group
>>
>>   • **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \mathrm{tags1}, j \in \mathrm{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable (*log=False*)

Disable the force.

> **Parameters** **log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable ()

Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy (*group*)

Get the energy of a particle group.

> **Parameters** **group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force (*group*)

Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
Get all the types of shapes in the current simulation.

Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*coeff*)
dpd_conservative has no energy shift modes

class hoomd.md.pair.**dpdlj**(*r_cut*, *nlist*, *kT*, *seed*, *name=None*)
Dissipative Particle Dynamics with a LJ conservative force

> **Parameters**
>
> - **r_cut** (*float*) – Default cutoff radius (in distance units).
> - **nlist** (*hoomd.md.nlist*) – Neighbor list
> - **kT** (*hoomd.variant* or *float*) – Temperature of thermostat (in energy units).
> - **seed** (*int*) – seed for the PRNG in the DPD thermostat.
> - **name** (*str*) – Name of the force instance.

dpdlj specifies that a DPD thermostat and a Lennard-Jones pair potential should be applied between every non-excluded particle pair in the simulation.

C. L. Phillips et. al. 2011 describes the DPD implementation details in HOOMD-blue. Cite it if you utilize the DPD functionality in your work.

$$F = F_{\mathrm{C}}(r) + F_{\mathrm{R,ij}}(r_{ij}) + F_{\mathrm{D,ij}}(v_{ij})$$

$$
\begin{aligned}
F_{\mathrm{C}}(r) &= \partial V_{\mathrm{LJ}}/\partial r \\
F_{\mathrm{R,ij}}(r_{ij}) &= -\theta_{ij}\sqrt{3}\sqrt{\frac{2k_b\gamma T}{\Delta t}} \cdot w(r_{ij}) \\
F_{\mathrm{D,ij}}(r_{ij}) &= -\gamma w^2(r_{ij})\left(\hat{r}_{ij} \circ v_{ij}\right)
\end{aligned}
$$

$$V_{\mathrm{LJ}}(r) = \quad 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \alpha \left(\frac{\sigma}{r}\right)^{6} \right] \quad r < r_{\mathrm{cut}}$$
$$= \quad\quad 0 \quad\quad r \geq r_{\mathrm{cut}}$$

$$w(r_{ij}) = \quad (1 - r/r_{\mathrm{cut}}) \quad r < r_{\mathrm{cut}}$$
$$= \quad\quad 0 \quad\quad r \geq r_{\mathrm{cut}}$$

where $\hat{r}_{ij}$ is a normalized vector from particle i to particle j, $v_{ij} = v_i - v_j$, and θ_{ij} is a uniformly distributed random number in the range [-1, 1].

Use `pair_coeff.set` to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in energy units)
- σ - *sigma* (in distance units)
- α - *alpha* (unitless) - *optional*: defaults to 1.0
- γ - *gamma* (in units of force/velocity)
- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

To use the DPD thermostat, an `hoomd.md.integrate.nve` integrator must be applied to the system and the user must specify a temperature. Use of the dpd thermostat pair force with other integrators will result in unphysical behavior.

Example:

```
nl = nlist.cell()
dpdlj = pair.dpdlj(r_cut=2.5, nlist=nl, kT=1.0, seed=0)
dpdlj.pair_coeff.set('A', 'A', epsilon=1.0, sigma = 1.0, gamma = 4.5)
dpdlj.pair_coeff.set('A', 'B', epsilon=0.0, sigma = 1.0 gamma = 4.5)
dpdlj.pair_coeff.set('B', 'B', epsilon=1.0, sigma = 1.0 gamma = 4.5, r_cut = 2.
↪0**(1.0/6.0))
dpdlj.pair_coeff.set(['A', 'B'], ['C', 'D'], epsilon = 3.0,sigma=1.0, gamma = 1.2)
dpdlj.set_params(T = 1.0)
integrate.mode_standard(dt=0.005)
integrate.nve(group=group.all())
```

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group
- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \mathrm{tags1}, j \in \mathrm{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint
- all elements in *tags1* and *tags2* are unique
- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)
> Disable the force.

>> **Parameters log** ([*bool*](#)) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

> Executing the disable command will remove the force from the simulation. Any [*hoomd.run()*](#) command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with [*enable()*](#).

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See [*disable()*](#).

get_energy(*group*)
> Get the energy of a particle group.

>> **Parameters group** ([*hoomd.group*](#)) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

>> **Parameters group** ([*hoomd.group*](#)) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

`get_net_virial`(*group*)

> Get the virial of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

Examples

> g = group.all() virial = force.get_net_virial(g)

`get_type_shapes`()

> Get all the types of shapes in the current simulation.

> Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

`set_params`(*kT=None*, *mode=None*)

> Changes parameters.

> > **Parameters**

> > > - **T** (*hoomd.variant* or *float*) – Temperature (if set) (in energy units)

> > > - **mode** (*str*) – energy shift/smoothing mode (default noshift).

> Examples:

```
dpdlj.set_params(kT=variant.linear_interp(points = [(0, 1.0), (1e5, 2.0)]))
dpdlj.set_params(kT=2.0, mode="shift")
```

class `hoomd.md.pair.`**`ewald`**(*r_cut*, *nlist*, *name=None*)

> Ewald pair potential.

> *ewald* specifies that a Ewald pair potential should be applied between every non-excluded particle pair in the simulation.

$$
\begin{aligned}
V_{\text{ewald}}(r) = \quad & q_i q_j \left[\text{erfc}\left(\kappa r + \tfrac{\alpha}{2\kappa}\right) \exp(\alpha r) + \text{erfc}\left(\kappa r - \tfrac{\alpha}{2\kappa}\right) \exp(-\alpha r)\right] & r < r_{\text{cut}} \\
= \quad & 0 & r \geq r_{\text{cut}}
\end{aligned}
$$

> The Ewald potential is designed to be used in conjunction with *hoomd.md.charge.pppm*.

> See *pair* for details on how forces are calculated and the available energy shifting and smoothing modes. Use *pair_coeff.set* to set potential coefficients.

> The following coefficients must be set per unique pair of particle types:

> - κ - *kappa* (Splitting parameter, in 1/distance units)

> - α - **alpha** (**Debye screening length, in 1/distance units**) New in version 2.1.

> - r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

> - r_{on} - *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

> Example:

```
nl = nlist.cell()
ewald = pair.ewald(r_cut=3.0, nlist=nl)
ewald.pair_coeff.set('A', 'A', kappa=1.0)
ewald.pair_coeff.set('A', 'A', kappa=1.0, alpha=1.5)
ewald.pair_coeff.set('A', 'B', kappa=1.0, r_cut=3.0, r_on=2.0);
```

> **Warning:** **DO NOT** use in conjunction with *hoomd.md.charge.pppm*. It automatically creates and configures *ewald* for you.

compute_energy(*tags1*, *tags2*)
    Compute the energy between two sets of particles.

> **Parameters**
>
>> - **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group
>>
>> - **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)
    Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
    Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy (*group*)
>   Get the energy of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

>   Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force (*group*)
>   Get the force of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

Examples

>   g = group.all() force = force.get_net_force(g)

get_net_virial (*group*)
>   Get the virial of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

>> **Returns** The last computed virial for the members in the group.

Examples

>   g = group.all() virial = force.get_net_virial(g)

get_type_shapes ()
>   Get all the types of shapes in the current simulation.

>   Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params (*coeff*)
>   *ewald* has no energy shift modes

class hoomd.md.pair.**force_shifted_lj** (*r_cut*, *nlist*, *name=None*)
>   Force-shifted Lennard-Jones pair potential.

>> **Parameters**

>>> - **r_cut** (*float*) – Default cutoff radius (in distance units).
>>> - **nlist** (*hoomd.md.nlist*) – Neighbor list
>>> - **name** (*str*) – Name of the force instance.

>   *force_shifted_lj* specifies that a modified Lennard-Jones pair force should be applied between non-excluded particle pair in the simulation. The force differs from the one calculated by *lj* by the subtraction of the value of the force at r_{cut}, such that the force smoothly goes to zero at the cut-off. The potential is modified by a linear function. This potential can be used as a substitute for *lj*, when the exact analytical form of the

latter is not required but a smaller cut-off radius is desired for computational efficiency. See Toxvaerd et. al. 2011 for a discussion of this potential.

$$V(r) = \quad 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \alpha \left(\frac{\sigma}{r}\right)^{6} \right] + \Delta V(r) \quad r < r_{\mathrm{cut}}$$
$$= \qquad\qquad\qquad 0 \qquad\qquad\qquad r \geq r_{\mathrm{cut}}$$

$$\Delta V(r) = -(r - r_{\mathrm{cut}}) \frac{\partial V_{\mathrm{LJ}}}{\partial r}(r_{\mathrm{cut}})$$

See `pair` for details on how forces are calculated and the available energy shifting and smoothing modes. Use `pair_coeff.set` to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in energy units)

- σ - *sigma* (in distance units)

- α - *alpha* (unitless) - *optional*: defaults to 1.0

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on}- *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

Example:

```
nl = nlist.cell()
fslj = pair.force_shifted_lj(r_cut=1.5, nlist=nl)
fslj.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
```

compute_energy (*tags1*, *tags2*)

Compute the energy between two sets of particles.

> **Parameters**
>
> - **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group
>
> - **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \mathrm{tags1}, j \in \mathrm{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
→array(tags[1:N:2]))
```

disable (*log=False*)

Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
   Enable the force.

   Examples:

```
force.enable()
```

   See *disable()*.

get_energy(*group*)
   Get the energy of a particle group.

   > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

   > **Returns** The last computed energy for the members in the group.

   Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
   Get the force of a particle group.

   > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

   > **Returns** The last computed force for the members in the group.

   ### Examples

   g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
   Get the virial of a particle group.

   > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

   > **Returns** The last computed virial for the members in the group.

   ### Examples

   g = group.all() virial = force.get_net_virial(g)

> **get_type_shapes**()
>> Get all the types of shapes in the current simulation.
>>
>> Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.
>
> **set_params**(*mode=None*)
>> Set parameters controlling the way forces are computed.
>>
>>> **Parameters mode** (*str*) – (if set) Set the mode with which potentials are handled at the cutoff.
>>
>> Valid values for *mode* are: "none" (the default), "shift", and "xplor":
>>
>> - **none** - No shifting is performed and potentials are abruptly cut off
>> - **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff
>> - **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.
>>
>> See *pair* for the equations.
>>
>> Examples:
>>
>> ```
>> mypair.set_params(mode="shift")
>> mypair.set_params(mode="no_shift")
>> mypair.set_params(mode="xplor")
>> ```

class hoomd.md.pair.**fourier**(*r_cut*, *nlist*, *name=None*)
> Fourier pair potential.
>
>> **Parameters**
>>
>> - **r_cut** (*float*) – Default cutoff radius (in distance units).
>> - **nlist** (*hoomd.md.nlist*) – Neighbor list
>> - **name** (*str*) – Name of the force instance.
>
> *fourier* specifies that a fourier series form potential.
>
> $$V_{\text{Fourier}}(r) = \quad \frac{1}{r^{12}} + \frac{1}{r^2}\sum_{n=1}^{4}[a_n cos(\frac{n\pi r}{r_{cut}}) + b_n sin(\frac{n\pi r}{r_{cut}})] \quad r < r_{\text{cut}}$$
> $$= \quad 0 \quad r \geq r_{\text{cut}}$$
>
> where:
>
> $$a_1 = \sum_{n=2}^{4}(-1)^n a_n cos(\frac{n\pi r}{r_{cut}})$$
>
> $$b_1 = \sum_{n=2}^{4} n(-1)^n b_n cos(\frac{n\pi r}{r_{cut}})$$
>
> is calculated to enforce close to zero value at $r_cut. See pair for details on how forces are calculated and the available energy shif$

The following coefficients must be set per unique pair of particle types:

- a - a (array of 3 values corresponding to a2, a3 and a4 in the Fourier series, unitless)
- a - b (array of 3 values corresponding to b2, b3 and b4 in the Fourier series, unitless)

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on} - *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

Example:

```
nl = nlist.cell()
fourier = pair.fourier(r_cut=3.0, nlist=nl)
fourier.pair_coeff.set('A', 'A', a=[a2,a3,a4], b=[b2,b3,b4])
```

compute_energy(*tags1*, *tags2*)

    Compute the energy between two sets of particles.

        Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in tags1, j \in tags2} V_{ij}(r)$$

    where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

    Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

    None of these properties are validated.

    Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
→array(tags[1:N:2]))
```

disable(*log=False*)

    Disable the force.

        Parameters log (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

    Examples:

```
force.disable()
force.disable(log=True)
```

    Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

    By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

    Enable the force.

    Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)
 Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
 Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
 Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
 Get all the types of shapes in the current simulation.

 Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)
 Set parameters controlling the way forces are computed.

> **Parameters mode** (*str*) – (if set) Set the mode with which potentials are handled at the cutoff.

 Valid values for *mode* are: "none" (the default), "shift", and "xplor":

- **none** - No shifting is performed and potentials are abruptly cut off

- **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff

- **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

See *pair* for the equations.

Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**gauss**(*r_cut*, *nlist*, *name=None*)

    Gaussian pair potential.

        Parameters

- **r_cut** (*float*) – Default cutoff radius (in distance units).

- **nlist** (*hoomd.md.nlist*) – Neighbor list

- **name** (*str*) – Name of the force instance.

gauss specifies that a Gaussian pair potential should be applied between every non-excluded particle pair in the simulation.

$$
\begin{aligned}
V_{\text{gauss}}(r) = \quad & \varepsilon \exp\left[-\tfrac{1}{2}\left(\tfrac{r}{\sigma}\right)^2\right] \quad & r < r_{\text{cut}} \\
= \quad & 0 \quad & r \geq r_{\text{cut}}
\end{aligned}
$$

See *pair* for details on how forces are calculated and the available energy shifting and smoothing modes. Use *pair_coeff.set* to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in energy units)

- σ - *sigma* (in distance units)

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on} - *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

Example:

```
nl = nlist.cell()
gauss = pair.gauss(r_cut=3.0, nlist=nl)
gauss.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
gauss.pair_coeff.set('A', 'B', epsilon=2.0, sigma=1.0, r_cut=3.0, r_on=2.0);
gauss.pair_coeff.set(['A', 'B'], ['C', 'D'], epsilon=3.0, sigma=0.5)
```

compute_energy(*tags1*, *tags2*)

    Compute the energy between two sets of particles.

        Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$
U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)
$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)
> Disable the force.

> > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

> Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

`get_net_virial`(*group*)

> Get the virial of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

> ### Examples

> g = group.all() virial = force.get_net_virial(g)

`get_type_shapes`()

> Get all the types of shapes in the current simulation.

> Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

`set_params`(*mode=None*)

> Set parameters controlling the way forces are computed.

> > **Parameters mode** (*str*) – (if set) Set the mode with which potentials are handled at the cutoff.

> Valid values for *mode* are: "none" (the default), "shift", and "xplor":

> - **none** - No shifting is performed and potentials are abruptly cut off

> - **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff

> - **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

> See *pair* for the equations.

> Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**gb**(*r_cut*, *nlist*, *name=None*)

> Gay-Berne anisotropic pair potential.

> > **Parameters**

> > - **r_cut** (*float*) – Default cutoff radius (in distance units).

> > - **nlist** (*hoomd.md.nlist*) – Neighbor list

> > - **name** (*str*) – Name of the force instance.

gb computes the Gay-Berne potential between anisotropic particles.

This version of the Gay-Berne potential supports identical pairs of uniaxial ellipsoids, with orientation-independent energy-well depth.

The interaction energy for this anisotropic pair potential is (Allen et. al. 2006):

$$V_{\mathrm{GB}}(\vec{r}, \vec{e}_i, \vec{e}_j) = \quad 4\varepsilon \left[\zeta^{-12} - \zeta^{-6} \right] \quad \zeta < \zeta_{\mathrm{cut}}$$
$$= \qquad\qquad 0 \qquad\qquad \zeta \geq \zeta_{\mathrm{cut}}$$

$$\zeta = \left(\frac{r - \sigma + \sigma_{\min}}{\sigma_{\min}} \right)$$

$$\sigma^{-2} = \frac{1}{2} \hat{\vec{r}} \cdot \vec{H}^{-1} \cdot \hat{\vec{r}}$$

$$\vec{H} = 2\ell_\perp^2 \vec{1} + (\ell_\parallel^2 - \ell_\perp^2)(\vec{e}_i \otimes \vec{e}_i + \vec{e}_j \otimes \vec{e}_j)$$

with $\sigma_{\min} = 2\min(\ell_\perp, \ell_\parallel)$.

The cut-off parameter r_{cut} is defined for two particles oriented parallel along the **long** axis, i.e. $\zeta_{\mathrm{cut}} = \left(\frac{r - \sigma_{\max} + \sigma_{\min}}{\sigma_{\min}} \right)$ where $\sigma_{\max} = 2\max(\ell_\perp, \ell_\parallel)$.

The quantities $\ell_\parallel$ and $\ell_\perp$ denote the semi-axis lengths parallel and perpendicular to particle orientation.

Use *pair_coeff.set* to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in energy units)

- $\ell_\perp$ - *lperp* (in distance units)

- $\ell_\parallel$ - *lpar* (in distance units)

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

Example:

```
nl = nlist.cell()
gb = pair.gb(r_cut=2.5, nlist=nl)
gb.pair_coeff.set('A', 'A', epsilon=1.0, lperp=0.45, lpar=0.5)
gb.pair_coeff.set('A', 'B', epsilon=2.0, lperp=0.45, lpar=0.5, r_cut=2**(1.0/6.
→0));
```

compute_energy (*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \mathrm{tags1}, j \in \mathrm{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
→array(tags[1:N:2]))
```

disable(*log=False*)
   Disable the force.

   > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

   Examples:

   ```
   force.disable()
   force.disable(log=True)
   ```

   Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

   By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
   Enable the force.

   Examples:

   ```
   force.enable()
   ```

   See *disable()*.

get_energy(*group*)
   Get the energy of a particle group.

   > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

   > **Returns** The last computed energy for the members in the group.

   Examples:

   ```
   g = group.all()
   energy = force.get_energy(g)
   ```

get_net_force(*group*)
   Get the force of a particle group.

   > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

   > **Returns** The last computed force for the members in the group.

   ### Examples

   g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
   Get the virial of a particle group.

   > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

   > **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
  Get all the types of shapes in the current simulation.

Example

```
>>> my_gb.get_type_shapes()
[{'type': 'Ellipsoid', 'a': 1.0, 'b': 1.0, 'c': 1.5}]
```

  Returns A list of dictionaries, one for each particle type in the system.

set_params(*mode=None*)
  Set parameters controlling the way forces are computed.

  Parameters mode (*str*) – (if set) Set the mode with which potentials are handled at the cutoff

  valid values for mode are: "none" (the default) and "shift":

  - *none* - No shifting is performed and potentials are abruptly cut off

  - *shift* - A constant shift is applied to the entire potential so that it is 0 at the cutoff

  Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
```

shape
  Get or set shape parameters per type.

  In addition to any pair-specific parameters required to characterize a pair potential, individual particles that have anisotropic interactions may also have their own shapes that affect the potentials. General anisotropic pair potentials may set per-particle shapes using this method.

class hoomd.md.pair.**lj**(*r_cut*, *nlist*, *name=None*)
  Lennard-Jones pair potential.

  Parameters

  - **r_cut** (*float*) – Default cutoff radius (in distance units).

  - **nlist** (*hoomd.md.nlist*) – Neighbor list

  - **name** (*str*) – Name of the force instance.

`lj` specifies that a Lennard-Jones pair potential should be applied between every non-excluded particle pair in the simulation.

$$\begin{aligned} V_{\mathrm{LJ}}(r) = & \quad 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \alpha \left(\frac{\sigma}{r}\right)^6 \right] & r < r_{\mathrm{cut}} \\ = & \quad 0 & r \geq r_{\mathrm{cut}} \end{aligned}$$

See `pair` for details on how forces are calculated and the available energy shifting and smoothing modes. Use `pair_coeff.set` to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in energy units)

- σ - *sigma* (in distance units)

- α - *alpha* (unitless) - *optional*: defaults to 1.0

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on}- *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

Example:

```
nl = nlist.cell()
lj = pair.lj(r_cut=3.0, nlist=nl)
lj.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
lj.pair_coeff.set('A', 'B', epsilon=2.0, sigma=1.0, alpha=0.5, r_cut=3.0, r_on=2.
↪0);
lj.pair_coeff.set('B', 'B', epsilon=1.0, sigma=1.0, r_cut=2**(1.0/6.0), r_on=2.0);
lj.pair_coeff.set(['A', 'B'], ['C', 'D'], epsilon=1.5, sigma=2.0)
```

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)

Disable the force.

Parameters log (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

> ### Examples

> g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
> Get all the types of shapes in the current simulation.

> Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)
> Set parameters controlling the way forces are computed.

> > **Parameters mode** (*str*) – (if set) Set the mode with which potentials are handled at the cutoff.

> Valid values for *mode* are: "none" (the default), "shift", and "xplor":

> - **none** - No shifting is performed and potentials are abruptly cut off

- **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff

- **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

See `pair` for the equations.

Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**lj1208**(*r_cut*, *nlist*, *name=None*)

Lennard-Jones 12-8 pair potential.

Parameters

- **r_cut** (*float*) – Default cutoff radius (in distance units).

- **nlist** (*hoomd.md.nlist*) – Neighbor list

- **name** (*str*) – Name of the force instance.

`lj1208` specifies that a Lennard-Jones pair potential should be applied between every non-excluded particle pair in the simulation.

$$
\begin{aligned}
V_{\mathrm{LJ}}(r) = \quad & 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \alpha \left(\frac{\sigma}{r}\right)^{8} \right] \quad & r < r_{\mathrm{cut}} \\
= \quad & 0 \quad & r \geq r_{\mathrm{cut}}
\end{aligned}
$$

See `pair` for details on how forces are calculated and the available energy shifting and smoothing modes. Use `pair_coeff.set` to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in energy units)

- σ - *sigma* (in distance units)

- α - *alpha* (unitless) - *optional*: defaults to 1.0

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on} - *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

New in version 2.2.

Changed in version 2.2.

Example:

```
nl = nlist.cell()
lj1208 = pair.lj1208(r_cut=3.0, nlist=nl)
lj1208.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0)
lj1208.pair_coeff.set('A', 'B', epsilon=2.0, sigma=1.0, alpha=0.5, r_cut=3.0, r_
↪on=2.0);
lj1208.pair_coeff.set('B', 'B', epsilon=1.0, sigma=1.0, r_cut=2**(1.0/6.0), r_
↪on=2.0);
lj1208.pair_coeff.set(['A', 'B'], ['C', 'D'], epsilon=1.5, sigma=2.0)
```

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
→array(tags[1:N:2]))
```

disable (*log=False*)

Disable the force.

Parameters log (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable ()

Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy (*group*)

Get the energy of a particle group.

Parameters group (*hoomd.group*) – The particle group to query the energy for.

Returns The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

> **Parameters group** ([*hoomd.group*](#)) – The particle group to query the force for.
>
> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

> **Parameters group** ([*hoomd.group*](#)) – The particle group to query the virial for.
>
> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()

Get all the types of shapes in the current simulation.

Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)

Set parameters controlling the way forces are computed.

> **Parameters mode** ([*str*](#)) – (if set) Set the mode with which potentials are handled at the cutoff.

Valid values for *mode* are: "none" (the default), "shift", and "xplor":

- **none** - No shifting is performed and potentials are abruptly cut off

- **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff

- **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

See [*pair*](#) for the equations.

Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**mie**(*r_cut*, *nlist*, *name=None*)

Mie pair potential.

> **Parameters**
>
> - **r_cut** ([*float*](#)) – Default cutoff radius (in distance units).
>
> - **nlist** ([*hoomd.md.nlist*](#)) – Neighbor list

- **name** (`str`) – Name of the force instance.

`mie` specifies that a Mie pair potential should be applied between every non-excluded particle pair in the simulation.

$$
\begin{aligned}
V_{\mathrm{mie}}(r) = \quad & \left(\tfrac{n}{n-m}\right)\left(\tfrac{n}{m}\right)^{\frac{m}{n-m}} \varepsilon \left[\left(\tfrac{\sigma}{r}\right)^n - \left(\tfrac{\sigma}{r}\right)^m \right] & r < r_{\mathrm{cut}} \\
= \quad & 0 & r \geq r_{\mathrm{cut}}
\end{aligned}
$$

See `pair` for details on how forces are calculated and the available energy shifting and smoothing modes. Use `pair_coeff.set` to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in energy units)
- σ - *sigma* (in distance units)
- n - *n* (unitless)
- m - *m* (unitless)
- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command
- r_{on}- *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

Example:

```
nl = nlist.cell()
mie = pair.mie(r_cut=3.0, nlist=nl)
mie.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0, n=12, m=6)
mie.pair_coeff.set('A', 'B', epsilon=2.0, sigma=1.0, n=14, m=7, r_cut=3.0, r_on=2.
→0);
mie.pair_coeff.set('B', 'B', epsilon=1.0, sigma=1.0, n=15.1, m=6.5, r_cut=2**(1.0/
→6.0), r_on=2.0);
mie.pair_coeff.set(['A', 'B'], ['C', 'D'], epsilon=1.5, sigma=2.0)
```

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group
- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$
U = \sum_{i \in \mathrm{tags1}, j \in \mathrm{tags2}} V_{ij}(r)
$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint
- all elements in *tags1* and *tags2* are unique
- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
 ↪array(tags[1:N:2]))
```

disable(*log=False*)

Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)

Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
> Get all the types of shapes in the current simulation.

> Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)
> Set parameters controlling the way forces are computed.

> > **Parameters mode** (`str`) – (if set) Set the mode with which potentials are handled at the cutoff.

> Valid values for *mode* are: "none" (the default), "shift", and "xplor":

> - **none** - No shifting is performed and potentials are abruptly cut off
>
> - **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff
>
> - **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

> See `pair` for the equations.

> Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**moliere**(*r_cut*, *nlist*, *name=None*)
> Moliere pair potential.

> > **Parameters**

> > - **r_cut** (`float`) – Default cutoff radius (in distance units).
> >
> > - **nlist** (`hoomd.md.nlist`) – Neighbor list
> >
> > - **name** (`str`) – Name of the force instance.

> `moliere` specifies that a Moliere type pair potential should be applied between every non-excluded particle pair in the simulation.

$$V_{\text{Moliere}}(r) = \frac{Z_i Z_j e^2}{4\pi\epsilon_0 r_{ij}} \left[0.35 \exp\left(-0.3\frac{r_{ij}}{a_F}\right) + 0.55 \exp\left(-1.2\frac{r_{ij}}{a_F}\right) + 0.10 \exp\left(-6.0\frac{r_{ij}}{a_F}\right) \right] \quad r < r_{\text{cut}}$$
$$= 0 \quad r > r_{\text{cut}}$$

> See `pair` for details on how forces are calculated and the available energy shifting and smoothing modes. Use `pair_coeff.set` to set potential coefficients.

> The following coefficients must be set per unique pair of particle types:

> - Z_i - Z_i - Atomic number of species i (unitless)
>
> - Z_j - Z_j - Atomic number of species j (unitless)
>
> - e - *elementary_charge* - The elementary charge (in charge units)

- a_0 - *a_0* - The Bohr radius (in distance units)
- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command
- r_{on}- *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

Example:

```
nl = nlist.cell()
moliere = pair.moliere(r_cut = 3.0, nlist=nl)
moliere.pair_coeff.set('A', 'B', Z_i = 54.0, Z_j = 7.0, elementary_charge = 1.0,
↪a_0 = 1.0);
```

compute_energy(*tags1*, *tags2*)
    Compute the energy between two sets of particles.

> **Parameters**
>
> - **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group
> - **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint
- all elements in *tags1* and *tags2* are unique
- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)
    Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy
> associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
    Enable the force.

    Examples:

```
force.enable()
```

    See *disable()*.

get_energy(*group*)
    Get the energy of a particle group.

        Parameters group (*hoomd.group*) – The particle group to query the energy for.

        Returns The last computed energy for the members in the group.

    Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
    Get the force of a particle group.

        Parameters group (*hoomd.group*) – The particle group to query the force for.

        Returns The last computed force for the members in the group.

Examples

    g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
    Get the virial of a particle group.

        Parameters group (*hoomd.group*) – The particle group to query the virial for.

        Returns The last computed virial for the members in the group.

Examples

    g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
    Get all the types of shapes in the current simulation.

    Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)
    Set parameters controlling the way forces are computed.

        Parameters mode (*str*) – (if set) Set the mode with which potentials are handled at the cutoff.

    Valid values for *mode* are: "none" (the default), "shift", and "xplor":

- **none** - No shifting is performed and potentials are abruptly cut off
- **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff
- **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

See `pair` for the equations.

Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**morse**(*r_cut*, *nlist*, *name=None*)

Morse pair potential.

`morse` specifies that a Morse pair potential should be applied between every non-excluded particle pair in the simulation.

$$
\begin{aligned}
V_{\mathrm{morse}}(r) = & \quad D_0 \left[\exp\left(-2\alpha\left(r-r_0\right)\right) - 2\exp\left(-\alpha\left(r-r_0\right)\right) \right] & r < r_{\mathrm{cut}} \\
= & \quad\quad\quad\quad\quad\quad\quad\quad 0 & r \geq r_{\mathrm{cut}}
\end{aligned}
$$

See `pair` for details on how forces are calculated and the available energy shifting and smoothing modes. Use `pair_coeff.set` to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- D_0 - *D0*, depth of the potential at its minimum (in energy units)

- α - *alpha*, controls the width of the potential well (in units of 1/distance)

- r_0 - *r0*, position of the minimum (in distance units)

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on} - *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

Example:

```
nl = nlist.cell()
morse = pair.morse(r_cut=3.0, nlist=nl)
morse.pair_coeff.set('A', 'A', D0=1.0, alpha=3.0, r0=1.0)
morse.pair_coeff.set('A', 'B', D0=1.0, alpha=3.0, r0=1.0, r_cut=3.0, r_on=2.0);
morse.pair_coeff.set(['A', 'B'], ['C', 'D'], D0=1.0, alpha=3.0)
```

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$
U = \sum_{i \in \mathrm{tags1}, j \in \mathrm{tags2}} V_{ij}(r)
$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)

Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)

Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

`get_net_virial`(*group*)
    Get the virial of a particle group.

        Parameters group (*hoomd.group*) – The particle group to query the virial for.

        Returns The last computed virial for the members in the group.

Examples

    g = group.all() virial = force.get_net_virial(g)

`get_type_shapes`()
    Get all the types of shapes in the current simulation.

    Since this behaves differently for different types of shapes, the default behavior just raises an exception.
    Subclasses can override this to properly return.

`set_params`(*mode=None*)
    Set parameters controlling the way forces are computed.

        Parameters mode (*str*) – (if set) Set the mode with which potentials are handled at the cutoff.

    Valid values for *mode* are: "none" (the default), "shift", and "xplor":

- **none** - No shifting is performed and potentials are abruptly cut off

- **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff

- **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

    See *pair* for the equations.

    Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**pair**(*r_cut*, *nlist*, *name=None*)
    Common pair potential documentation.

Users should not invoke *pair* directly. It is a base command that provides common features to all standard pair forces. Common documentation for all pair potentials is documented here.

All pair force commands specify that a given potential energy and force be computed on all non-excluded particle pairs in the system within a short range cutoff distance r_{cut}.

The force $\vec{F}$ applied between each pair of particles is:

$$\begin{aligned} \vec{F} &= -\nabla V(r) & r < r_{\mathrm{cut}} \\ &= 0 & r \geq r_{\mathrm{cut}} \end{aligned}$$

where $\vec{r}$ is the vector pointing from one particle to the other in the pair, and $V(r)$ is chosen by a mode switch (see *set_params()*):

$$\begin{aligned} V(r) &= V_{\mathrm{pair}}(r) & \text{mode is no\_shift} \\ &= V_{\mathrm{pair}}(r) - V_{\mathrm{pair}}(r_{\mathrm{cut}}) & \text{mode is shift} \\ &= S(r) \cdot V_{\mathrm{pair}}(r) & \text{mode is xplor and } r_{\mathrm{on}} < r_{\mathrm{cut}} \\ &= V_{\mathrm{pair}}(r) - V_{\mathrm{pair}}(r_{\mathrm{cut}}) & \text{mode is xplor and } r_{\mathrm{on}} \geq r_{\mathrm{cut}} \end{aligned}$$

$S(r)$ is the XPLOR smoothing function:

$$
\begin{aligned}
S(r) &= 1 & r < r_{\mathrm{on}} \\
&= \frac{(r_{\mathrm{cut}}^2 - r^2)^2 \cdot (r_{\mathrm{cut}}^2 + 2r^2 - 3r_{\mathrm{on}}^2)}{(r_{\mathrm{cut}}^2 - r_{\mathrm{on}}^2)^3} & r_{\mathrm{on}} \le r \le r_{\mathrm{cut}} \\
&= 0 & r > r_{\mathrm{cut}}
\end{aligned}
$$

and $V_{\mathrm{pair}}(r)$ is the specific pair potential chosen by the respective command.

Enabling the XPLOR smoothing function $S(r)$ results in both the potential energy and the force going smoothly to 0 at $r = r_{\mathrm{cut}}$, reducing the rate of energy drift in long simulations. r_{on} controls the point at which the smoothing starts, so it can be set to only slightly modify the tail of the potential. It is suggested that you plot your potentials with various values of r_{on} in order to find a good balance between a smooth potential function and minimal modification of the original $V_{\mathrm{pair}}(r)$. A good value for the LJ potential is $r_{\mathrm{on}} = 2 \cdot \sigma$.

The split smoothing / shifting of the potential when the mode is `xplor` is designed for use in mixed WCA / LJ systems. The WCA potential and it's first derivative already go smoothly to 0 at the cutoff, so there is no need to apply the smoothing function. In such mixed systems, set r_{on} to a value greater than r_{cut} for those pairs that interact via WCA in order to enable shifting of the WCA potential to 0 at the cutoff.

The following coefficients must be set per unique pair of particle types. See *hoomd.md.pair* for information on how to set coefficients:

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command
- r_{on} - *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

When $r_{\mathrm{cut}} \le 0$ or is set to False, the particle type pair interaction is excluded from the neighbor list. This mechanism can be used in conjunction with multiple neighbor lists to make efficient calculations in systems with large size disparity. Functionally, this is equivalent to setting $r_{\mathrm{cut}} = 0$ in the pair force because negative r_{cut} has no physical meaning.

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group
- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \mathrm{tags1}, j \in \mathrm{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint
- all elements in *tags1* and *tags2* are unique
- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
→array(tags[1:N:2]))
```

disable(*log=False*)
> Disable the force.

> > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy
> > associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

> Executing the disable command will remove the force from the simulation. Any *hoomd.run()* com-
> mand executed after disabling a force will not calculate or use the force during the simulation. A disabled
> force can be re-enabled with *enable()*.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the
> simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used
> throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would
> be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

Examples

> g = group.all() virial = force.get_net_virial(g)

get_type_shapes ()
> Get all the types of shapes in the current simulation.
>
> Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params (*mode=None*)
> Set parameters controlling the way forces are computed.
>
> > **Parameters mode** (`str`) – (if set) Set the mode with which potentials are handled at the cutoff.
>
> Valid values for *mode* are: "none" (the default), "shift", and "xplor":
>
> * **none** - No shifting is performed and potentials are abruptly cut off
>
> * **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff
>
> * **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.
>
> See `pair` for the equations.
>
> Examples:
>
> ```
> mypair.set_params(mode="shift")
> mypair.set_params(mode="no_shift")
> mypair.set_params(mode="xplor")
> ```

class hoomd.md.pair.**reaction_field** (*r_cut*, *nlist*, *name=None*)
> Onsager reaction field pair potential.
>
> > **Parameters**
> >
> > * **r_cut** (`float`) – Default cutoff radius (in distance units).
> >
> > * **nlist** (`hoomd.md.nlist`) – Neighbor list
> >
> > * **name** (`str`) – Name of the force instance.
>
> `reaction_field` specifies that an Onsager reaction field pair potential should be applied between every non-excluded particle pair in the simulation.
>
> Reaction field electrostatics is an approximation to the screened electrostatic interaction, which assumes that the medium can be treated as an electrostatic continuum of dielectric constant ϵ_{RF} outside the cutoff sphere of radius r_{cut}. See: Barker et. al. 1973.
>
> $$V_{\mathrm{RF}}(r) = \varepsilon \left[\frac{1}{r} + \frac{(\epsilon_{RF} - 1)r^2}{(2\epsilon_{RF} + 1)r_c^3} \right]$$
>
> By default, the reaction field potential does not require charge or diameter to be set. Two parameters, ε and ϵ_{RF} are needed. If $epsilon_{RF}$ is specified as zero, it will represent infinity.
>
> If *use_charge* is set to True, the following formula is evaluated instead: .. math:
>
> ```
> V_{\mathrm{RF}}(r) = q_i q_j \varepsilon \left[ \frac{1}{r} +
>     \frac{(\epsilon_{RF}-1) r^2}{(2 \epsilon_{RF} + 1) r_c^3} \right]
> ```
>
> where q_i and q_j are the charges of the particle pair.
>
> See `pair` for details on how forces are calculated and the available energy shifting and smoothing modes. Use `pair_coeff.set` to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in units of energy*distance)

- ϵ_{RF} - *eps_rf* (dimensionless)

- r_{cut} - *r_cut* (in units of distance) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on} - *r_on* (in units of distance) - *optional*: defaults to the global r_cut specified in the pair command

- *use_charge* (boolean), evaluate potential using particle charges - *optional*: defaults to False

New in version 2.1.

Example:

```
nl = nlist.cell()
reaction_field = pair.reaction_field(r_cut=3.0, nlist=nl)
reaction_field.pair_coeff.set('A', 'A', epsilon=1.0, eps_rf=1.0)
reaction_field.pair_coeff.set('A', 'B', epsilon=-1.0, eps_rf=0.0)
reaction_field.pair_coeff.set('B', 'B', epsilon=1.0, eps_rf=0.0)
reaction_field.pair_coeff.set(system.particles.types, system.particles.types,
↪epsilon=1.0, eps_rf=0.0, use_charge=True)
```

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)

Disable the force.

Parameters log (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)
Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
Get all the types of shapes in the current simulation.

Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)
Set parameters controlling the way forces are computed.

Parameters mode (`str`) – (if set) Set the mode with which potentials are handled at the cutoff.

Valid values for *mode* are: "none" (the default), "shift", and "xplor":

- **none** - No shifting is performed and potentials are abruptly cut off

- **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff

- **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

See `pair` for the equations.

Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**slj**(*r_cut*, *nlist*, *d_max=None*, *name=None*)
Shifted Lennard-Jones pair potential.

Parameters

- **r_cut** (`float`) – Default cutoff radius (in distance units).

- **nlist** (`hoomd.md.nlist`) – Neighbor list

- **name** (`str`) – Name of the force instance.

- **d_max** (`float`) – Maximum diameter particles in the simulation will have (in distance units)

`slj` specifies that a shifted Lennard-Jones type pair potential should be applied between every non-excluded particle pair in the simulation.

$$
\begin{aligned}
V_{\mathrm{SLJ}}(r) = \quad & 4\varepsilon \left[\left(\frac{\sigma}{r-\Delta}\right)^{12} - \left(\frac{\sigma}{r-\Delta}\right)^{6} \right] & r < (r_{\mathrm{cut}} + \Delta) \\
= \quad & 0 & r \geq (r_{\mathrm{cut}} + \Delta)
\end{aligned}
$$

where $\Delta = (d_i + d_j)/2 - 1$ and d_i is the diameter of particle i.

See `pair` for details on how forces are calculated and the available energy shifting and smoothing modes. Use `pair_coeff.set` to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in energy units)

- σ - *sigma* (in distance units) - *optional*: defaults to 1.0

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

> **Attention:** Due to the way that pair.slj modifies the cutoff criteria, a shift_mode of *xplor* is not supported.

The actual cutoff radius for pair.slj is shifted by the diameter of two particles interacting. Thus to determine the maximum possible actual r_cut in simulation pair.slj must know the maximum diameter of all the particles over the entire run, *d_max* . This value is either determined automatically from the initialization or can be set by the user and can be modified between runs with `hoomd.md.nlist.nlist.set_params()`. In most cases, the correct value can be identified automatically.

The specified value of *d_max* will be used to properly determine the neighbor lists during the following *hoomd. run()* commands. If not specified, *slj* will set d_max to the largest diameter in particle data at the time it is initialized.

If particle diameters change after initialization, it is **imperative** that *d_max* be the largest diameter that any particle will attain at any time during the following *hoomd.run()* commands. If *d_max* is smaller than it should be, some particles will effectively have a smaller value of *r_cut* then was set and the simulation will be incorrect. *d_max* can be changed between runs by calling *hoomd.md.nlist.nlist.set_params()*.

Example:

```
nl = nlist.cell()
slj = pair.slj(r_cut=3.0, nlist=nl, d_max = 2.0)
slj.pair_coeff.set('A', 'A', epsilon=1.0)
slj.pair_coeff.set('A', 'B', epsilon=2.0, r_cut=3.0);
slj.pair_coeff.set('B', 'B', epsilon=1.0, r_cut=2**(1.0/6.0));
slj.pair_coeff.set(['A', 'B'], ['C', 'D'], epsilon=2.0)
```

compute_energy(*tags1*, *tags2*)

> Compute the energy between two sets of particles.

> **Parameters**

>> • **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

>> • **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

> • *tags1* and *tags2* are disjoint

> • all elements in *tags1* and *tags2* are unique

> • *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)

> Disable the force.

>> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)

Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()

Get all the types of shapes in the current simulation.

Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)

Set parameters controlling the way forces are computed.

See *pair.set_params()*.

Note: **xplor** is not a valid setting for slj.

---

class hoomd.md.pair.**square_density**(*r_cut*, *nlist*, *name=None*)
Soft potential for simulating a van-der-Waals liquid

Parameters

- **r_cut** (*float*) – Default cutoff radius (in distance units).
- **nlist** (*hoomd.md.nlist*) – Neighbor list
- **name** (*str*) – Name of the force instance.

square_density specifies that the three-body potential should be applied to every non-bonded particle pair in the simulation, that is harmonic in the local density.

The self energy per particle takes the form

$$\Psi^{ex} = B(\rho - A)^2$$

which gives a pair-wise additive, three-body force

$$\vec{f}_{ij} = \left(B(n_i - A) + B(n_j - A)\right) w'_{ij} \vec{e}_{ij}$$

Here, w_{ij} is a quadratic, normalized weighting function,

$$w(x) = \frac{15}{2\pi r_{c,\text{weight}}^3}(1 - r/r_{c,\text{weight}})^2$$

The local density at the location of particle *i* is defined as

$$n_i = \sum_{j \neq i} w_{ij}\left(\left|\vec{r}_i - \vec{r}_j\right|\right)$$

The following coefficients must be set per unique pair of particle types:

- *A* - *A* (in units of volume^-1) - mean density (*default*: 0)
- *B* - *B* (in units of energy*volume^2) - coefficient of the harmonic density term

Example:

```
nl = nlist.cell()
sqd = pair.van_der_waals(r_cut=3.0, nlist=nl)
sqd.pair_coeff.set('A', 'A', A=0.1)
sqd.pair_coeff.set('A', 'A', B=1.0)
```

For further details regarding this multibody potential, see

Warning: Currently HOOMD does not support reverse force communication between MPI domains on the GPU. Since reverse force communication is required for the calculation of multi-body potentials, attempting to use the square_density potential on the GPU with MPI will result in an error.

---

[1] P. B. Warren, "Vapor-liquid coexistence in many-body dissipative particle dynamics" Phys. Rev. E. Stat. Nonlin. Soft Matter Phys., vol. 68, no. 6 Pt 2, p. 066702, 2003.

compute_energy(*tags1*, *tags2*)
Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
→array(tags[1:N:2]))
```

disable(*log=False*)

Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)

Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.
>
> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.
>
> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()

Get all the types of shapes in the current simulation.

Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)

Set parameters controlling the way forces are computed.

> **Parameters mode** (*str*) – (if set) Set the mode with which potentials are handled at the cutoff.

Valid values for *mode* are: "none" (the default), "shift", and "xplor":

- **none** - No shifting is performed and potentials are abruptly cut off
- **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff
- **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

See *pair* for the equations.

Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**table**(*width*, *nlist*, *name=None*)

Tabulated pair potential.

> **Parameters**
>
> - **width** (*int*) – Number of points to use to interpolate V and F.
> - **nlist** (*hoomd.md.nlist*) – Neighbor list (default of None automatically creates a global cell-list based neighbor list)

- **name** (str) – Name of the force instance

$table$ specifies that a tabulated pair potential should be applied between every non-excluded particle pair in the simulation.

The force $\vec{F}$ is (in force units):

$$
\begin{aligned}
\vec{F}(\vec{r}) &= & 0 & \quad r < r_{\min} \\
&= & F_{\mathrm{user}}(r)\hat{r} & \quad r_{\min} \leq r < r_{\max} \\
&= & 0 & \quad r \geq r_{\max}
\end{aligned}
$$

and the potential $V(r)$ is (in energy units)

$$
\begin{aligned}
V(r) &= & 0 & \quad r < r_{\min} \\
&= & V_{\mathrm{user}}(r) & \quad r_{\min} \leq r < r_{\max} \\
&= & 0 & \quad r \geq r_{\max}
\end{aligned}
$$

where $\vec{r}$ is the vector pointing from one particle to the other in the pair.

$F_{\mathrm{user}}(r)$ and $V_{\mathrm{user}}(r)$ are evaluated on *width* grid points between $r_{\min}$ and $r_{\max}$. Values are interpolated linearly between grid points. For correctness, you must specify the force defined by: $F = -\frac{\partial V}{\partial r}$.

The following coefficients must be set per unique pair of particle types:

- $V_{\mathrm{user}}(r)$ and $F_{\mathrm{user}}(r)$ - evaluated by $func$ (see example)

- coefficients passed to $func$ - *coeff* (see example)

- $_{\min}$ - *rmin* (in distance units)

- $_{\max}$ - *rmax* (in distance units)

Set table from a given function

When you have a functional form for V and F, you can enter that directly into python. $table$ will evaluate the given function over *width* points between *rmin* and *rmax* and use the resulting values in the table:

```python
def lj(r, rmin, rmax, epsilon, sigma):
    V = 4 * epsilon * ( (sigma / r)**12 - (sigma / r)**6);
    F = 4 * epsilon / r * ( 12 * (sigma / r)**12 - 6 * (sigma / r)**6);
    return (V, F)

nl = nlist.cell()
table = pair.table(width=1000, nlist=nl)
table.pair_coeff.set('A', 'A', func=lj, rmin=0.8, rmax=3.0, coeff=dict(epsilon=1.
↪5, sigma=1.0))
table.pair_coeff.set('A', 'B', func=lj, rmin=0.8, rmax=3.0, coeff=dict(epsilon=2.
↪0, sigma=1.2))
table.pair_coeff.set('B', 'B', func=lj, rmin=0.8, rmax=3.0, coeff=dict(epsilon=0.
↪5, sigma=1.0))
```

Set a table from a file

When you have no function for for *V* or *F*, or you otherwise have the data listed in a file, $table$ can use the given values directly. You must first specify the number of rows in your tables when initializing pair.table. Then use $set\_from\_file()$ to read the file:

```
nl = nlist.cell()
table = pair.table(width=1000, nlist=nl)
table.set_from_file('A', 'A', filename='table_AA.dat')
table.set_from_file('A', 'B', filename='table_AB.dat')
table.set_from_file('B', 'B', filename='table_BB.dat')
```

Note: For potentials that diverge near r=0, make sure to set *rmin* to a reasonable value. If a potential does not diverge near r=0, then a setting of *rmin=0* is valid.

---

disable (*log=False*)
> Disable the force.

> > **Parameters** **log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

> ```
> force.disable()
> force.disable(log=True)
> ```

> Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable ()
> Enable the force.

> Examples:

> ```
> force.enable()
> ```

> See *disable()*.

get_energy (*group*)
> Get the energy of a particle group.

> > **Parameters** **group** (*hoomd.group*) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

> ```
> g = group.all()
> energy = force.get_energy(g)
> ```

get_net_force (*group*)
> Get the force of a particle group.

> > **Parameters** **group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial (*group*)

Get the virial of a particle group.

> **Parameters** **group** (*hoomd.group*) – The particle group to query the virial for.
>
> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

set_from_file (*a*, *b*, *filename*)

Set a pair interaction from a file.

> **Parameters**
>
> - **a** (*str*) – Name of type A in pair
>
> - **b** (*str*) – Name of type B in pair
>
> - **filename** (*str*) – Name of the file to read

The provided file specifies V and F at equally spaced r values.

Example:

```
#r   V     F
1.0 2.0 -3.0
1.1 3.0 -4.0
1.2 2.0 -3.0
1.3 1.0 -2.0
1.4 0.0 -1.0
1.5 -1.0 0.0
```

The first r value sets *rmin*, the last sets *rmax*. Any line with # as the first non-whitespace character is is treated as a comment. The *r* values must monotonically increase and be equally spaced. The table is read directly into the grid points used to evaluate $F_{\text{user}}(r)$ and $_{\text{user}}(r)$.

class hoomd.md.pair.**tersoff** (*r_cut*, *nlist*, *name=None*)

Tersoff Potential.

> **Parameters**
>
> - **r_cut** (*float*) – Default cutoff radius (in distance units).
>
> - **nlist** (*hoomd.md.nlist*) – Neighbor list
>
> - **name** (*str*) – Name of the force instance.

tersoff specifies that the Tersoff three-body potential should be applied to every non-bonded particle pair in the simulation. Despite the fact that the Tersoff potential accounts for the effects of third bodies, it is included in the pair potentials because the species of the third body is irrelevant. It can thus use type-pair parameters similar to those of the pair potentials.

The Tersoff potential is a bond-order potential based on the Morse potential that accounts for the weakening of individual bonds with increasing coordination number. It does this by computing a modifier to the attractive term of the potential. The modifier contains the effects of third-bodies on the bond energies. The potential also includes a smoothing function around the cutoff. The smoothing function used in this work is exponential in

nature as opposed to the sinusoid used by Tersoff. The exponential function provides continuity up (I believe) the second derivative.

compute_energy(*tags1*, *tags2*)
Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)
Disable the force.

Parameters log (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

> ### Examples

> g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
> Get all the types of shapes in the current simulation.

> Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*mode=None*)
> Set parameters controlling the way forces are computed.

> > **Parameters mode** (`str`) – (if set) Set the mode with which potentials are handled at the cutoff.

> Valid values for *mode* are: "none" (the default), "shift", and "xplor":

> * **none** - No shifting is performed and potentials are abruptly cut off
> * **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff
> * **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.

> See `pair` for the equations.

> Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**yukawa**(*r_cut*, *nlist*, *name=None*)

Yukawa pair potential.

Parameters

- **r_cut** (*float*) – Default cutoff radius (in distance units).

- **nlist** (*hoomd.md.nlist*) – Neighbor list

- **name** (*str*) – Name of the force instance.

yukawa specifies that a Yukawa pair potential should be applied between every non-excluded particle pair in the simulation.

$$
\begin{aligned}
V_{\text{yukawa}}(r) &= \quad \varepsilon \frac{\exp(-\kappa r)}{r} \quad & r < r_{\text{cut}} \\
&= \qquad 0 & r \geq r_{\text{cut}}
\end{aligned}
$$

See *pair* for details on how forces are calculated and the available energy shifting and smoothing modes. Use *pair_coeff.set* to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in energy units)

- κ - *kappa* (in units of 1/distance)

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on} - *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

Example:

```
nl = nlist.cell()
yukawa = pair.lj(r_cut=3.0, nlist=nl)
yukawa.pair_coeff.set('A', 'A', epsilon=1.0, kappa=1.0)
yukawa.pair_coeff.set('A', 'B', epsilon=2.0, kappa=0.5, r_cut=3.0, r_on=2.0);
yukawa.pair_coeff.set(['A', 'B'], ['C', 'D'], epsilon=0.5, kappa=3.0)
```

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (*ndarray<int32>*) – a numpy array of particle tags in the first group

- **tags2** (*ndarray<int32>*) – a numpy array of particle tags in the second group

$$
U = \sum_{i \in \text{tags1}, j \in \text{tags2}} V_{ij}(r)
$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)
> Disable the force.

> > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

> Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
>   Get all the types of shapes in the current simulation.
>
>   Since this behaves differently for different types of shapes, the default behavior just raises an exception.
>   Subclasses can override this to properly return.

set_params(*mode=None*)
>   Set parameters controlling the way forces are computed.
>
>   >   **Parameters mode** (`str`) – (if set) Set the mode with which potentials are handled at the cutoff.
>
>   Valid values for *mode* are: "none" (the default), "shift", and "xplor":
>
>   - **none** - No shifting is performed and potentials are abruptly cut off
>
>   - **shift** - A constant shift is applied to the entire potential so that it is 0 at the cutoff
>
>   - **xplor** - A smoothing function is applied to gradually decrease both the force and potential to 0 at the
>   cutoff when ron < rcut, and shifts the potential to 0 at the cutoff when ron >= rcut.
>
>   See [`pair`](#) for the equations.
>
>   Examples:

```
mypair.set_params(mode="shift")
mypair.set_params(mode="no_shift")
mypair.set_params(mode="xplor")
```

class hoomd.md.pair.**zbl**(*r_cut*, *nlist*, *name=None*)
>   ZBL pair potential.
>
>   >   **Parameters**
>   >
>   >   - **r_cut** (`float`) – Default cutoff radius (in distance units).
>   >
>   >   - **nlist** (`hoomd.md.nlist`) – Neighbor list
>   >
>   >   - **name** (`str`) – Name of the force instance.
>
>   [`zbl`](#) specifies that a Ziegler-Biersack-Littmark pair potential should be applied between every non-excluded
>   particle pair in the simulation.

$$V_{\mathrm{ZBL}}(r) = \quad \frac{Z_i Z_j e^2}{4\pi\epsilon_0 r_{ij}} \left[0.1818 \exp\left(-3.2\frac{r_{ij}}{a_F}\right) + 0.5099 \exp\left(-0.9423\frac{r_{ij}}{a_F}\right) + 0.2802 \exp\left(-0.4029\frac{r_{ij}}{a_F}\right) + 0.02817 \exp\left(-0.201\right.\right.$$
$$= \quad\quad 0,$$

>   See [`pair`](#) for details on how forces are calculated and the available energy shifting and smoothing modes. Use
>   [`pair_coeff.set`](#) to set potential coefficients.
>
>   The following coefficients must be set per unique pair of particle types:
>
>   - Z_i - Z_i - Atomic number of species i (unitless)
>
>   - Z_j - Z_j - Atomic number of species j (unitless)
>
>   - *e* - *elementary_charge* - The elementary charge (in charge units)

- a_0 - *a_0* - The Bohr radius (in distance units)

- r_{cut} - *r_cut* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

- r_{on}- *r_on* (in distance units) - *optional*: defaults to the global r_cut specified in the pair command

Example:

```
nl = nlist.cell()
zbl = pair.zbl(r_cut = 3.0, nlist=nl)
zbl.pair_coeff.set('A', 'B', Z_i = 54.0, Z_j = 7.0, elementary_charge = 1.0, a_0
↪= 1.0);
```

compute_energy(*tags1*, *tags2*)

Compute the energy between two sets of particles.

Parameters

- **tags1** (ndarray<int32>) – a numpy array of particle tags in the first group

- **tags2** (ndarray<int32>) – a numpy array of particle tags in the second group

$$U = \sum_{i \in \mathrm{tags1}, j \in \mathrm{tags2}} V_{ij}(r)$$

where $V_{ij}(r)$ is the pairwise energy between two particles i and j.

Assumed properties of the sets *tags1* and *tags2* are:

- *tags1* and *tags2* are disjoint

- all elements in *tags1* and *tags2* are unique

- *tags1* and *tags2* are contiguous numpy arrays of dtype int32

None of these properties are validated.

Examples:

```
tags=numpy.linspace(0,N-1,1, dtype=numpy.int32)
# computes the energy between even and odd particles
U = mypair.compute_energy(tags1=numpy.array(tags[0:N:2]), tags2=numpy.
↪array(tags[1:N:2]))
```

disable(*log=False*)

Disable the force.

Parameters **log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
    Enable the force.

    Examples:

```
force.enable()
```

    See *disable()*.

get_energy(*group*)
    Get the energy of a particle group.

>   **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

>   **Returns** The last computed energy for the members in the group.

    Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
    Get the force of a particle group.

>   **Parameters group** (*hoomd.group*) – The particle group to query the force for.

>   **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
    Get the virial of a particle group.

>   **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

>   **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
    Get all the types of shapes in the current simulation.

    Since this behaves differently for different types of shapes, the default behavior just raises an exception. Subclasses can override this to properly return.

set_params(*coeff*)
    zbl has no energy shift modes

2.16.12 md.update

Overview

md.update.constraint_ellipsoid	Constrain particles to the surface of a ellipsoid.
md.update.enforce2d	Enforces 2D simulation.
md.update.rescale_temp	Rescales particle velocities.
md.update.zero_momentum	Zeroes system momentum.
md.update.mueller_plathe_flow	Updater class for a shear flow according to an algorithm published by Mueller Plathe.:

Details

Update particle properties.

When an updater is specified, it acts on the particle system each time step to change it in some way. See the documentation of specific updaters to find out what they do.

class hoomd.md.update.**constraint_ellipsoid**(*group, r=None, rx=None, ry=None, rz=None, P=(0, 0, 0)*)

Constrain particles to the surface of a ellipsoid.

> **Parameters**
>
> - **group** (*hoomd.group*) – Group for which the update will be set
>
> - **P** (*tuple*) – (x,y,z) tuple indicating the position of the center of the ellipsoid (in distance units).
>
> - **rx** (*float*) – radius of an ellipsoid in the X direction (in distance units).
>
> - **ry** (*float*) – radius of an ellipsoid in the Y direction (in distance units).
>
> - **rz** (*float*) – radius of an ellipsoid in the Z direction (in distance units).
>
> - **r** (*float*) – radius of a sphere (in distance units), such that r=rx=ry=rz.

constraint_ellipsoid specifies that all particles are constrained to the surface of an ellipsoid. Each time step particles are projected onto the surface of the ellipsoid. Method from: http://www.geometrictools.com/Documentation/DistancePointEllipseEllipsoid.pdf

---

Attention: For the algorithm to work, we must have $rx >= rz$, $ry >= rz$, $rz > 0$.

Note: This method does not properly conserve virial coefficients.

Note: random thermal forces from the integrator are applied in 3D not 2D, therefore they aren't fully accurate. Suggested use is therefore only for T=0.

Examples:

```
update.constraint_ellipsoid(P=(-1,5,0), r=9)
update.constraint_ellipsoid(rx=7, ry=5, rz=3)
```

disable()

Disables the updater.

Examples:

```
updater.disable()
```

Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()
  Enables the updater.

  Examples:

```
updater.enable()
```

  See also:

  disable()

restore_state()
  Restore the state information from the file used to initialize the simulations

set_period(*period*)
  Changes the updater period.

  Parameters **period** (*int*) – New period to set.

  Examples:

```
updater.set_period(100);
updater.set_period(1);
```

  While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.md.update.**enforce2d**
  Enforces 2D simulation.

  Every time step, particle velocities and accelerations are modified so that their z components are 0: forcing 2D simulations when other calculations may cause particles to drift out of the plane. Using enforce2d is only allowed when the system is specified as having only 2 dimensions.

  Examples:

```
update.enforce2d()
```

disable()
  Disables the updater.

  Examples:

```
updater.disable()
```

  Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()
  Enables the updater.

  Examples:

```
updater.enable()
```

See also:

[*disable()*](#)

restore_state()
>   Restore the state information from the file used to initialize the simulations

set_period(*period*)
>   Changes the updater period.

>   > **Parameters period** ([*int*](#)) – New period to set.

>   Examples:

```
updater.set_period(100);
updater.set_period(1);
```

>   While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.md.update.**mueller_plathe_flow**(*group*, *flow_target*, *slab_direction*, *flow_direction*, *n_slabs*, *max_slab=-1*, *min_slab=-1*)
>   Updater class for a shear flow according to an algorithm published by Mueller Plathe.:

>   > "Florian Mueller-Plathe. Reversing the perturbation in nonequilibrium molecular dynamics: An easy way to calculate the shear viscosity of fluids. Phys. Rev. E, 59:4894-4898, May 1999."

>   The simulation box is divided in a number of slabs. Two distinct slabs of those are chosen. The "max" slab searched for the max. velocity component in flow direction, the "min" is searched for the min. velocity component. Afterward, both velocity components are swapped.

>   This introduces a momentum flow, which drives the flow. The strength of this flow, can be controlled by the flow_target variant, which defines the integrated target momentum flow. The searching and swapping is repeated until the target is reached. Depending on the target sign, the "max" and "min" slap might be swapped.

>   **Parameters**

>   > - **group** ([*hoomd.group*](#)) – Group for which the update will be set

>   > - **flow_target** ([*hoomd.variant*](#)) – Integrated target flow. The unit is the in the natural units of the simulation: [flow_target] = [timesteps] x $\mathcal{M}$ x $\frac{\mathcal{D}}{\tau}$. The unit of [timesteps] is your discretization dt x τ.

>   > - **slab_direction** (X, Y, or Z) – Direction perpendicular to the slabs..

>   > - **flow_direction** (X, Y, or Z) – Direction of the flow..

>   > - **n_slabs** ([*int*](#)) – Number of slabs. You want as many as possible for small disturbed volume, where the unphysical swapping is done. But each slab has to contain a sufficient number of particle.

>   > - **max_slab** ([*int*](#)) – Id < n_slabs where the max velocity component is search for. If set < 0 the value is set to its default n_slabs/2.

>   > - **min_slab** ([*int*](#)) – Id < n_slabs where the min velocity component is search for. If set < 0 the value is set to its default 0.

> **Attention:**
>
> - This updater has to be always applied every timestep.
>
> - This updater works currently only with orthorhombic boxes.

New in version v2.1.

Examples:

```
#const integrated flow with 0.1 slope for max 1e8 timesteps
const_flow = hoomd.variant.linear_interp( [(0,0),(1e8,0.1*1e8)] )
#velocity gradient in z direction and shear flow in x direction.
update.mueller_plathe_flow(all,const_flow,md.update.mueller_plathe_flow.Z,md.
↪update.mueller_plathe_flow.X,100)
```

X = None
    Direction Enum X for this class

Y = None
    Direction Enum Y for this class

Z = None
    Direction Enum Z for this class

disable()
    Disables the updater.

    Examples:

    ```
    updater.disable()
    ```

    Executing the disable command will remove the updater from the system. Any *hoomd.run()* command
    executed after disabling an updater will not use that updater during the simulation. A disabled updater can
    be re-enabled with *enable()*

enable()
    Enables the updater.

    Examples:

    ```
    updater.enable()
    ```

    See also:

    disable()

get_flow_epsilon()
    Get the tolerance between target flow and actual achieved flow.

get_max_slab()
    Get the slab id of max velocity search.

get_min_slab()
    Get the slab id of min velocity search.

get_n_slabs()
    Get the number of slabs.

get_summed_exchanged_momentum()
    Returned the summed up exchanged velocity of the full simulation.

has_max_slab()
    Returns, whether this MPI instance is part of the max slab.

has_min_slab()
    Returns, whether this MPI instance is part of the min slab.

restore_state()
    Restore the state information from the file used to initialize the simulations

set_flow_epsilon(*epsilon*)
    Set the tolerance between target flow and actual achieved flow.

    Args: epsilon (float): New tolerance for the deviation of actual and achieved flow.

set_period(*period*)
    Changes the updater period.

        Parameters period(*int*) – New period to set.

    Examples:

```
updater.set_period(100);
updater.set_period(1);
```

    While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.md.update.**rescale_temp**(*kT*, *period=1*, *phase=0*)
    Rescales particle velocities.

        Parameters

- **kT** (*hoomd.variant* or *float*) – Temperature set point (in energy units)
- **period** (*int*) – Velocities will be rescaled every *period* time steps
- **phase** (*int*) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0*.

Every *period* time steps, particle velocities and angular momenta are rescaled by equal factors so that they are consistent with a given temperature in the equipartition theorem

$$\langle 1/2mv^2 \rangle = k_B T$$
$$\langle 1/2I\omega^2 \rangle = k_B T$$

> **Attention:** *rescale_temp* does **not** run on the GPU, and will significantly slow down simulations.

Examples:

```
update.rescale_temp(kT=1.2)
rescaler = update.rescale_temp(kT=0.5)
update.rescale_temp(period=100, kT=1.03)
update.rescale_temp(period=100, kT=hoomd.variant.linear_interp([(0, 4.0), (1e6, 1.
↪0)]))
```

disable()
    Disables the updater.

    Examples:

```
updater.disable()
```

Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()
    Enables the updater.

    Examples:

```
updater.enable()
```

    See also:

    disable()

restore_state()
    Restore the state information from the file used to initialize the simulations

set_params(*kT=None*)
    Change rescale_temp parameters.

        Parameters kT (*hoomd.variant* or *float*) – New temperature set point (in energy units)

    Examples:

```
rescaler.set_params(kT=2.0)
```

set_period(*period*)
    Changes the updater period.

        Parameters period (*int*) – New period to set.

    Examples:

```
updater.set_period(100);
updater.set_period(1);
```

    While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.md.update.**zero_momentum**(*period=1, phase=0*)
    Zeroes system momentum.

        Parameters

            • **period** (*int*) – Momentum will be zeroed every *period* time steps

            • **phase** (*int*) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0*.

Every *period* time steps, particle velocities are modified such that the total linear momentum of the system is set to zero.

Examples:

```
update.zero_momentum()
zeroer= update.zero_momentum(period=10)
```

disable()
    Disables the updater.

Examples:

```
updater.disable()
```

Executing the disable command will remove the updater from the system. Any *hoomd.run()* command executed after disabling an updater will not use that updater during the simulation. A disabled updater can be re-enabled with *enable()*

enable()
Enables the updater.

Examples:

```
updater.enable()
```

See also:

disable()

restore_state()
Restore the state information from the file used to initialize the simulations

set_period(*period*)
Changes the updater period.

> **Parameters period** (*int*) – New period to set.

Examples:

```
updater.set_period(100);
updater.set_period(1);
```

While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

2.16.13 md.wall

Geometry

md.wall.cylinder	Cylinder wall.
md.wall.group	Defines a wall group.
md.wall.plane	Plane wall.
md.wall.sphere	Sphere wall.

Overview

md.wall.force_shifted_lj	Force-shifted Lennard-Jones wall potential.
md.wall.gauss	Gaussian wall potential.
md.wall.lj	Lennard-Jones wall potential.
md.wall.mie	Mie potential wall potential.
md.wall.morse	Morse wall potential.
md.wall.slj	Shifted Lennard-Jones wall potential
md.wall.wallpotential	Generic wall potential.
md.wall.yukawa	Yukawa wall potential.

Details

Wall potentials.

Wall potentials add forces to any particles within a certain distance, r_{cut}, of each wall. In the extrapolated mode, all particles deemed outside of the wall boundary are included as well.

Wall geometries are used to specify half-spaces. There are two half spaces for each of the possible geometries included and each can be selected using the inside parameter. In order to fully specify space, it is necessary that one half space be closed and one open. Setting *inside=True* for closed half-spaces and *inside=False* for open ones. See *wallpotential* for more information on how the concept of half-spaces are used in implementing wall forces.

> **Attention:** The current wall force implementation does not support NPT integrators.

Wall groups (*group*) are used to pass wall geometries to wall forces. By themselves, wall groups do nothing. Only when you specify a wall force (i.e. *lj*), are forces actually applied between the wall and the

class hoomd.md.wall.**cylinder**(*r=0.0*, *origin=(0.0, 0.0, 0.0)*, *axis=(0.0, 0.0, 1.0)*, *inside=True*)
Cylinder wall.

>> **Parameters**
>>
>> - **r** (*float*) – Cylinder radius (in distance units)
>> - **origin** (*tuple*) – Cylinder origin (in x,y,z coordinates)
>> - **axis** (*tuple*) – Cylinder axis vector (in x,y,z coordinates)
>> - **inside** (*bool*) – Selects the half-space to be used (bool)

> Define a cylindrical half-space:
>
> - inside = True selects the space inside the radius of the cylinder and includes the cylinder surface.
> - inside = False selects the space outside the radius of the cylinder.
>
> Use in function calls or by reference in the creation or modification of wall groups.
>
> For an example see *sphere*.

class hoomd.md.wall.**force_shifted_lj**(*walls*, *r_cut=False*, *name=''*)
Force-shifted Lennard-Jones wall potential.

>> **Parameters**
>>
>> - **walls** (*group*) – Wall group containing half-space geometries for the force to act in.
>> - **r_cut** (*float*) – The global r_cut value for the force. Defaults to False or 0 if not specified.
>> - **name** (*str*) – The force name which will be used in the metadata and log files.

> Wall force evaluated using the Force-shifted Lennard-Jones potential. See *hoomd.md.pair.force_shifted_lj* for force details and base parameters and *wallpotential* for generalized wall potential implementation.
>
> Example:

```
walls=wall.group()
# add walls to interact with
wall_force_fslj=wall.force_shifted_lj(walls, r_cut=3.0)
wall_force_fslj.force_coeff.set('A', epsilon=1.0, sigma=1.0)
```

<div align="right">(continues on next page)</div>

```
wall_force_fslj.force_coeff.set('B', epsilon=1.5, sigma=3.0, r_cut = 8.0)
wall_force_fslj.force_coeff.set(['C','D'], epsilon=1.0, sigma=1.0, alpha = 1.5)
```

disable(*log=False*)

Disable the force.

> **Parameters log** ([*bool*](#)) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any [*hoomd.run()*](#) command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with [*enable()*](#).

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

Enable the force.

Examples:

```
force.enable()
```

See [*disable()*](#).

get_energy(*group*)

Get the energy of a particle group.

> **Parameters group** ([*hoomd.group*](#)) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

> **Parameters group** ([*hoomd.group*](#)) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

> **Parameters group** ([*hoomd.group*](#)) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

> g = group.all() virial = force.get_net_virial(g)

class `hoomd.md.wall.`**`gauss`**(*walls*, *r_cut=False*, *name=''*)

> Gaussian wall potential.

> **Parameters**
>
> - **walls** (`group`) – Wall group containing half-space geometries for the force to act in.
> - **r_cut** (`float`) – The global r_cut value for the force. Defaults to False or 0 if not specified.
> - **name** (`str`) – The force name which will be used in the metadata and log files.

> Wall force evaluated using the Gaussian potential. See `hoomd.md.pair.gauss` for force details and base parameters and `wallpotential` for generalized wall potential implementation

> Example:

```
walls=wall.group()
# add walls to interact with
wall_force_gauss=wall.gauss(walls, r_cut=3.0)
wall_force_gauss.force_coeff.set('A', epsilon=1.0, sigma=1.0)
wall_force_gauss.force_coeff.set('A', epsilon=2.0, sigma=1.0, r_cut=3.0)
wall_force_gauss.force_coeff.set(['C', 'D'], epsilon=3.0, sigma=0.5)
```

> **`disable`**(*log=False*)
>
> > Disable the force.
>
> > **Parameters** **log** (`bool`) – Set to True if you plan to continue logging the potential energy associated with this force.
>
> > Examples:

```
force.disable()
force.disable(log=True)
```

> > Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.
>
> > By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

> **`enable`**()
>
> > Enable the force.
>
> > Examples:

```
force.enable()
```

> > See `disable()`.

> **`get_energy`**(*group*)
>
> > Get the energy of a particle group.

Parameters group (`hoomd.group`) – The particle group to query the energy for.

Returns The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
    Get the force of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the force for.
>
> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
    Get the virial of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the virial for.
>
> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.wall.**group**(**walls*)
    Defines a wall group.

> **Parameters walls** (`list`) – Wall objects to be included in the group.

All wall forces use a wall group as an input so it is necessary to create a wall group object before any wall force can be created. Modifications of the created wall group may occur at any time before `hoomd.run()` is invoked. Current supported geometries are spheres, cylinder, and planes. The maximum number of each type of wall is 20, 20, and 60 respectively.

The **inside** parameter used in each wall geometry is used to specify the half-space that is to be used for the force implementation. See `wallpotential` for more general details and `sphere cylinder`, and `plane` for the definition of inside for each geometry.

An effective use of wall forces **requires** considering the geometry of the system. Walls are only evaluated in one simulation box and are not periodic. It is therefore important to ensure that the walls that intersect with a periodic boundary meet.

Note: The entire structure can easily be viewed by printing the group object.

Note: While all x,y,z coordinates can be given as a list or tuple, only origin parameters are points in x,y,z space. Normal and axis parameters are vectors and must have a nonzero magnitude.

Note: Wall structure modifications between `hoomd.run()` calls will be implemented in the next run. However, modifications must be done carefully since moving the wall can result in particles moving to a relative position which causes exceptionally high forces resulting in particles moving many times the box length in one move.

Example:

```
In[0]:
# Creating wall geometry definitions using convenience functions
wallstructure=wall.group()
wallstructure.add_sphere(r=1.0,origin=(0,1,3))
wallstructure.add_sphere(1.0,[0,-1,3],inside=False)
wallstructure.add_cylinder(r=1.0,origin=(1,1,1),axis=(0,0,3),inside=True)
wallstructure.add_cylinder(4.0,[0,0,0],(1,0,1))
wallstructure.add_cylinder(5.5,(1,1,1),(3,-1,1),False)
wallstructure.add_plane(origin=(3,2,1),normal=(2,1,4))
wallstructure.add_plane((0,0,0),(10,2,1))
wallstructure.add_plane((0,0,0),(0,2,1))
print(wallstructure)

Out[0]:
Wall_Data_Structure:
spheres:2{
[0:    Radius=1.0   Origin=(0.0, 1.0, 3.0)   Inside=True]
[1:    Radius=1.0   Origin=(0.0, -1.0, 3.0)  Inside=False]}
cylinders:3{
[0:    Radius=1.0   Origin=(1.0, 1.0, 1.0)   Axis=(0.0, 0.0, 3.0)    Inside=True]
[1:    Radius=4.0   Origin=(0.0, 0.0, 0.0)   Axis=(1.0, 0.0, 1.0)    Inside=True]
[2:    Radius=5.5   Origin=(1.0, 1.0, 1.0)   Axis=(3.0, -1.0, 1.0)   Inside=False]}
planes:3{
[0:    Origin=(3.0, 2.0, 1.0)   Normal=(2.0, 1.0, 4.0)]
[1:    Origin=(0.0, 0.0, 0.0)   Normal=(10.0, 2.0, 1.0)]
[2:    Origin=(0.0, 0.0, 0.0)   Normal=(0.0, 2.0, 1.0)]}

In[1]:
# Deleting wall geometry definitions using convenience functions in all accepted␣
↪types
wallstructure.del_plane(range(3))
wallstructure.del_cylinder([0,2])
wallstructure.del_sphere(1)
print(wallstructure)

Out[1]:
Wall_Data_Structure:
spheres:1{
[0:    Radius=1.0   Origin=(0.0, 1.0, 3.0)   Inside=True]}
cylinders:1{
[0:    Radius=4.0   Origin=(0.0, 0.0, 0.0)   Axis=(1.0, 0.0, 1.0)    Inside=True]}
planes:0{}

In[2]:
# Modifying wall geometry definitions using convenience functions
wallstructure.spheres[0].r=2.0
wallstructure.cylinders[0].origin=[1,2,1]
wallstructure.cylinders[0].axis=(0,0,1)
print(wallstructure)
```

(continues on next page)

```
Out[2]:
Wall_Data_Structure:
spheres:1{
[0:   Radius=2.0  Origin=(0.0, 1.0, 3.0)  Inside=True]}
cylinders:1{
[0:   Radius=4.0  Origin=(1.0, 2.0, 1.0)  Axis=(0.0, 0.0, 1.0)    Inside=True]}
planes:0{}
```

add(*wall*)

> Generic wall add for wall objects.
>
> Generic convenience function to add any wall object to the group. Accepts *sphere*, *cylinder*, *plane*, and lists of any combination of these.

add_cylinder(*r*, *origin*, *axis*, *inside=True*)

> Adds a cylinder to the wall group.
>
> > **Parameters**
> >
> > - **r** (*float*) – Cylinder radius (in distance units)
> >
> > - **origin** (*tuple*) – Cylinder origin (in x,y,z coordinates)
> >
> > - **axis** (*tuple*) – Cylinder axis vector (in x,y,z coordinates)
> >
> > - **inside** (*bool*) – Selects the half-space to be used (bool)
>
> Adds a cylinder with the specified parameters to the group.

add_plane(*origin*, *normal*, *inside=True*)

> Adds a plane to the wall group.
>
> > **Parameters**
> >
> > - **origin** (*tuple*) – Plane origin (in x,y,z coordinates)
> >
> > - **normal** (*tuple*) – Plane normal vector (in x,y,z coordinates)
> >
> > - **inside** (*bool*) – Selects the half-space to be used (bool)
>
> Adds a plane with the specified parameters to the wallgroup.planes list.

add_sphere(*r*, *origin*, *inside=True*)

> Adds a sphere to the wall group.
>
> > **Parameters**
> >
> > - **r** (*float*) – Sphere radius (in distance units)
> >
> > - **origin** (*tuple*) – Sphere origin (in x,y,z coordinates)
> >
> > - **inside** (*bool*) – Selects the half-space to be used (bool)
>
> Adds a sphere with the specified parameters to the group.

del_cylinder(**indexs*)

> Deletes the cylinder or cylinders in index.
>
> > **Parameters** **index** (*list*) – The index of cylinder(s) desired to delete. Accepts int, range, and lists.
>
> Removes the specified cylinder or cylinders from the wallgroup.cylinders list.

---

del_plane(**indexs*)
> Deletes the plane or planes in index.

>> **Parameters index** (*[list](#)*) – The index of plane(s) desired to delete. Accepts int, range, and lists.

> Removes the specified plane or planes from the wallgroup.planes list.

del_sphere(**indexs*)
> Deletes the sphere or spheres in index.

>> **Parameters index** (*[list](#)*) – The index of sphere(s) desired to delete. Accepts int, range, and lists.

> Removes the specified sphere or spheres from the wallgroup.spheres list.

class hoomd.md.wall.**lj**(*walls*, *r_cut=False*, *name=''*)
> Lennard-Jones wall potential.

>> **Parameters**

>>> - **walls** (*[group](#)*) – Wall group containing half-space geometries for the force to act in.
>>> - **r_cut** (*[float](#)*) – The global r_cut value for the force. Defaults to False or 0 if not specified.
>>> - **name** (*[str](#)*) – The force name which will be used in the metadata and log files.

> Wall force evaluated using the Lennard-Jones potential. See *[hoomd.md.pair.lj](#)* for force details and base parameters and *[wallpotential](#)* for generalized wall potential implementation

> Standard mode:

```
walls=wall.group()
#add walls
lj=wall.lj(walls, r_cut=3.0)
lj.force_coeff.set('A', sigma=1.0,epsilon=1.0)   #plotted below in red
lj.force_coeff.set('B', sigma=1.0,epsilon=1.0, r_cut=2.0**(1.0/2.0))
lj.force_coeff.set(['A','B'], epsilon=2.0, sigma=1.0, alpha=1.0, r_cut=3.0)
```

> Extrapolated mode:

```
walls=wall.group()
#add walls
lj_extrap=wall.lj(walls, r_cut=3.0)
lj_extrap.force_coeff.set('A', sigma=1.0,epsilon=1.0, r_extrap=1.1) #plotted in
→blue below
```

> V(r) plot:

disable (*log=False*)

Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable ()

Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy (*group*)

Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

> > ### Examples

> > g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

> > ### Examples

> > g = group.all() virial = force.get_net_virial(g)

class hoomd.md.wall.**mie**(*walls*, *r_cut=False*, *name=''*)
> Mie potential wall potential.

> > **Parameters**

> > - **walls** (*group*) – Wall group containing half-space geometries for the force to act in.

> > - **r_cut** (*float*) – The global r_cut value for the force. Defaults to False or 0 if not specified.

> > - **name** (*str*) – The force name which will be used in the metadata and log files.

> Wall force evaluated using the Mie potential. See *hoomd.md.pair.mie* for force details and base parameters and *wallpotential* for generalized wall potential implementation

> Example:

```
walls=wall.group()
# add walls to interact with
wall_force_mie=wall.mie(walls, r_cut=3.0)
wall_force_mie.force_coeff.set('A', epsilon=1.0, sigma=1.0, n=12, m=6)
wall_force_mie.force_coeff.set('A', epsilon=2.0, sigma=1.0, n=14, m=7, r_cut=3.0)
wall_force_mie.force_coeff.set('B', epsilon=1.0, sigma=1.0, n=15.1, m=6.5, r_
↪cut=2**(1.0/6.0))
```

> **disable**(*log=False*)
> > Disable the force.

> > > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> > Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See `disable()`.

get_energy(*group*)
> Get the energy of a particle group.

>> **Parameters group** (`hoomd.group`) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

>> **Parameters group** (`hoomd.group`) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

>> **Parameters group** (`hoomd.group`) – The particle group to query the virial for.

>> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.wall.**morse**(*walls*, *r_cut=False*, *name=''*)
> Morse wall potential.

>> **Parameters**

>>> • **walls** (*group*) – Wall group containing half-space geometries for the force to act in.

>>> • **r_cut** (*float*) – The global r_cut value for the force. Defaults to False or 0 if not specified.

- **name** (*str*) – The force name which will be used in the metadata and log files.

Wall force evaluated using the Morse potential. See *hoomd.md.pair.morse* for force details and base parameters and *wallpotential* for generalized wall potential implementation

Example:

```
walls=wall.group()
# add walls to interact with
wall_force_morse=wall.morse(walls, r_cut=3.0)
wall_force_morse.force_coeff.set('A', D0=1.0, alpha=3.0, r0=1.0)
wall_force_morse.force_coeff.set('A', D0=1.0, alpha=3.0, r0=1.0, r_cut=3.0)
wall_force_morse.force_coeff.set(['C', 'D'], D0=1.0, alpha=3.0)
```

disable(*log=False*)
    Disable the force.

    Parameters **log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

    Examples:

    ```
    force.disable()
    force.disable(log=True)
    ```

    Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

    By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
    Enable the force.

    Examples:

    ```
    force.enable()
    ```

    See *disable()*.

get_energy(*group*)
    Get the energy of a particle group.

    Parameters **group** (*hoomd.group*) – The particle group to query the energy for.

    Returns The last computed energy for the members in the group.

    Examples:

    ```
    g = group.all()
    energy = force.get_energy(g)
    ```

get_net_force(*group*)
    Get the force of a particle group.

    Parameters **group** (*hoomd.group*) – The particle group to query the force for.

    Returns The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
Get the virial of a particle group.

>**Parameters group** (*hoomd.group*) – The particle group to query the virial for.

>**Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.wall.**plane**(*origin=(0.0, 0.0, 0.0)*, *normal=(0.0, 0.0, 1.0)*, *inside=True*)
Plane wall.

>**Parameters**
>
>>- **origin** (*tuple*) – Plane origin (in x,y,z coordinates)n <i>Default : (0.0, 0.0, 0.0)</i>
>>- **normal** (*tuple*) – Plane normal vector (in x,y,z coordinates)n <i>Default : (0.0, 0.0, 1.0)</i>
>>- **inside** (*bool*) – Selects the half-space to be used (bool)n <i>Default : True</i>

Define a planar half space.

- inside = True selects the space on the side of the plane to which the normal vector points and includes the plane surface.
- inside = False selects the space on the side of the plane opposite the normal vector.

Use in function calls or by reference in the creation or modification of wall groups.

For an example see *sphere*.

class hoomd.md.wall.**slj**(*walls*, *r_cut=False*, *d_max=None*, *name=''*)
Shifted Lennard-Jones wall potential

>**Parameters**
>
>>- **walls** (*group*) – Wall group containing half-space geometries for the force to act in.
>>- **r_cut** (*float*) – The global r_cut value for the force. Defaults to False or 0 if not specified.
>>- **name** (*str*) – The force name which will be used in the metadata and log files.

Wall force evaluated using the Shifted Lennard-Jones potential. Note that because slj is dependent upon particle diameters the following correction is necessary to the force details in the *hoomd.md.pair.slj* description.

$\Delta = d_i/2 - 1$ where d_i is the diameter of particle i. See *hoomd.md.pair.slj* for force details and base parameters and *wallpotential* for generalized wall potential implementation

Example:

```
walls=wall.group()
# add walls to interact with
wall_force_slj=wall.slj(walls, r_cut=3.0)
wall_force_slj.force_coeff.set('A', epsilon=1.0, sigma=1.0)
wall_force_slj.force_coeff.set('A', epsilon=2.0, sigma=1.0, r_cut=3.0)
wall_force_slj.force_coeff.set('B', epsilon=1.0, sigma=1.0, r_cut=2**(1.0/6.0))
```

disable(*log=False*)
> Disable the force.

>> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy
>> associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

> Executing the disable command will remove the force from the simulation. Any `hoomd.run()` com-
> mand executed after disabling a force will not calculate or use the force during the simulation. A disabled
> force can be re-enabled with `enable()`.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the
> simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used
> throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would
> be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See `disable()`.

get_energy(*group*)
> Get the energy of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

>> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.wall.**sphere**(*r=0.0*, *origin=(0.0, 0.0, 0.0)*, *inside=True*)
   Sphere wall.

   Parameters

   - **r** (*float*) – Sphere radius (in distance units)
   - **origin** (*tuple*) – Sphere origin (in x,y,z coordinates)
   - **inside** (*bool*) – Selects the half-space to be used

Define a spherical half-space:

- inside = True selects the space inside the radius of the sphere and includes the sphere surface.
- inside = False selects the space outside the radius of the sphere.

Use in function calls or by reference in the creation or modification of wall groups.

The following example is intended to demonstrate cylinders and planes as well. Note that the distinction between points and vectors is reflected in the default parameters.

Examples:

```
In[0]:
# One line initialization
one_line_walls=wall.group(wall.sphere(r=3,origin=(0,0,0)),wall.cylinder(r=2.5,
→axis=(0,0,1),inside=True), wall.plane(normal=(1,0,0)))
print(one_line_walls)
full_wall_object=wall.group([wall.sphere()]*20,[wall.cylinder()]*20,[wall.
→plane()]*60)
# Sharing wall group elements and access by reference
common_sphere=wall.sphere()
linked_walls1=wall.group(common_sphere,wall.plane(origin=(3,0,0),normal=(-1,0,0)))
linked_walls2=wall.group(common_sphere,wall.plane(origin=(-3,0,0),normal=(1,0,0)))
common_sphere.r=5.0
linked_walls1.spheres[0].origin=(0,0,1)
print(linked_walls1)
print(linked_walls2)

Out[0]:
Wall_Data_Structure:
spheres:1{
[0:   Radius=3   Origin=(0.0, 0.0, 0.0)  Inside=True]}
cylinders:1{
[0:   Radius=2.5  Origin=(0.0, 0.0, 0.0)  Axis=(0.0, 0.0, 1.0)    Inside=True]}
planes:1{
[0:   Origin=(0.0, 0.0, 0.0)  Normal=(1.0, 0.0, 0.0)]}
Wall_Data_Structure:
spheres:1{
[0:   Radius=5.0  Origin=(0.0, 0.0, 1.0)  Inside=True]}
cylinders:0{}
planes:1{
[0:   Origin=(3.0, 0.0, 0.0)  Normal=(-1.0, 0.0, 0.0)]}
Wall_Data_Structure:
spheres:1{
[0:   Radius=5.0  Origin=(0.0, 0.0, 1.0)  Inside=True]}
cylinders:0{}
```

(continues on next page)

```
planes:1{
[0:    Origin=(-3.0, 0.0, 0.0) Normal=(1.0, 0.0, 0.0)]}
```

class hoomd.md.wall.**wallpotential**(*walls*, *r_cut*, *name=''*)
Generic wall potential.

wallpotential should not be used directly. It is a base class that provides common features to all standard wall potentials. Rather than repeating all of that documentation in many different places, it is collected here.

All wall potential commands specify that a given potential energy and potential be computed on all particles in the system within a cutoff distance, r_{cut}, from each wall in the given wall group. The force $\vec{F}$ is in the direction of $\vec{r}$, the vector pointing from the particle to the wall or half-space boundary and $V_{\text{pair}}(r)$ is the specific pair potential chosen by the respective command. Wall forces are implemented with the concept of half-spaces in mind. There are two modes which are allowed currently in wall potentials: standard and extrapolated.

Standard Mode.

In the standard mode, when $r_{\text{extrap}} \leq 0$, the potential energy is only applied to the half-space specified in the wall group. $V(r)$ is evaluated in the same manner as when the mode is shift for the analogous *pair* potentials within the boundaries of the half-space.

$$V(r) = V_{\text{pair}}(r) - V_{\text{pair}}(r_{\text{cut}})$$

For inside=True (closed) half-spaces:

$$
\begin{aligned}
\vec{F} = & \quad -\nabla V(r) & 0 \leq r < r_{\text{cut}} \\
= & \quad 0 & r \geq r_{\text{cut}} \\
= & \quad 0 & r < 0
\end{aligned}
$$

For inside=False (open) half-spaces:

$$
\begin{aligned}
\vec{F} = & \quad -\nabla V(r) & 0 < r < r_{\text{cut}} \\
= & \quad 0 & r \geq r_{\text{cut}} \\
= & \quad 0 & r \leq 0
\end{aligned}
$$

The wall potential can be linearly extrapolated beyond a minimum separation from the wall r_{extrap} in the active half-space. This can be useful for bringing particles outside the half-space into the active half-space. It can also be useful for typical wall force usages by effectively limiting the maximum force experienced by the particle due to the wall. The potential is extrapolated into **both** half-spaces and the cutoff r_{cut} only applies in the active half-space. The user should then be careful using this mode with multiple nested walls. It is intended to be used primarily for initialization.

The extrapolated potential has the following form:

$$
\begin{aligned}
V_{\text{extrap}}(r) = & \quad V(r) & , r > r_{\text{extrap}} \\
= & \quad V(r_{\text{extrap}}) + (r_{\text{extrap}} - r)\vec{F}(r_{\text{extrap}}) \cdot \vec{n} & , r \leq r_{\text{extrap}}
\end{aligned}
$$

where $\vec{n}$ is the normal into the active half-space. This gives an effective force on the particle due to the wall:

$$
\begin{aligned}
\vec{F}(r) = & \quad \vec{F}_{\text{pair}}(r) & , r > r_{\text{extrap}} \\
= & \quad \vec{F}_{\text{pair}}(r_{\text{extrap}}) & , r \leq r_{\text{extrap}}
\end{aligned}
$$

where $\vec{F}_{\text{pair}}$ is given by the gradient of the pair force

$$
\begin{aligned}
\vec{F}_{\text{pair}}(r) = & \quad -\nabla V_{\text{pair}}(r) & , r < r_{\text{cut}} \\
= & \quad 0 & , r \geq r_{\text{cut}}
\end{aligned}
$$

In other words, if r_{extrap} is chosen so that the pair force would point into the active half-space, the extrapolated potential will push all particles into the active half-space. See `lj` for a pictorial example.

To use extrapolated mode, the following coefficients must be set per unique particle types:

- All parameters required by the pair potential base for the wall potential
- r_{cut} - *r_cut* (in distance units) - *Optional: Defaults to global r_cut for the force if given or 0.0 if not*
- r_{extrap} - *r_extrap* (in distance units) - *Optional: Defaults to 0.0*

Generic Example

Note that the walls object below must be created before it is given as an argument to the force object. However, walls can be modified at any time before `hoomd.run()` is called and it will update itself appropriately. See `group` for more details about specifying the walls to be used:

```
walls=wall.group()
# Edit walls
my_force=wall.pairpotential(walls)
my_force.force_coeff.set('A', all required arguments)
my_force.force_coeff.set(['B','C'],r_cut=0.3, all required arguments)
my_force.force_coeff.set(['B','C'],r_extrap=0.3, all required arguments)
```

A specific example can be found in `lj`

Attention: The current wall force implementation does not support NPT integrators.

Note: The virial due to walls is computed, but the pressure and reported by `hoomd.analyze.log` is not well defined. The volume (area) of the box enters into the pressure computation, which is not correct in a confined system. It may not even be possible to define an appropriate volume with soft walls.

Note: An effective use of wall forces **requires** considering the geometry of the system. Each wall is only evaluated in one simulation box and thus is not periodic. Forces will be evaluated and added to all particles from all walls in the wall group. Additionally there are no safeguards requiring a wall to exist inside the box to have interactions. This means that an attractive force existing outside the simulation box would pull particles across the periodic boundary where they would immediately cease to have any interaction with that wall. It is therefore up to the user to use walls in a physically meaningful manner. This includes the geometry of the walls, their interactions, and as noted here their location.

Note: When $r_{cut} \leq 0$ or is set to False the particle type wall interaction is excluded.

Note: While wall potentials are based on the same potential energy calculations as pair potentials, Features of pair potentials such as specified neighborlists, and alternative force shifting modes are not supported.

---

disable(*log=False*)
    Disable the force.

> **Parameters log** (`bool`) – Set to True if you plan to continue logging the potential energy
> associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

Examples:

```
force.enable()
```

See `disable()`.

get_energy(*group*)
> Get the energy of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.wall.**yukawa**(*walls*, *r_cut=False*, *name=''*)
    Yukawa wall potential.

        Parameters

- **walls** (*group*) – Wall group containing half-space geometries for the force to act in.
- **r_cut** (*float*) – The global r_cut value for the force. Defaults to False or 0 if not specified.
- **name** (*str*) – The force name which will be used in the metadata and log files.

Wall force evaluated using the Yukawa potential. See *hoomd.md.pair.yukawa* for force details and base parameters and *wallpotential* for generalized wall potential implementation

Example:

```
walls=wall.group()
# add walls to interact with
wall_force_yukawa=wall.yukawa(walls, r_cut=3.0)
wall_force_yukawa.force_coeff.set('A', epsilon=1.0, kappa=1.0)
wall_force_yukawa.force_coeff.set('A', epsilon=2.0, kappa=0.5, r_cut=3.0)
wall_force_yukawa.force_coeff.set(['C', 'D'], epsilon=0.5, kappa=3.0)
```

disable(*log=False*)
    Disable the force.

        Parameters log (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

    Examples:

```
force.disable()
force.disable(log=True)
```

    Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

    By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
    Enable the force.

    Examples:

```
force.enable()
```

    See *disable()*.

get_energy(*group*)
    Get the energy of a particle group.

        Parameters group (*hoomd.group*) – The particle group to query the energy for.

        Returns The last computed energy for the members in the group.

    Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

2.16.14 md.special_pair

Overview

md.special_pair.lj	LJ special pair potential.
md.special_pair.coulomb	Coulomb special pair potential.

Details

Potentials between special pairs of particles

Special pairs are used to implement interactions between designated pairs of particles. They act much like bonds, except that the interaction potential is typically a pair potential, such as LJ.

By themselves, special pairs that have been specified in an initial configuration do nothing. Only when you specify an force (i.e. special_pairs.lj), are forces actually calculated between the listed particles.

class hoomd.md.special_pair.**coeff**

Define special_pair coefficients.

The coefficients for all special pair potentials are specified using this class. Coefficients are specified per pair type.

There are two ways to set the coefficients for a particular special_pair potential. The first way is to save the special_pair potential in a variable and call *set ()* directly. See below for an example of this.

The second method is to build the coeff class first and then assign it to the special_pair potential. There are some advantages to this method in that you could specify a complicated set of special_pair potential coefficients in a separate python file and import it into your job script.

Example:

```
my_coeffs = hoomd.md.special_pair.coeff();
special_pair_force.pair_coeff.set('pairtype1', epsilon=1, sigma=1)
special_pair_force.pair_coeff.set('backbone', epsilon=1.2, sigma=1)
```

set (*type*, ***coeffs*)
> Sets parameters for special_pair types.

> > **Parameters**

> > > - **type** (*str*) – Type of special_pair (or a list of type names)

> > > - **coeffs** – Named coefficients (see below for examples)

> Calling *set()* results in one or more parameters being set for a special_pair type. Types are identified by name, and parameters are also added by name. Which parameters you need to specify depends on the special_pair potential you are setting these coefficients for, see the corresponding documentation.

> All possible special_pair types as defined in the simulation box must be specified before executing run(). You will receive an error if you fail to do so. It is not an error, however, to specify coefficients for special_pair types that do not exist in the simulation. This can be useful in defining a potential field for many different types of special_pairs even when some simulations only include a subset.

> Examples:

```
my_special_pair_force.special_pair_coeff.set('pair1', epsilon=1, sigma=1)
my_special_pair_force.pair_coeff.set('pair2', epsilon=0.5, sigma=0.7)
my_special_pair_force.pair_coeff.set(['special_pairA','special_pairB'],␣
↪epsilon=0, sigma=1)
```

> **Note:** Single parameters can be updated. If both `k` and `r0` have already been set for a particle type, then executing `coeff.set('polymer', r0=1.0)` will update the value of `r0` and leave the other parameters as they were previously set.

---

class hoomd.md.special_pair.**coulomb** (*name=None*)
> Coulomb special pair potential.

> > **Parameters name** (*str*) – Name of the special_pair instance.

coulomb specifies a Coulomb potential energy between the two particles in each defined pair.

This is useful for implementing e.g. special 1-4 interactions in all-atom force fields. It uses a standard Coulomb interaction with a scaling parameter. This allows for using this for scaled 1-4 interactions like in OPLS where both the 1-4 LJ and Coulomb interactions are scaled by 0.5.

$$\begin{aligned} V_{\text{Coulomb}}(r) = \quad & \alpha \cdot \left[\frac{q_a q_b}{r} \right] & r < r_{\text{cut}} \\ = \quad & 0 & r \geq r_{\text{cut}} \end{aligned}$$

where $\vec{r}$ is the vector pointing from one particle to the other in the bond.

Coefficients:

- α - Coulomb scaling factor (defaults to 1.0)

- q_a - charge of particle a (in hoomd charge units)

- q_b - charge of particle b (in hoomd charge units)

- r_{cut} - *r_cut* (in distance units)

Example:

```
coul = special_pair.coulomb(name="myOPLS_style")
coul.pair_coeff.set('pairtype_1', alpha=0.5, r_cut=1.1)
```

Note: The energy of special pair interactions is reported in a log quantity **special_pair_coul_energy**, which is separate from those of other non-bonded interactions. Therefore, the total energy of non-bonded interactions is obtained by adding that of standard and special interactions.

New in version 2.2.

Changed in version 2.2.

disable(*log=False*)
    Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
    Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy(*group*)
    Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
    Get the force of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial (*group*)

Get the virial of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the virial for.
>
> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

class hoomd.md.special_pair.**lj** (*name=None*)

LJ special pair potential.

> **Parameters name** (`str`) – Name of the special_pair instance.

`lj` specifies a Lennard-Jones potential energy between the two particles in each defined pair.

This is useful for implementing e.g. special 1-4 interactions in all-atom force fields.

The pair potential uses the standard LJ definition.

$$
\begin{aligned}
V_{\text{LJ}}(r) = & \quad 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \alpha \left(\frac{\sigma}{r}\right)^6 \right] \quad r < r_{\text{cut}} \\
= & \qquad\qquad 0 \qquad\qquad\qquad r \geq r_{\text{cut}}
\end{aligned}
$$

where $\vec{r}$ is the vector pointing from one particle to the other in the bond.

Coefficients:

- ε - *epsilon* (in energy units)
- σ - *sigma* (in distance units)
- α - *alpha* (unitless) - *optional*: defaults to 1.0
- r_{cut} - *r_cut* (in distance units)

Example:

```
lj = special_pair.lj(name="my_pair")
lj.pair_coeff.set('pairtype_1', epsilon=5.4, sigma=0.47, r_cut=1.1)
```

Note: The energy of special pair interactions is reported in a log quantity **special_pair_lj_energy**, which is separate from those of other non-bonded interactions. Therefore, the total energy of nonbonded interactions is obtained by adding that of standard and special interactions.

New in version 2.1.

disable (*log=False*)

Disable the force.

> **Parameters log** (`bool`) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
    Enable the force.

    Examples:

```
force.enable()
```

    See *disable()*.

get_energy(*group*)
    Get the energy of a particle group.

        Parameters **group** (*hoomd.group*) – The particle group to query the energy for.

        Returns The last computed energy for the members in the group.

    Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
    Get the force of a particle group.

        Parameters **group** (*hoomd.group*) – The particle group to query the force for.

        Returns The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
    Get the virial of a particle group.

        Parameters **group** (*hoomd.group*) – The particle group to query the virial for.

        Returns The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

2.17 mpcd

Overview

`hoomd.mpcd.integrator`	MPCD integrator

Details

Multiparticle collision dynamics.

Simulating complex fluids and soft matter using conventional molecular dynamics methods (`hoomd.md`) can be computationally demanding due to large disparities in the relevant length and time scales between molecular-scale solvents and mesoscale solutes such as polymers, colloids, and deformable materials like cells. One way to overcome this challenge is to simplify the model for the solvent while retaining its most important interactions with the solute. MPCD is a particle-based simulation method for resolving solvent-mediated fluctuating hydrodynamic interactions with a microscopically detailed solute model. This method has been successfully applied to a simulate a broad class of problems, including polymer solutions and colloidal suspensions both in and out of equilibrium.

Algorithm

In MPCD, the solvent is represented by point particles having continuous positions and velocities. The solvent particles propagate in alternating streaming and collision steps. During the streaming step, particles evolve according to Newton's equations of motion. Typically, no external forces are applied to the solvent, and streaming is straightforward with a large time step. Particles are then binned into local cells and undergo a stochastic multiparticle collision within the cell. Collisions lead to the build up of hydrodynamic interactions, and the frequency and nature of the collisions, along with the solvent properties, determine the transport coefficients. All standard collision rules conserve linear momentum within the cell and can optionally be made to enforce angular-momentum conservation. Currently, we have implemented the following collision rules with linear-momentum conservation only:

- `srd` – Stochastic rotation dynamics
- `at` – Andersen thermostat

Solute particles can be coupled to the solvent during the collision step. This is particularly useful for soft materials like polymers. Standard molecular dynamics integration can be applied to the solute. Coupling to the MPCD solvent introduces both hydrodynamic interactions and a heat bath that acts as a thermostat. In the future, fluid-solid coupling will also be introduced during the streaming step to couple hard particles and boundaries.

Details of this implementation of the MPCD algorithm for HOOMD-blue can be found in M. P. Howard et al. (2018).

Getting started

MPCD is intended to be used as an add-on to the standard MD methods in `hoomd.md`. To get started, take the following steps:

1. Initialize any solute particles using standard methods (`hoomd.init`).
2. Initialize the MPCD solvent particles using one of the methods in `mpcd.init`. Additional details on how to manipulate the solvent particle data can be found in `mpcd.data`.
3. Create an MPCD `integrator`.
4. Choose the appropriate streaming method from `mpcd.stream`.
5. Choose the appropriate collision rule from `mpcd.collide`, and set the collision rule parameters.

6. Setup an MD integrator and any interactions between solute particles.

7. Optionally, configure the sorting frequency to improve performance (see *update.sort*).

8. Run your simulation!

Example script for a pure bulk SRD fluid:

```python
import hoomd
hoomd.context.initialize()
from hoomd import mpcd

# Initialize (empty) solute in box.
box = hoomd.data.boxdim(L=100.)
hoomd.init.read_snapshot(hoomd.data.make_snapshot(N=0, box=box))

# Initialize MPCD particles and set sorting period.
s = mpcd.init.make_random(N=int(10*box.get_volume()), kT=1.0, seed=7)
s.sorter.set_period(period=25)

# Create MPCD integrator with streaming and collision methods.
mpcd.integrator(dt=0.1)
mpcd.stream.bulk(period=1)
mpcd.collide.srd(seed=42, period=1, angle=130., kT=1.0)

hoomd.run(2000)
```

Stability

hoomd.mpcd is currently **stable**, but remains under development. When upgrading versions, existing job scripts may need to be need to be updated. Such modifications will be noted in the change log.

Maintainer: Michael P. Howard, University of Texas at Austin.

class hoomd.mpcd.**integrator**(*dt*, *aniso=None*)
  MPCD integrator

  Parameters

  - **dt** (*float*) – Each time step of the simulation *hoomd.run()* will advance the real time of the system forward by *dt* (in time units).

  - **aniso** (*bool*) – Whether to integrate rotational degrees of freedom (bool), default None (autodetect).

  The MPCD integrator enables the MPCD algorithm concurrently with standard MD *integrate* methods. An integrator must be created in order for *stream* and *collide* methods to take effect. Embedded MD particles require the creation of an appropriate integration method. Typically, this will just be *nve*.

  In MPCD simulations, *dt* defines the amount of time that the system is advanced forward every time step. MPCD streaming and collision steps can be defined to occur in multiples of *dt*. In these cases, any MD particle data will be updated every *dt*, while the MPCD particle data is updated asynchronously for performance. For example, if MPCD streaming happens every 5 steps, then the particle data will be updated as follows:

```
        0     1     2     3     4     5
MD:     |---->|---->|---->|---->|---->|
MPCD:   |---------------------------->|
```

If the MPCD particle data is accessed via the snapshot interface at time step 3, it will actually contain the MPCD particle data for time step 5. The MD particles can be read at any time step because their positions are updated every step.

Examples:

```
mpcd.integrator(dt=0.1)
mpcd.integrator(dt=0.01, aniso=True)
```

restore_state()
> Restore the state information from the file used to initialize the simulations

set_params(*dt=None*, *aniso=None*)
> Changes parameters of an existing integration mode.

> > **Parameters**

> > > • **dt** (`float`) – New time step delta (if set) (in time units).

> > > • **aniso** (`bool`) – Anisotropic integration mode (bool), default None (autodetect).

> Examples:

```
integrator.set_params(dt=0.007)
integrator.set_params(dt=0.005, aniso=False)
```

Modules

2.17.1 mpcd.collide

Overview

at
srd

Details

MPCD collision methods

An MPCD collision method is required to update the particle velocities over time. It is meant to be used in conjunction with an *integrator* and streaming method (see *stream*). Particles are binned into cells based on their positions, and all particles in a cell undergo a stochastic collision that updates their velocities while conserving linear momentum. Collision rules can optionally be extended to also enforce angular-momentum conservation. The stochastic collision lead to a build up of hydrodynamic interactions, and the choice of collision rule and solvent properties determine the transport coefficients.

class hoomd.mpcd.collide.**at**(*seed*, *period*, *kT*, *group=None*)
> Andersen thermostat method

> > **Parameters**

> > > • **seed** (`int`) – Seed to the collision method random number generator (must be positive)

> > > • **period** (`int`) – Number of integration steps between collisions

> > > • **kT** (*hoomd.variant* or `float`) – Temperature set point for the thermostat (in energy units).

- **group** (`hoomd.group`) – Group of particles to embed in collisions

This class implements the Andersen thermostat collision rule for MPCD, as described by Allahyarov and Gompper. Every *period* steps, the particles are binned into cells. The size of the cell can be selected as a property of the MPCD system (see `data.system.set_params()`). New particle velocities are then randomly drawn from a Gaussian distribution (using *seed*) relative to the center-of-mass velocity for the cell. The random velocities are given zero-mean so that the cell momentum is conserved. This collision rule naturally imparts the canonical (NVT) ensemble consistent with *kT*. The properties of the AT fluid are tuned using *period*, *kT*, the underlying size of the MPCD cell list, and the particle density.

Note: The *period* must be chosen as a multiple of the MPCD `stream` period. Other values will result in an error when `hoomd.run()` is called.

When the total mean-free path of the MPCD particles is small, the underlying MPCD cell list must be randomly shifted in order to ensure Galilean invariance. Because the performance penalty from grid shifting is small, shifting is enabled by default in all simulations. Disable it using `set_params()` if you are sure that you do not want to use it.

HOOMD particles in *group* can be embedded into the collision step (see `embed()`). A separate integration method (`integrate`) must be specified in order to integrate the positions of particles in *group*. The recommended integrator is `nve`.

Examples:

```
collide.at(seed=42, period=1, kT=1.0)
collide.at(seed=77, period=50, kT=1.5, group=hoomd.group.all())
```

disable()
    Disable the collision method

    Examples:

    ```
    method.disable()
    ```

    Disabling the collision method removes it from the current MPCD system definition. Only one collision method can be attached to the system at any time, so use this method to remove the current collision method before adding another.

embed(*group*)
    Embed a particle group into the MPCD collision

        Parameters **group** (`hoomd.group`) – Group of particles to embed

    The *group* is embedded into the MPCD collision step and cell properties. During collisions, the embedded particles are included in determining per-cell quantities, and the collisions are applied to the embedded particles.

    No integrator is generated for *group*. Usually, you will need to create a separate method to integrate the embedded particles. The recommended (and most common) integrator to use is `nve`. It is generally **not** a good idea to use a thermostatting integrator for the embedded particles, since the MPCD particles themselves already act as a heat bath that will thermalize the embedded particles.

    Examples:

    ```
    polymer = hoomd.group.type('P')
    md.integrate.nve(group=polymer)
    method.embed(polymer)
    ```

enable()
> Enable the collision method

> Examples:

```
method.enable()
```

> Enabling the collision method adds it to the current MPCD system definition. Only one collision method can be attached to the system at any time. If another method is already set, *disable()* must be called first before switching.

set_params(*shift=None*, *kT=None*)
> Set parameters for the SRD collision method

> **Parameters**

> > • **shift** (*bool*) – If True, perform a random shift of the underlying cell list.

> > • **kT** (*hoomd.variant* or *float*) – Temperature set point for the thermostat (in energy units).

> Examples:

```
srd.set_params(shift=False)
srd.set_params(shift=True, kT=1.0)
srd.set_params(kT=hoomd.data.variant.linear_interp([[0,1.0],[100,5.0]]))
```

set_period(*period*)
> Set the collision period.

> > **Parameters period** (*int*) – New collision period.

> The MPCD collision period can only be changed to a new value on a simulation timestep that is a multiple of both the previous *period* and the new *period*. An error will be raised if it is not.

> Examples:

```
# The initial period is 5.
# The period can be updated to 2 on step 10.
hoomd.run_upto(10)
method.set_period(period=2)

# The period can be updated to 4 on step 12.
hoomd.run_upto(12)
hoomd.set_period(period=4)
```

class hoomd.mpcd.collide.**srd**(*seed*, *period*, *angle*, *kT=False*, *group=None*)
> Stochastic rotation dynamics method

> **Parameters**

> > • **seed** (*int*) – Seed to the collision method random number generator (must be positive)

> > • **period** (*int*) – Number of integration steps between collisions

> > • **angle** (*float*) – SRD rotation angle (degrees)

> > • **kT** (*hoomd.variant* or *float* or bool) – Temperature set point for the thermostat (in energy units). If False (default), no thermostat is applied and an NVE simulation is run.

> > • **group** (*hoomd.group*) – Group of particles to embed in collisions

This class implements the classic stochastic rotation dynamics collision rule for MPCD as first proposed by Malevanets and Kapral. Every *period* steps, the particles are binned into cells. The size of the cell can be selected as a property of the MPCD system (see `data.system.set_params()`). The particle velocities are then rotated by *angle* around an axis randomly drawn from the unit sphere. The rotation is done relative to the average velocity, so this rotation rule conserves momentum and energy within each cell, and so also globally. The properties of the SRD fluid are tuned using *period*, *angle*, *kT*, the underlying size of the MPCD cell list, and the particle density.

Note: The *period* must be chosen as a multiple of the MPCD `stream` period. Other values will result in an error when `hoomd.run()` is called.

When the total mean-free path of the MPCD particles is small, the underlying MPCD cell list must be randomly shifted in order to ensure Galilean invariance. Because the performance penalty from grid shifting is small, shifting is enabled by default in all simulations. Disable it using `set_params()` if you are sure that you do not want to use it.

HOOMD particles in *group* can be embedded into the collision step (see `embed()`). A separate integration method (`integrate`) must be specified in order to integrate the positions of particles in *group*. The recommended integrator is `nve`.

The SRD method naturally imparts the NVE ensemble to the system comprising the MPCD particles and *group*. Accordingly, the system must be properly initialized to the correct temperature. (SRD has an H theorem, and so particles exchange momentum to reach an equilibrium temperature.) A thermostat can be applied in conjunction with the SRD method through the *kT* parameter. SRD employs a Maxwell-Boltzmann thermostat on the cell level, which generates the (correct) isothermal ensemble. The temperature is defined relative to the cell-average velocity, and so can be used to dissipate heat in nonequilibrium simulations. Under this thermostat, the SRD algorithm still conserves momentum, but energy is of course no longer conserved.

Examples:

```
collide.srd(seed=42, period=1, angle=130.)
collide.srd(seed=77, period=50, angle=130., group=hoomd.group.all())
collide.srd(seed=1991, period=10, angle=90., kT=1.5)
```

disable()

    Disable the collision method

    Examples:

```
method.disable()
```

    Disabling the collision method removes it from the current MPCD system definition. Only one collision method can be attached to the system at any time, so use this method to remove the current collision method before adding another.

embed(*group*)

    Embed a particle group into the MPCD collision

        Parameters group (`hoomd.group`) – Group of particles to embed

    The *group* is embedded into the MPCD collision step and cell properties. During collisions, the embedded particles are included in determining per-cell quantities, and the collisions are applied to the embedded particles.

    No integrator is generated for *group*. Usually, you will need to create a separate method to integrate the embedded particles. The recommended (and most common) integrator to use is `nve`. It is generally **not** a good idea to use a thermostatting integrator for the embedded particles, since the MPCD particles themselves already act as a heat bath that will thermalize the embedded particles.

Examples:

```
polymer = hoomd.group.type('P')
md.integrate.nve(group=polymer)
method.embed(polymer)
```

enable()
    Enable the collision method

    Examples:

```
method.enable()
```

Enabling the collision method adds it to the current MPCD system definition. Only one collision method can be attached to the system at any time. If another method is already set, *disable()* must be called first before switching.

set_params(*angle=None*, *shift=None*, *kT=None*)
    Set parameters for the SRD collision method

    Parameters

    - **angle** (*float*) – SRD rotation angle (degrees)

    - **shift** (*bool*) – If True, perform a random shift of the underlying cell list

    - **kT** (*hoomd.variant* or *float* or bool) – Temperature set point for the thermostat (in energy units). If False, any set thermostat is removed and an NVE simulation is run.

    Examples:

```
srd.set_params(angle=90.)
srd.set_params(shift=False)
srd.set_params(angle=130., shift=True, kT=1.0)
srd.set_params(kT=hoomd.data.variant.linear_interp([[0,1.0],[100,5.0]]))
srd.set_params(kT=False)
```

set_period(*period*)
    Set the collision period.

    Parameters period(*int*) – New collision period.

The MPCD collision period can only be changed to a new value on a simulation timestep that is a multiple of both the previous *period* and the new *period*. An error will be raised if it is not.

Examples:

```
# The initial period is 5.
# The period can be updated to 2 on step 10.
hoomd.run_upto(10)
method.set_period(period=2)

# The period can be updated to 4 on step 12.
hoomd.run_upto(12)
hoomd.set_period(period=4)
```

2.17.2 mpcd.data

Overview

snapshot	MPCD system snapshot
system	MPCD system data
make_snapshot	Creates an empty MPCD system snapshot

Details

MPCD data structures

MPCD and HOOMD

MPCD data is currently initialized in a secondary step from HOOMD using a snapshot interface. Even if only MPCD particles are present in the system, an empty HOOMD system must first be created. Once the HOOMD system has been initialized (see *hoomd.init*), an MPCD snapshot can be created using:

```
>>> snap = mpcd.data.make_snapshot(100)
```

The MPCD system can then initialized from the snapshot (see *hoomd.mpcd.init*):

```
>>> mpcd.init.read_snapshot(snap)
```

Because the MPCD data is stored separately from the HOOMD data, special care must be taken when using certain commands that operate on the HOOMD system data. For example, the HOOMD box size is not permitted to be changed after the MPCD particle data has been initialized (see *hoomd.mpcd.init*), so any resizes or replications of the HOOMD system must occur before then:

```
>>> hoomd_sys.replicate(2,2,2)
>>> snap.replicate(2,2,2)
>>> mpcd_sys = mpcd.init.read_snapshot(snap)
>>> hoomd_sys.replicate(2,1,1)
**ERROR**
```

Similarly, *box_resize* will also fail after the MPCD system has been initialized.

During a simulation, the MPCD particle data can be read, modified, and restored using *take_snapshot()* and *restore_snapshot()*:

```
snap = mpcd_sys.take_snapshot()
# modify snapshot
mpcd_sys.restore_snapshot(snap)
```

MPCD and MPI

MPCD supports MPI parallelization through domain decomposition. The MPCD data in the snapshot is only valid on rank 0, and is distributed to all ranks through the snapshot collective calls.

Particle data

All MPCD particle data is accessible through the *particles* snapshot property. The size of the MPCD particle data *N* can be resized:

```
>>> snap.particles.resize(200)
>>> print(snap.particles.N)
200
```

Because the number of MPCD particles in a simulation is large, fewer particle properties are tracked per particle than for standard HOOMD particles. All particle data can be set as for standard snapshots using numpy arrays. Each particle is assigned a tag from 0 to *N* (exclusive) that is tracked. The following particle properties are recorded:

- Particle positions are stored as an Nx3 numpy array:

```
>>> snap.particles.position[4] = [1., 2., 3.]
>>> print(snap.particles.position[4])
[ 1. 2. 3.]
```

  By default, all positions are initialized with zeros.

- Particle velocities can similarly be manipulated as an Nx3 numpy array:

```
>>> snap.particles.velocity[2] = [0.5, 1.5, -0.25]
>>> print(snap.particles.velocity[2])
[0.5 1.5 -0.25]
```

  By default, all velocities are initialized with zeros. It is important to reassign these to a sensible value consistent with the temperature of the system.

- Each particle can be assigned a type (a name for the kind of the particle). First, a list of possible types for the system should be set:

```
>>> snap.particles.types = ['A','B']
print(snapshot.particles.types)
```

  Then, an index is assigned to each particle corresponding to the type:

```
>>> snap.particles.typeid[1] = 1 # B
>>> snap.particles.typeid[2] = 0 # A
```

  By default, all particles are assigned a type index of 0, and no types are set. If no types are specified, type A is created by default at initialization.

- All MPCD particles have the same mass, which can be accessed or set:

```
>>> snap.particles.mass = 1.5
>>> print(snap.mass)
1.5
```

  By default, all particles are assigned unit mass.

hoomd.mpcd.data.**make_snapshot**(*N=0*)

 Creates an empty MPCD system snapshot

> **Parameters** **N** (*int*) – Number of MPCD particles in the snapshot
>
> **Returns** MPCD snapshot
>
> **Return type** snap (*hoomd.mpcd.data.snapshot*)

 Examples:

```
snap = mpcd.data.make_snapshot()
snap = mpcd.data.make_snapshot(N=50)
```

Notes

The HOOMD system **must** be initialized **before** the MPCD snapshot is taken, or an error will be raised.

class hoomd.mpcd.data.**snapshot**(*sys_snap*)

    MPCD system snapshot

        Parameters sys_snap (*object*) – The C++ representation of the system data snapshot

    The MPCD system snapshot must be initialized after the HOOMD system.

    This class is not intended to be initialized directly by the user, but rather returned by *make_snapshot()* or *take_snapshot()*.

    particles

        MPCD particle data snapshot

    replicate(*nx=1, ny=1, nz=1*)

        Replicate the MPCD system snapshot

        Parameters

- **nx** (*int*) – Number of times to replicate snapshot in *x*
- **ny** (*int*) – Number of times to replicate snapshot in *y*
- **nz** (*int*) – Number of times to replicate snapshot in *z*

        Examples:

```
snap.replicate(nx=2,ny=1,nz=3)
```

        This method is intended only to be used with *hoomd.data.system_data.replicate()* **prior** to initialization of the MPCD system. The MPCD snapshot must be replicated to a size consistent with the system at the time of initialization. An error will be raised otherwise.

class hoomd.mpcd.data.**system**(*sysdata*)

    MPCD system data

        Parameters sysdata (*object*) – C++ representation of the MPCD system data

    This class is not intended to be initialized by the user, but is the result returned by *hoomd.mpcd.init*.

    restore_snapshot(*snapshot*)

        Replaces the current MPCD system state

        Parameters snapshot (*hoomd.mpcd.data.snapshot*) – MPCD system snapshot

    The MPCD system data is replaced by the contents of *snapshot*.

    Examples:

```
snap = mpcd_sys.take_snapshot()
snap.particles.typeid[2] = 1
mpcd_sys.restore_snapshot(snap)
```

    set_params(*cell=None*)

        Set parameters of the MPCD system

        Parameters cell (*float*) – Edge length of an MPCD cell.

    Every MPCD system is given a cell list for binning particles (see *mpcd.collide*). The size of the cell list sets the length scale over which hydrodynamic interactions are resolved. By default, the system is given a cell size of 1.0, i.e., the cell sets the unit of length, which is typical for most use cases. If your

simulation has a different fundamental unit of length, you can adjust the cell size, but be aware that this will also change the fluid properties.

take_snapshot (*particles=True*)

Takes a snapshot of the current state of the MPCD system

> **Parameters particles** (`bool`) – If true, include particle data in snapshot

Examples:

```
snap = mpcd_sys.take_snapshot()
```

2.17.3 mpcd.force

Overview

`block`	Block force.
`constant`	Constant force.
`sine`	Sine force.

Details

MPCD external force fields.

An external field specifies the force to be applied per MPCD particle in the equations of motion (see `mpcd.stream`). The external force should be compatible with the chosen streaming geometry. Global momentum conservation is typically broken by adding an external force field; care should be chosen that the force field does not cause the system to net accelerate (i.e., it must maintain *average* momentum conservation). Additionally, a thermostat will likely be required to maintain temperature control in the driven system (see `mpcd.collide`).

Note: The external force **must** be attached to a streaming method (see `mpcd.stream`) using *set_force* to take effect. On its own, the force object will not affect the system.

class hoomd.mpcd.force.**block**(*F, H=None, w=None*)

Block force.

> **Parameters**
>
> - **F** (`float`) – Magnitude of the force in *x* per particle.
> - **H** (`float or None`) – Half-width between centers of block regions.
> - **w** (`float or None`) – Half-width of blocks.

Imposes a constant force in *x* as a function of position in *z*:

$$\mathbf{F} = \begin{cases} +F\mathbf{e}_x & |r_z - H| < w \\ -F\mathbf{e}_x & |r_z + H| < w \\ \mathbf{0} & \text{otherwise} \end{cases} \tag{2.1}$$

The force is applied in blocks defined by *H* and *w* so that the force in *x* is $+F$ in the upper block, $-F$ in the lower block, and zero otherwise. The blocks must lie fully within the simulation box or an error will be raised. The blocks also should not overlap (the force will be zero in any overlapping regions), and a warning will be issued if the blocks overlap.

This force field can be used to implement the double-parabola method for measuring viscosity by setting $H = L_z/4$ and $w = L_z/4$, where L_z is the size of the simulation box in z. If H or w is None, it will default to this value based on the current simulation box.

Examples:

```
# fully specified blocks
force.block(F=1.0, H=5.0, w=5.0)

# default blocks to full box
force.block(F=0.5)
```

Note: The external force **must** be attached to a streaming method (see `mpcd.stream`) using *set_force* to take effect. On its own, the force object will not affect the system.

New in version 2.6.

class hoomd.mpcd.force.**constant**(*F*)

Constant force.

> **Parameters F** (`tuple`) – 3d vector specifying the force per particle.

The same constant-force is applied to all particles, independently of time and their positions. This force is useful for simulating pressure-driven flow in conjunction with a confined geometry (e.g., `slit`) having no-slip boundary conditions.

Examples:

```
# tuple
force.constant((1.,0.,0.))

# list
force.constant([1.,2.,3.])

# NumPy array
g = np.array([0.,0.,-1.])
force.constant(g)
```

Note: The external force **must** be attached to a streaming method (see `mpcd.stream`) using *set_force* to take effect. On its own, the force object will not affect the system.

New in version 2.6.

class hoomd.mpcd.force.**sine**(*F*, *k*)

Sine force.

> **Parameters**
>
> - **F** (`float`) – Magnitude of the force in *x* per particle.
> - **k** (`float`) – Wavenumber for the force.

Applies a force in *x* that is sinusoidally varying in *z*.

$$\mathbf{F}(\mathbf{r}) = F\sin(kr_z)\mathbf{e}_x$$

Typically, the wavenumber should be something that is commensurate with the simulation box. For example, $k = 2\pi/L_z$ will generate one period of the sine in `bulk` geometry.

Examples:

```
# one period
k0 = 2.*np.pi/box.Lz
force.sine(F=1.0, k=k0)

# two periods
force.sine(F=0.5, k=2*k0)
```

The user will need to determine what value of *k* makes sense for their problem, as it is too difficult to validate all values of *k* for all streaming geometries.

Note: The external force **must** be attached to a streaming method (see `mpcd.stream`) using *set_force* to take effect. On its own, the force object will not affect the system.

New in version 2.6.

2.17.4 mpcd.init

Overview

`make_random`	Initialize particles randomly
`read_snapshot`	Initialize from a snapshot

Details

MPCD system initialization

Commands to initialize the MPCD system data. Currently, random initialization and snapshot initialization (see `hoomd.mpcd.data`) are supported. Random initialization is useful for large systems where a snapshot is impractical. Snapshot initialization is useful when you require fine control over the particle properties and initial configuration.

`hoomd.mpcd.init.`**`make_random`**(*N*, *kT*, *seed*)
> Initialize particles randomly

> > **Parameters**

> > > • **N** (`int`) – Total number of MPCD particles

> > > • **kT** (`float`) – Temperature of MPCD particles (in energy units)

> > > • **seed** (`int`) – Random seed for initialization

> > **Returns** Initialized MPCD system data (`hoomd.mpcd.data.system`)

> MPCD particles are randomly initialized into the simulation box. An MPCD system can be randomly initialized only **after** the HOOMD system is first initialized (see `hoomd.init`). The system can only be initialized one time. The total number of particles *N* is evenly divided between all domains. Random positions are then drawn uniformly within the (local) box. Particle velocities are drawn from a Maxwell-Boltzmann distribution consistent with temperature *kT*. All MPCD particles are given unit mass and type A.

> Examples:

```
mpcd.init.make_random(N=1250000000, kT=1.0, seed=42)
```

Notes

Random number generation is performed using C++11 `mt19937` seeded by *seed* plus the rank number in MPI simulations. This random number generator is separate from other generators used in MPCD, so *seed* can be reasonably recycled elsewhere.

hoomd.mpcd.init.**read_snapshot**(*snapshot*)
> Initialize from a snapshot

> > **Parameters snapshot** (*hoomd.mpcd.data.snapshot*) – MPCD system data snapshot

> > **Returns** Initialized MPCD system data (*hoomd.mpcd.data.system*)

> An MPCD system can be initialized from a snapshot **after** the HOOMD system is first initialized (see *hoomd.init*). The system can only be initialized one time. If no type is specified in the snapshot, a default type *A* will be assigned to the MPCD particles.

> Examples:

> ```
> snap = mpcd.data.make_snapshot(N=10)
> snap.particles.position[:] = L * np.random.random((10,3))
> mpcd.init.read_snapshot(snap)
> ```

> **Notes**

> It is expected that the snapshot has the same box size as the HOOMD system. By default, this is how a new snapshot is initialized. If the HOOMD system is resized after the MPCD snapshot is created and before initialization from the MPCD snapshot, an error will be raised if the MPCD snapshot is not properly resized.

2.17.5 mpcd.integrate

Overview

slit	NVE integration with bounce-back rules in a slit channel.
slit_pore	NVE integration with bounce-back rules in a slit pore channel.

Details

MPCD integration methods

Defines bounce-back methods for integrating solutes (MD particles) embedded in an MPCD solvent. The integration scheme is velocity Verlet (NVE) with bounce-back performed at the solid boundaries defined by a geometry, as in *mpcd.stream*. This gives a simple approximation of the interactions required to keep a solute bounded in a geometry, and more complex interactions can be specified, for example, by writing custom external fields.

Similar caveats apply to these methods as for the *mpcd.stream* methods. In particular:

1. The simulation box is periodic, but the geometry imposes inherently non-periodic boundary conditions. You must ensure that the box is sufficiently large to enclose the geometry and that all particles lie inside it, or an error will be raised at runtime.

2. You must also ensure that particles do not self-interact through the periodic boundaries. This is usually achieved for simple pair potentials by padding the box size by the largest cutoff radius. Failure to do so may result in

unphysical interactions.

3. Bounce-back rules do not always enforce no-slip conditions at surfaces properly. It may still be necessary to add additional 'ghost' MD particles in the surface to achieve the right boundary conditions and reduce density fluctuations.

The integration methods defined here are not restricted to only MPCD simulations: they can be used with both `md.integrate.mode_standard` and `mpcd.integrator`. For example, the same integration methods might be used to run DPD simulations with surfaces.

These bounce-back methods do not support anisotropic integration because torques are currently not computed for collisions with the boundary. Similarly, rigid bodies will also not be treated correctly because the integrators are not aware of the extent of the particles; the surface reflections are treated as point particles. An error will be raised if an anisotropic integration mode is specified.

class hoomd.mpcd.integrate.**slit**(*group*, *H*, *V=0.0*, *boundary='no_slip'*)
> NVE integration with bounce-back rules in a slit channel.

> **Parameters**

>> • **group** (*hoomd.group*) – Group of particles on which to apply this method.

>> • **H** (*float*) – channel half-width

>> • **V** (*float*) – wall speed (default: 0)

>> • **boundary** – 'slip' or 'no_slip' boundary condition at wall (default: 'no_slip')

> This integration method applies to particles in *group* in the parallel-plate channel geometry. This method is the MD analog of `stream.slit`, which documents additional details about the geometry.

> A `hoomd.compute.thermo` is automatically specified and associated with *group*.

> Examples:

> ```
> all = group.all()
> slit = mpcd.integrate.slit(group=all, H=5.0)
> slit = mpcd.integrate.slit(group=all, H=10.0, V=1.0)
> ```

> New in version 2.7.

> **disable**()
>> Disables the integration method.

>> Examples:

>> ```
>> method.disable()
>> ```

>> Executing the disable command will remove the integration method from the simulation. Any `hoomd.run()` command executed after disabling an integration method will not apply the integration method to the particles during the simulation. A disabled integration method can be re-enabled with `enable()`.

> **enable**()
>> Enables the integration method.

>> Examples:

>> ```
>> method.enable()
>> ```

>> **See also:**

>> `disable()`.

set_params(*H=None*, *V=None*, *boundary=None*)

    Set parameters for the slit geometry.

        Parameters

- **H** (*float*) – channel half-width

- **V** (*float*) – wall speed (default: 0)

- **boundary** – 'slip' or 'no_slip' boundary condition at wall (default: 'no_slip')

    Examples:

```
slit.set_params(H=8.)
slit.set_params(V=2.0)
slit.set_params(boundary='slip')
slit.set_params(H=5, V=0., boundary='no_slip')
```

class hoomd.mpcd.integrate.**slit_pore**(*group*, *H*, *L*, *boundary='no_slip'*)

    NVE integration with bounce-back rules in a slit pore channel.

        Parameters

- **group** (*hoomd.group*) – Group of particles on which to apply this method.

- **H** (*float*) – channel half-width.

- **L** (*float*) – pore half-length.

- **boundary** – 'slip' or 'no_slip' boundary condition at wall (default: 'no_slip')

This integration method applies to particles in *group* in the parallel-plate (slit) pore geometry. This method is the MD analog of *stream.slit_pore*, which documents additional details about the geometry.

A *hoomd.compute.thermo* is automatically specified and associated with *group*.

Examples:

```
all = group.all()
slit_pore = mpcd.integrate.slit_pore(group=all, H=10.0, L=10.)
```

New in version 2.7.

disable()

    Disables the integration method.

    Examples:

```
method.disable()
```

    Executing the disable command will remove the integration method from the simulation. Any *hoomd.run()* command executed after disabling an integration method will not apply the integration method to the particles during the simulation. A disabled integration method can be re-enabled with *enable()*.

enable()

    Enables the integration method.

    Examples:

```
method.enable()
```

    See also:

    disable().

set_params (*H=None*, *L=None*, *boundary=None*)
>   Set parameters for the slit pore geometry.

>   **Parameters**

>   - **H** (*float*) – channel half-width.

>   - **L** (*float*) – pore half-length.

>   - **boundary** – 'slip' or 'no_slip' boundary condition at wall (default: 'no_slip')

>   Examples:

```
slit_pore.set_params(H=8.)
slit_pore.set_params(L=2.0)
slit_pore.set_params(boundary='slip')
slit_pore.set_params(H=5, L=4., boundary='no_slip')
```

2.17.6 mpcd.stream

Overview

bulk	Bulk fluid streaming geometry.
slit	Parallel plate (slit) streaming geometry.
slit_pore	Parallel plate (slit) pore streaming geometry.

Details

MPCD streaming methods

An MPCD streaming method is required to update the particle positions over time. It is meant to be used in conjunction with an *integrator* and collision method (see *collide*). Particle positions are propagated ballistically according to Newton's equations using a velocity-Verlet scheme for a time Δt:

$$\mathbf{v}(t + \Delta t/2) = \mathbf{v}(t) + (\mathbf{f}/m)(\Delta t/2)$$
$$\mathbf{r}(t + \Delta t) = \mathbf{r}(t) + \mathbf{v}(t + \Delta t/2)\Delta t$$
$$\mathbf{v}(t + \Delta t) = \mathbf{v}(t + \Delta t/2) + (\mathbf{f}/m)(\Delta t/2)$$

where $\mathbf{r}$ and $\mathbf{v}$ are the particle position and velocity, respectively, and $\mathbf{f}$ is the external force acting on the particles of mass m. For a list of forces that can be applied, see *mpcd.force*.

Since one of the main strengths of the MPCD algorithm is that it can be coupled to complex boundaries, the streaming geometry can be configured. MPCD solvent particles will be reflected from boundary surfaces using specular reflections (bounce-back) rules consistent with either "slip" or "no-slip" hydrodynamic boundary conditions. (The external force is only applied to the particles at the beginning and the end of this process.) To help fully enforce the boundary conditions, "virtual" MPCD particles can be inserted near the boundary walls.

Although a streaming geometry is enforced on the MPCD solvent particles, there are a few important caveats:

1. Embedded particles are not coupled to the boundary walls. They must be confined by an appropriate method, e.g., an external potential, an explicit particle wall, or a bounce-back method (see *mpcd.integrate*).

2. The confined geometry exists inside a fully periodic simulation box. Hence, the box must be padded large enough that the MPCD cells do not interact through the periodic boundary. Usually, this means adding at least one extra layer of cells in the confined dimensions. Your periodic simulation box will be validated by the confined geometry.

3. It is an error for MPCD particles to lie "outside" the confined geometry. You must initialize your system carefully using the snapshot interface to ensure all particles are "inside" the geometry. An error will be raised otherwise.

class `hoomd.mpcd.stream.`**bulk**(*period=1*)
    Bulk fluid streaming geometry.

        Parameters **period**(`int`) – Number of integration steps between collisions.

    `bulk` performs the streaming step for MPCD particles in a fully periodic geometry (2D or 3D). This geometry is appropriate for modeling bulk fluids. The streaming time Δt is equal to *period* steps of the `integrator`. For a pure MPCD fluid, typically *period* should be 1. When particles are embedded in the MPCD fluid through the collision step, *period* should be equal to the MPCD collision *period* for best performance. The MPCD particle positions will be updated every time the simulation timestep is a multiple of *period*. This is equivalent to setting a *phase* of 0 using the terminology of other periodic `update` methods.

    Example for pure MPCD fluid:

```
mpcd.integrator(dt=0.1)
mpcd.collide.srd(seed=42, period=1, angle=130.)
mpcd.stream.bulk(period=1)
```

    Example for embedded particles:

```
mpcd.integrator(dt=0.01)
mpcd.collide.srd(seed=42, period=10, angle=130., group=hoomd.group.all())
mpcd.stream.bulk(period=10)
```

    disable()
        Disable the streaming method

        Examples:

```
method.disable()
```

        Disabling the streaming method removes it from the current MPCD system definition. Only one streaming method can be attached to the system at any time, so use this method to remove the current streaming method before adding another.

    enable()
        Enable the streaming method

        Examples:

```
method.enable()
```

        Enabling the streaming method adds it to the current MPCD system definition. Only one streaming method can be attached to the system at any time. If another method is already set, `disable()` must be called first before switching. Streaming will occur when the timestep is the next multiple of *period*.

    remove_force()
        Remove the external force field for streaming.

        > **Warning:** This only removes the force on the MPCD particles. If you have embedded particles, you must separately disable any corresponding external force.

        Example:

```
streamer.remove_force()
```

set_force(*force*)
> Set the external force field for streaming.

> > **Parameters force** (`mpcd.force`) – External force field to apply to MPCD particles.

> Setting an external *force* will generate a flow of the MPCD particles subject to the boundary conditions of the streaming geometry. Note that the force field should be chosen in a way that makes sense for the geometry (e.g., so that the box is not continually accelerating).

> > **Warning:** The *force* applies only to the MPCD particles. If you have embedded particles, you should usually additionally specify a force from `md.force` for that particle group.

> Examples:

```
f = mpcd.force.constant(field=(1.0,0.0,0.0))
streamer.set_force(f)
```

set_period(*period*)
> Set the streaming period.

> > **Parameters period** (`int`) – New streaming period.

> The MPCD streaming period can only be changed to a new value on a simulation timestep that is a multiple of both the previous *period* and the new *period*. An error will be raised if it is not.

> Examples:

```
# The initial period is 5.
# The period can be updated to 2 on step 10.
hoomd.run_upto(10)
method.set_period(period=2)

# The period can be updated to 4 on step 12.
hoomd.run_upto(12)
hoomd.set_period(period=4)
```

class hoomd.mpcd.stream.**slit**(*H*, *V=0.0*, *boundary='no_slip'*, *period=1*)
> Parallel plate (slit) streaming geometry.

> > **Parameters**

> > > - **H** (`float`) – channel half-width
> > > - **V** (`float`) – wall speed (default: 0)
> > > - **boundary** (`str`) – boundary condition at wall ("slip" or "no_slip"")
> > > - **period** (`int`) – Number of integration steps between collisions

> The slit geometry represents a fluid confined between two infinite parallel plates. The slit is centered around the origin, and the walls are placed at $z = -H$ and $z = +H$, so the total channel width is *2H*. The walls may be put into motion, moving with speeds $-V$ and $+V$ in the *x* direction, respectively. If combined with a no-slip boundary condition, this motion can be used to generate simple shear flow.

> The "inside" of the `slit` is the space where $|z| < H$.

> Examples:

```
stream.slit(period=10, H=30.)
stream.slit(period=1, H=25., V=0.1)
```

New in version 2.6.

disable()
> Disable the streaming method

> Examples:

```
method.disable()
```

> Disabling the streaming method removes it from the current MPCD system definition. Only one streaming method can be attached to the system at any time, so use this method to remove the current streaming method before adding another.

enable()
> Enable the streaming method

> Examples:

```
method.enable()
```

> Enabling the streaming method adds it to the current MPCD system definition. Only one streaming method can be attached to the system at any time. If another method is already set, *disable()* must be called first before switching. Streaming will occur when the timestep is the next multiple of *period*.

remove_filler()
> Remove the virtual particle filler.

> Example:

```
slit.remove_filler()
```

> New in version 2.6.

remove_force()
> Remove the external force field for streaming.

> **Warning:** This only removes the force on the MPCD particles. If you have embedded particles, you must separately disable any corresponding external force.

> Example:

```
streamer.remove_force()
```

set_filler(*density*, *kT*, *seed*, *type='A'*)
> Add virtual particles to slit channel.

> **Parameters**
>> • **density** (*float*) – Density of virtual particles.
>>
>> • **kT** (*float*) – Temperature of virtual particles.
>>
>> • **seed** (*int*) – Seed to pseudo-random number generator for virtual particles.
>>
>> • **type** (*str*) – Type of the MPCD particles to fill with.

The virtual particle filler draws particles within the volume *outside* the slit walls that could be overlapped by any cell that is partially *inside* the slit channel (between the parallel plates). The particles are drawn from the velocity distribution consistent with *kT* and with the given *density*. The mean of the distribution is zero in *y* and *z*, but is equal to the wall speed in *x*. Typically, the virtual particle density and temperature are set to the same conditions as the solvent.

The virtual particles will act as a weak thermostat on the fluid, and so energy is no longer conserved. Momentum will also be sunk into the walls.

Example:

```
slit.set_filler(density=5.0, kT=1.0, seed=42)
```

New in version 2.6.

set_force (*force*)
   Set the external force field for streaming.

> **Parameters force** (`mpcd.force`) – External force field to apply to MPCD particles.

Setting an external *force* will generate a flow of the MPCD particles subject to the boundary conditions of the streaming geometry. Note that the force field should be chosen in a way that makes sense for the geometry (e.g., so that the box is not continually accelerating).

> **Warning:** The *force* applies only to the MPCD particles. If you have embedded particles, you should usually additionally specify a force from `md.force` for that particle group.

Examples:

```
f = mpcd.force.constant(field=(1.0,0.0,0.0))
streamer.set_force(f)
```

set_params (*H=None*, *V=None*, *boundary=None*)
   Set parameters for the slit geometry.

> **Parameters**
>
> - **H** (`float`) – channel half-width
>
> - **V** (`float`) – wall speed (default: 0)
>
> - **boundary** (`str`) – boundary condition at wall ("slip" or "no_slip"")

Changing any of these parameters will require the geometry to be constructed and validated, so do not change these too often.

Examples:

```
slit.set_params(H=15.0)
slit.set_params(V=0.2, boundary="no_slip")
```

New in version 2.6.

set_period (*period*)
   Set the streaming period.

> **Parameters period** (`int`) – New streaming period.

The MPCD streaming period can only be changed to a new value on a simulation timestep that is a multiple of both the previous *period* and the new *period*. An error will be raised if it is not.

Examples:

```
# The initial period is 5.
# The period can be updated to 2 on step 10.
hoomd.run_upto(10)
method.set_period(period=2)

# The period can be updated to 4 on step 12.
hoomd.run_upto(12)
hoomd.set_period(period=4)
```

class hoomd.mpcd.stream.**slit_pore**(*H*, *L*, *boundary='no_slip'*, *period=1*)

Parallel plate (slit) pore streaming geometry.

> **Parameters**
>
> - **H** (`float`) – channel half-width
> - **L** (`float`) – pore half-length
> - **boundary** (`str`) – boundary condition at wall ("slip" or "no_slip"")
> - **period** (`int`) – Number of integration steps between collisions

The slit pore geometry represents a fluid partially confined between two parallel plates that have finite length in *x*. The slit pore is centered around the origin, and the walls are placed at $z = -H$ and $z = +H$, so the total channel width is *2H*. They extend from $x = -L$ to $x = +L$ (total length *2L*), where additional solid walls with normals in *x* prevent penetration into the regions above / below the plates. The plates are infinite in *y*. Outside the pore, the simulation box has full periodic boundaries; it is not confined by any walls. This model hence mimics a narrow pore in, e.g., a membrane.
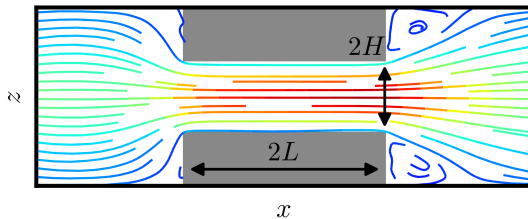
The "inside" of the `slit_pore` is the space where $|z| < H$ for $|x| < L$, and the entire space where $|x| \geq L$.

Examples:

```
stream.slit_pore(period=10, H=30., L=10.)
stream.slit_pore(period=1, H=25., L=25.)
```

New in version 2.7.

disable()

Disable the streaming method

Examples:

```
method.disable()
```

Disabling the streaming method removes it from the current MPCD system definition. Only one streaming method can be attached to the system at any time, so use this method to remove the current streaming method before adding another.

enable()

Enable the streaming method

Examples:

```
method.enable()
```

Enabling the streaming method adds it to the current MPCD system definition. Only one streaming method can be attached to the system at any time. If another method is already set, `disable()` must be called first before switching. Streaming will occur when the timestep is the next multiple of *period*.

remove_filler()
> Remove the virtual particle filler.

> Example:

```
slit_pore.remove_filler()
```

remove_force()
> Remove the external force field for streaming.

> **Warning:** This only removes the force on the MPCD particles. If you have embedded particles, you must separately disable any corresponding external force.

> Example:

```
streamer.remove_force()
```

set_filler(*density*, *kT*, *seed*, *type='A'*)
> Add virtual particles to slit pore.

> **Parameters**
> - **density** (*float*) – Density of virtual particles.
> - **kT** (*float*) – Temperature of virtual particles.
> - **seed** (*int*) – Seed to pseudo-random number generator for virtual particles.
> - **type** (*str*) – Type of the MPCD particles to fill with.

The virtual particle filler draws particles within the volume *outside* the slit pore boundaries that could be overlapped by any cell that is partially *inside* the slit pore. The particles are drawn from the velocity distribution consistent with *kT* and with the given *density*. The mean of the distribution is zero in *x*, *y*, and *z*. Typically, the virtual particle density and temperature are set to the same conditions as the solvent.

The virtual particles will act as a weak thermostat on the fluid, and so energy is no longer conserved. Momentum will also be sunk into the walls.

Example:

```
slit_pore.set_filler(density=5.0, kT=1.0, seed=42)
```

set_force(*force*)
> Set the external force field for streaming.

> **Parameters force** (*mpcd.force*) – External force field to apply to MPCD particles.

Setting an external *force* will generate a flow of the MPCD particles subject to the boundary conditions of the streaming geometry. Note that the force field should be chosen in a way that makes sense for the geometry (e.g., so that the box is not continually accelerating).

> **Warning:** The *force* applies only to the MPCD particles. If you have embedded particles, you should usually additionally specify a force from `md.force` for that particle group.

Examples:

```
f = mpcd.force.constant(field=(1.0,0.0,0.0))
streamer.set_force(f)
```

set_params (*H=None*, *L=None*, *boundary=None*)
    Set parameters for the slit geometry.

>   **Parameters**
>
>   - **H** (`float`) – channel half-width
>
>   - **L** (`float`) – pore half-length
>
>   - **boundary** (`str`) – boundary condition at wall ("slip" or "no_slip"")

Changing any of these parameters will require the geometry to be constructed and validated, so do not change these too often.

Examples:

```
slit_pore.set_params(H=15.0)
slit_pore.set_params(L=10.0, boundary="no_slip")
```

set_period (*period*)
    Set the streaming period.

>   **Parameters** **period** (`int`) – New streaming period.

The MPCD streaming period can only be changed to a new value on a simulation timestep that is a multiple of both the previous *period* and the new *period*. An error will be raised if it is not.

Examples:

```
# The initial period is 5.
# The period can be updated to 2 on step 10.
hoomd.run_upto(10)
method.set_period(period=2)

# The period can be updated to 4 on step 12.
hoomd.run_upto(12)
hoomd.set_period(period=4)
```

2.17.7 mpcd.update

Overview

`sort`	Sorts MPCD particles in memory to improve cache coherency.

Details

MPCD particle updaters

Updates properties of MPCD particles.

class hoomd.mpcd.update.**sort**(*system*, *period=50*)

Sorts MPCD particles in memory to improve cache coherency.

> **Parameters**
>
> - **system** (*hoomd.mpcd.data.system*) – MPCD system to create sorter for
>
> - **period** (*int*) – Sort whenever the timestep is a multiple of *period*. .. versionadded:: 2.6

> **Warning:** Do not create *hoomd.mpcd.update.sort* explicitly in your script. HOOMD creates a sorter by default.

Every *period* time steps, particles are reordered in memory based on the cell list generated at the current timestep. Sorting can significantly improve performance of all other cell-based steps of the MPCD algorithm. The efficiency of the sort operation obviously depends on the number of particles, and so the *period* should be tuned to give the maximum performance.

Note: The *period* should be no smaller than the MPCD collision period, or unnecessary cell list builds will occur.

Essentially all MPCD systems benefit from sorting, and so a sorter is created by default with the MPCD system. To disable it or modify parameters, save the system and access the sorter through it:

```
s = mpcd.init.read_snapshot(snap)
# the sorter is only available after initialization
s.sorter.set_period(period=5)
s.sorter.disable()
```

set_period(*period*)

Change the sorting period.

> **Parameters** **period** (*int*) – New period to set.

Examples:

```
sorter.set_period(100)
sorter.set_period(1)
```

> While the simulation is running, the action of each updater is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

tune(*start*, *stop*, *step*, *tsteps*, *quiet=False*)

Tune the sorting period.

> **Parameters**
>
> - **start** (*int*) – Start of tuning interval to scan (inclusive).
>
> - **stop** (*int*) – End of tuning interval to scan (inclusive).
>
> - **step** (*int*) – Spacing between tuning points.
>
> - **tsteps** (*int*) – Number of timesteps to run at each tuning point.
>
> - **quiet** (*bool*) – Quiet the individual run calls.
>
> **Returns** The optimal sorting period from the scanned range.

Return type int

The optimal sorting period for the MPCD particles is determined from a sequence of short runs. The sorting period is first set to *start*. The TPS value is determined for a run of length *tsteps*. This run is repeated 3 times, and the median TPS of the runs is saved. The sorting period is then incremented by *step*, and the process is repeated until *stop* is reached. The period giving the fastest TPS is determined, and the sorter period is updated to this value. The results of the scan are also reported as output, and the fastest sorting period is also returned.

Note: A short warmup run is **required** before calling *tune()* in order to ensure the runtime autotuners have found optimal kernel launch parameters.

Examples:

```
# warmup run
hoomd.run(5000)

# tune sorting period
sorter.tune(start=5, stop=50, step=5, tsteps=1000)
```

2.18 dem

Details

Simulate rounded, faceted shapes in molecular dynamics.

The DEM component provides forces which apply short-range, purely repulsive interactions between contact points of two shapes. The resulting interaction is consistent with expanding the given polygon or polyhedron by a disk or sphere of a particular rounding radius.

The pair forces located in *hoomd.dem.pair* behave like other hoomd pair forces, computing forces and torques for each particle based on its interactions with its neighbors. Also included are geometric helper utilities in *hoomd.dem.utils*.

2.18.1 Initialization

When initializing systems, be sure to set the inertia tensor of DEM particles. Axes with an inertia tensor of 0 (the default) will not have their rotational degrees of freedom integrated. Because only the three principal components of inertia are given to hoomd, particle vertices should also be specified in the principal reference frame so that the inertia tensor is diagonal.

Example:

```
snap = hoomd.data.make_snapshot(512, box=hoomd.data.boxdim(L=10))
snap.particles.moment_inertia[:] = (10, 10, 10)
system = hoomd.init.read_snapshot(snap)
```

2.18.2 Integration

To allow particles to rotate, use integrators which can update rotational degrees of freedom:

- *hoomd.md.integrate.nve*

- *hoomd.md.integrate.nvt*
- *hoomd.md.integrate.npt*
- *hoomd.md.integrate.langevin*
- *hoomd.md.integrate.brownian*

Note that the Nosé-Hoover thermostats used in *hoomd.md.integrate.nvt* and *hoomd.md.integrate.npt* work by rescaling momenta and angular momenta. This can lead to instabilities in the start of the simulation if particles are initialized with 0 angular momentum and no neighbor interactions. Two easy fixes for this problem are to initialize each particle with some angular momentum or to first run for a few steps with *hoomd.md.integrate.langevin* or *hoomd.md.integrate.brownian*.

2.18.3 Data Storage

To store trajectories of DEM systems, use a format that knows about anisotropic particles, such as:

- *hoomd.dump.getar*
- *hoomd.dump.gsd*

Stability

hoomd.dem is **stable**. When upgrading from version 2.x to 2.y (y > x), existing job scripts that follow *documented* interfaces for functions and classes will not require any modifications. **Maintainer:** Matthew Spellings.

Modules

2.18.4 dem.pair

Overview

WCA
SWCA

Details

DEM pair potentials.

class hoomd.dem.pair.**SWCA**(*nlist*, *radius=1.0*, *d_max=None*)

Specify a purely repulsive Weeks-Chandler-Andersen DEM force with a particle-varying rounding radius.

> **Parameters**
>
> - **nlist** (*hoomd.md.nlist*) – Neighbor list to use
> - **radius** (*float*) – Unshifted rounding radius r to apply to the shape vertices
> - **d_max** (*float*) – maximum rounding diameter among all particles in the system

The SWCA potential enables simulation of particles with heterogeneous rounding radii. The effect is as if a *hoomd.md.pair.slj* interaction with $r_{cut} = 2^{1/6}\sigma$ and $\sigma = 2 \cdot r$ were applied between the contact points of each pair of particles.

Examples:

```
# 2D system of squares
squares = hoomd.dem.pair.SWCA(radius=.5)
squares.setParams('A', [[1, 1], [-1, 1], [-1, -1], [1, -1]])
# 3D system of rounded square plates
squarePlates = hoomd.dem.pair.SWCA(radius=.5)
squarePlates.setParams('A',
    vertices=[[1, 1, 0], [-1, 1, 0], [-1, -1, 0], [1, -1, 0]],
    faces=[[0, 1, 2, 3]], center=False)
# 3D system of some convex shape specified by vertices
(vertices, faces) = hoomd.dem.utils.convexHull(vertices)
shapes = hoomd.dem.pair.SWCA(radius=.5)
shapes.setParams('A', vertices=vertices, faces=faces)
```

disable(*log=False*)

> Disable the force.

> > **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

> Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()

> Enable the force.

> Examples:

```
force.enable()
```

> See *disable()*.

get_energy(*group*)

> Get the energy of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

> Get the force of a particle group.

> > **Parameters group** (*hoomd.group*) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

Get the virial of a particle group.

> **Parameters group** (`hoomd.group`) – The particle group to query the virial for.
>
> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

get_type_shapes()

Get all the types of shapes in the current simulation.

This assumes all 3D shapes are convex.

Examples

Types depend on the number of shape vertices and system dimensionality. One vertex will yield a Sphere (2D and 3D), while multiple vertices will give a Polygon (2D) or ConvexPolyhedron (3D).

```
>>> mc.get_type_shapes()   # one vertex in 3D
[{'type': 'Sphere', 'diameter': 1.0}]
>>> mc.get_type_shapes()   # one vertex in 2D
[{'type': 'Sphere', 'diameter': 1.5}]
>>> mc.get_type_shapes()  # multiple vertices in 3D
[{'type': 'ConvexPolyhedron', 'rounding_radius': 0.1,
  'vertices': [[0.5, 0.5, 0.5], [0.5, -0.5, -0.5],
               [-0.5, 0.5, -0.5], [-0.5, -0.5, 0.5]]}]
>>> mc.get_type_shapes()  # multiple vertices in 2D
[{'type': 'Polygon', 'rounding_radius': 0.1,
  'vertices': [[-0.5, -0.5], [0.5, -0.5], [0.5, 0.5], [-0.5, 0.5]]}]
```

> **Returns** A list of dictionaries, one for each particle type in the system.

setParams2D(*type*, *vertices*, *center=False*)

Set the vertices for a given particle type.

> **Parameters**
>
> - **type** (`str`) – Name of the type to set the shape of
> - **vertices** (`list`) – List of (2D) points specifying the coordinates of the shape
> - **center** (`bool`) – If True, subtract the center of mass of the shape from the vertices before setting them for the shape

Shapes are specified as a list of 2D coordinates. Edges will be made between all adjacent pairs of vertices, including one between the last and first vertex.

setParams3D(*type*, *vertices*, *faces*, *center=False*)

Set the vertices for a given particle type.

> **Parameters**
>
> - **type** (`str`) – Name of the type to set the shape of

- **vertices** (*list*) – List of (3D) points specifying the coordinates of the shape

- **faces** (*list*) – List of lists of indices specifying which coordinates comprise each face of a shape.

- **center** (*bool*) – If True, subtract the center of mass of the shape from the vertices before setting them for the shape

Shapes are specified as a list of coordinates (*vertices*) and another list containing one list for each polygonal face (*faces*). The elements of each list inside *faces* are integer indices specifying which vertex in *vertices* comprise the face.

update_coeffs()
  Noop for this potential

class hoomd.dem.pair.**WCA**(*nlist, radius=1.0*)
  Specify a purely repulsive Weeks-Chandler-Andersen DEM force with a constant rounding radius.

  Parameters

- **nlist** (*hoomd.md.nlist*) – Neighbor list to use

- **radius** (*float*) – Rounding radius r to apply to the shape vertices

  The effect is as if a *hoomd.md.pair.lj* interaction with $r_{cut} = 2^{1/6}\sigma$ and $\sigma = 2 \cdot r$ were applied between the contact points of each pair of particles.

  Examples:

```
# 2D system of squares
squares = hoomd.dem.pair.WCA(radius=.5)
squares.setParams('A', [[1, 1], [-1, 1], [-1, -1], [1, -1]])
# 3D system of rounded square plates
squarePlates = hoomd.dem.pair.WCA(radius=.5)
squarePlates.setParams('A',
    vertices=[[1, 1, 0], [-1, 1, 0], [-1, -1, 0], [1, -1, 0]],
    faces=[[0, 1, 2, 3]], center=False)
# 3D system of some convex shape specified by vertices
(vertices, faces) = hoomd.dem.utils.convexHull(vertices)
shapes = hoomd.dem.pair.WCA(radius=.5)
shapes.setParams('A', vertices=vertices, faces=faces)
```

disable(*log=False*)
  Disable the force.

    Parameters **log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

  Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

>> **Parameters** **group** (*hoomd.group*) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

>> **Parameters** **group** (*hoomd.group*) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

>> **Parameters** **group** (*hoomd.group*) – The particle group to query the virial for.

>> **Returns** The last computed virial for the members in the group.

> ### Examples

> g = group.all() virial = force.get_net_virial(g)

get_type_shapes()
> Get all the types of shapes in the current simulation.

> This assumes all 3D shapes are convex.

> ### Examples

> Types depend on the number of shape vertices and system dimensionality. One vertex will yield a Sphere (2D and 3D), while multiple vertices will give a Polygon (2D) or ConvexPolyhedron (3D).

```
>>> mc.get_type_shapes()  # one vertex in 3D
[{'type': 'Sphere', 'diameter': 1.0}]
>>> mc.get_type_shapes()  # one vertex in 2D
[{'type': 'Sphere', 'diameter': 1.5}]
>>> mc.get_type_shapes()  # multiple vertices in 3D
```

(continues on next page)

```
[{'type': 'ConvexPolyhedron', 'rounding_radius': 0.1,
   'vertices': [[0.5, 0.5, 0.5], [0.5, -0.5, -0.5],
               [-0.5, 0.5, -0.5], [-0.5, -0.5, 0.5]]}]
>>> mc.get_type_shapes()  # multiple vertices in 2D
[{'type': 'Polygon', 'rounding_radius': 0.1,
   'vertices': [[-0.5, -0.5], [0.5, -0.5], [0.5, 0.5], [-0.5, 0.5]]}]
```

> **Returns** A list of dictionaries, one for each particle type in the system.

setParams2D(*type*, *vertices*, *center=False*)
> Set the vertices for a given particle type.

> > **Parameters**
> >
> > - **type** (`str`) – Name of the type to set the shape of
> >
> > - **vertices** (`list`) – List of (2D) points specifying the coordinates of the shape
> >
> > - **center** (`bool`) – If True, subtract the center of mass of the shape from the vertices before setting them for the shape

> Shapes are specified as a list of 2D coordinates. Edges will be made between all adjacent pairs of vertices, including one between the last and first vertex.

setParams3D(*type*, *vertices*, *faces*, *center=False*)
> Set the vertices for a given particle type.

> > **Parameters**
> >
> > - **type** (`str`) – Name of the type to set the shape of
> >
> > - **vertices** (`list`) – List of (3D) points specifying the coordinates of the shape
> >
> > - **faces** (`list`) – List of lists of indices specifying which coordinates comprise each face of a shape.
> >
> > - **center** (`bool`) – If True, subtract the center of mass of the shape from the vertices before setting them for the shape

> Shapes are specified as a list of coordinates (*vertices*) and another list containing one list for each polygonal face (*faces*). The elements of each list inside *faces* are integer indices specifying which vertex in *vertices* comprise the face.

update_coeffs()
> Noop for this potential

2.18.5 dem.utils

Overview

Details

Various helper utilities for geometry.

hoomd.dem.utils.**area**(*vertices*, *factor=1.0*)
> Computes the signed area of a polygon in 2 or 3D.

> > **Parameters**
> >
> > - **vertices** (`list`) – (x, y) or (x, y, z) coordinates for each vertex

- **factor** (`float`) – Factor to scale the resulting area by

hoomd.dem.utils.**center**(*vertices*, *faces=None*)

    Centers shapes in 2D or 3D.

    Parameters

- **vertices** (`list`) – List of (x, y) or (x, y, z) coordinates in 2D or 3D, respectively
- **faces** (`list`) – List of vertex indices for 3D polyhedra, or None for 2D. Faces should be in right-hand order.

    Returns a list of vertices shifted to have the center of mass of the given points at the origin. Shapes should be specified in right-handed order. If the input shape has no mass, return the input.

> **Warning:** All faces should be specified in right-handed order.

hoomd.dem.utils.**convexHull**(*vertices*, *tol=1e-06*)

    Compute the 3D convex hull of a set of vertices and merge coplanar faces.

    Parameters

- **vertices** (`list`) – List of (x, y, z) coordinates
- **tol** (`float`) – Floating point tolerance for merging coplanar faces

    Returns an array of vertices and a list of faces (vertex indices) for the convex hull of the given set of vertice.

> **Note:** This method uses scipy's quickhull wrapper and therefore requires scipy.

hoomd.dem.utils.**massProperties**(*vertices*, *faces=None*, *factor=1.0*)

    Compute the mass, center of mass, and inertia tensor of a polygon or polyhedron

    Parameters

- **vertices** (`list`) – List of (x, y) or (x, y, z) coordinates in 2D or 3D, respectively
- **faces** (`list`) – List of vertex indices for 3D polyhedra, or None for 2D. Faces should be in right-hand order.
- **factor** (`float`) – Factor to scale the resulting results by

    Returns (mass, center of mass, moment of inertia tensor in (xx, xy, xz, yy, yz, zz) order) specified by the given list of vertices and faces. Note that the faces must be listed in a consistent order so that normals are all pointing in the correct direction from the face. If given a list of 2D vertices, return the same but for the 2D polygon specified by the vertices.

> **Warning:** All faces should be specified in right-handed order.

    The computation for the 3D case follows "Polyhedral Mass Properties (Revisited) by David Eberly, available at:

    http://www.geometrictools.com/Documentation/PolyhedralMassProperties.pdf

hoomd.dem.utils.**rmax**(*vertices*, *radius=0.0*, *factor=1.0*)

    Compute the maximum distance among a set of vertices

    Parameters

- **vertices** (`list`) – list of (x, y) or (x, y, z) coordinates

- **factor** (*float*) – Factor to scale the result by

hoomd.dem.utils.**spheroArea**(*vertices*, *radius=1.0*, *factor=1.0*)

Computes the area of a spheropolygon.

> **Parameters**
>
> - **vertices** (*list*) – List of (x, y) coordinates, in right-handed (counterclockwise) order
> - **radius** (*float*) – Rounding radius of the disk to expand the polygon by
> - **factor** (*float*) – Factor to scale the resulting area by

2.19 cgcmm

Details

CGCMM

Coarse grained CGCMM potential.

Stability

hoomd.cgcmm is **unstable**. When upgrading from version 2.x to 2.y (y > x), existing job scripts may need to be updated. **Maintainer needed!** This package is not maintained.

Deprecated since version 2.6: The cgcmm component has not been maintained in many years and will be removed.

Modules

2.19.1 cgcmm.angle

Overview

cgcmm.angle.cgcmm

Details

CGCMM angle potentials.

class hoomd.cgcmm.angle.**cgcmm**

CGCMM angle potential.

The command angle.cgcmm defines a regular harmonic potential energy between every defined triplet of particles in the simulation, but in addition in adds the repulsive part of a CGCMM pair potential between the first and the third particle.

B. Levine et. al. 2011 describes the CGCMM implementation details in HOOMD-blue. Cite it if you utilize the CGCMM potential in your work.

The total potential is thus:

$$V(\theta) = \frac{1}{2} k \left(\theta - \theta_0 \right)^2$$

where θ is the current angle between the three particles and either:

$$V_{\mathrm{LJ}}(r_{13}) - V_{\mathrm{LJ}}(r_c) \text{ with } V_{\mathrm{LJ}}(r) = 4\varepsilon \left[\left(\frac{\sigma}{r} \right)^{12} - \left(\frac{\sigma}{r} \right)^6 \right] \quad \text{for } r <= r_c \ \ r_c = \sigma \cdot 2^{\frac{1}{6}}$$

$$V_{\mathrm{LJ}}(r_{13}) - V_{\mathrm{LJ}}(r_c) \text{ with } V_{\mathrm{LJ}}(r) = \frac{27}{4}\varepsilon \left[\left(\frac{\sigma}{r} \right)^{9} - \left(\frac{\sigma}{r} \right)^6 \right] \quad \text{for } r <= r_c \ \ r_c = \sigma \cdot \left(\frac{3}{2} \right)^{\frac{1}{3}}$$

$$V_{\mathrm{LJ}}(r_{13}) - V_{\mathrm{LJ}}(r_c) \text{ with } V_{\mathrm{LJ}}(r) = \frac{3\sqrt{3}}{2}\varepsilon \left[\left(\frac{\sigma}{r} \right)^{12} - \left(\frac{\sigma}{r} \right)^4 \right] \quad \text{for } r <= r_c \ \ r_c = \sigma \cdot 3^{\frac{1}{8}}$$

with r_{13} being the distance between the two outer particles of the angle.

Coefficients:

- θ_0 - rest angle `t0` (in radians)

- k - potential constant `k` (in units of energy/radians^2)

- ε - strength of potential `epsilon` (in energy units)

- σ - distance of interaction `sigma` (in distance units)

Coefficients $k, \theta_0, \varepsilon,$ and σ and Lennard-Jones exponents pair must be set for each type of angle in the simulation using *set_coeff()*.

disable (*log=False*)
  Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable ()
  Enable the force.

Examples:

```
force.enable()
```

See *disable()*.

get_energy (*group*)
  Get the energy of a particle group.

> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

> **Returns** The last computed energy for the members in the group.

Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)

> Get the force of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

Examples

g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)

> Get the virial of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

set_coeff(*angle_type*, *k*, *t0*, *exponents*, *epsilon*, *sigma*)

> Sets the CG-CMM angle coefficients for a particular angle type.

> > **Parameters**

> > > - **angle_type** (`str`) – Angle type to set coefficients for
> > > - **k** (`float`) – Coefficient k (in units of energy/radians^2)
> > > - **t0** (`float`) – Coefficient θ_0 (in radians)
> > > - **exponents** (`str`) – is the type of CG-angle exponents we want to use for the repulsion.
> > > - **epsilon** (`float`) – is the 1-3 repulsion strength (in energy units)
> > > - **sigma** (`float`) – is the CG particle radius (in distance units)

> Examples:

```
cgcmm.set_coeff('polymer', k=3.0, t0=0.7851, exponents=126, epsilon=1.0,
↪sigma=0.53)
cgcmm.set_coeff('backbone', k=100.0, t0=1.0, exponents=96, epsilon=23.0,
↪sigma=0.1)
cgcmm.set_coeff('residue', k=100.0, t0=1.0, exponents='lj12_4', epsilon=33.0,
↪sigma=0.02)
cgcmm.set_coeff('cg96', k=100.0, t0=1.0, exponents='LJ9-6', epsilon=9.0,
↪sigma=0.3)
```

2.19.2 cgcmm.pair

Overview

cgcmm.pair.cgcmm	CMM coarse-grain model pair potential.

Details

CGCMM pair potentials.

class hoomd.cgcmm.pair.**cgcmm**(*r_cut*, *nlist*)

CMM coarse-grain model pair potential.

> **Parameters**
>
> - **r_cut** (*float*) – Default cutoff radius (in distance units).
>
> - **nlist** (*hoomd.md.nlist*) – Neighbor list

cgcmm specifies that a special version of Lennard-Jones pair force should be added to every non-bonded particle pair in the simulation. This potential version is used in the CMM coarse grain model and uses a combination of Lennard-Jones potentials with different exponent pairs between different atom pairs.

B. Levine et. al. 2011 describes the CGCMM implementation details in HOOMD-blue. Cite it if you utilize the CGCMM potential in your work.

Multiple potential functions can be selected:

$$V_{\mathrm{LJ}}(r) = 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \alpha \left(\frac{\sigma}{r}\right)^{6} \right]$$

$$V_{\mathrm{LJ}}(r) = \frac{27}{4}\varepsilon \left[\left(\frac{\sigma}{r}\right)^{9} - \alpha \left(\frac{\sigma}{r}\right)^{6} \right]$$

$$V_{\mathrm{LJ}}(r) = \frac{3\sqrt{3}}{2}\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \alpha \left(\frac{\sigma}{r}\right)^{4} \right]$$

See *hoomd.md.pair.pair* for details on how forces are calculated and the available energy shifting and smoothing modes. Use *pair_coeff.set* to set potential coefficients.

The following coefficients must be set per unique pair of particle types:

- ε - *epsilon* (in energy units)

- σ - *sigma* (in distance units)

- α - *alpha* (unitless) - *optional*: defaults to 1.0

- exponents, the choice of LJ-exponents, currently supported are 12-6, 9-6, and 12-4.

We support three keyword variants 124 (native), lj12_4 (LAMMPS), LJ12-4 (MPDyn).

Example:

```
nl = nlist.cell()
cg = pair.cgcmm(r_cut=3.0, nlist=nl)
cg.pair_coeff.set('A', 'A', epsilon=1.0, sigma=1.0, alpha=1.0, exponents='LJ12-6')
cg.pair_coeff.set('W', 'W', epsilon=3.7605, sigma=1.285588, alpha=1.0, exponents=
→'lj12_4')
cg.pair_coeff.set('OA', 'OA', epsilon=1.88697479, sigma=1.09205882, alpha=1.0,␣
→exponents='96')
```

disable(*log=False*)

Disable the force.

> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy associated with this force.

Examples:

```
force.disable()
force.disable(log=True)
```

Executing the disable command will remove the force from the simulation. Any `hoomd.run()` command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with `enable()`.

By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See `disable()`.

get_energy(*group*)
> Get the energy of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the energy for.

> > **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the force for.

> > **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

> > **Parameters group** (`hoomd.group`) – The particle group to query the virial for.

> > **Returns** The last computed virial for the members in the group.

> ### Examples

> g = group.all() virial = force.get_net_virial(g)

2.20 deprecated

Details

Deprecated functionalities

Commands in the `hoomd.deprecated` package are leftovers from previous versions of HOOMD-blue that are kept temporarily for users whose workflow depends on them. Deprecated features may be removed in a future version.

Stability

`hoomd.deprecated` is **deprecated**. When upgrad from version 2.x to 2.y (y > x), functions and classes in the package may be removed. Continued support for features in this package is not provided. These legacy functions will remain as long as they require minimal code modifications to maintain. **Maintainer:** *not maintained*.

Modules

2.20.1 deprecated.analyze

Overview

deprecated.analyze.msd	Mean-squared displacement.

Details

Deprecated analyzers.

class hoomd.deprecated.analyze.**msd**(*filename*, *groups*, *period*, *header_prefix=''*, *r0_file=None*, *overwrite=False*, *phase=0*)

Mean-squared displacement.

> **Parameters**
>
> - **filename** (`str`) – File to write the data to.
> - **groups** (`list`) – List of groups to calculate the MSDs of.
> - **period** (`int`) – Quantities are logged every *period* time steps.
> - **header_prefix** (`str`) – (optional) Specify a string to print before the header.
> - **r0_file** (`str`) – hoomd_xml file specifying the positions (and images) to use for $\vec{r}_0$.
> - **overwrite** (`bool`) – set to True to overwrite the file *filename* if it exists.
> - **phase** (`int`) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0.*

Deprecated since version 2.0: analyze.msd will be replaced by a more general system capable of window averaging in a future release.

msd can be given any number of groups of particles. Every *period* time steps, it calculates the mean squared displacement of each group (referenced to the particle positions at the time step the command is issued at) and prints the calculated values out to a file.

The mean squared displacement (MSD) for each group is calculated as:

$$\langle |\vec{r} - \vec{r}_0|^2 \rangle$$

and values are correspondingly written in units of distance squared.

The file format is the same convenient delimited format used by :py:class'hoomd.analyze.log'.

msd is capable of appending to an existing msd file (the default setting) for use in restarting in long jobs. To generate a correct msd that does not reset to 0 at the start of each run, save the initial state of the system in a hoomd_xml file, including position and image data at a minimum. In the continuation job, specify this file in the *r0_file* argument to analyze.msd.

Examples:

```
msd = analyze.msd(filename='msd.log', groups=[group1, group2],
                  period=100)

analyze.msd(groups=[group1, group2, group3], period=1000,
            filename='msd.log', header_prefix='#')

analyze.msd(filename='msd.log', groups=[group1], period=10,
            header_prefix='Log of group1 msd, run 5\n')
```

A group variable (*groupN* above) can be created by any number of group creation functions. See group for a list.

By default, columns in the file are separated by tabs, suitable for importing as a tab-delimited spreadsheet. The delimiter can be changed to any string using *set_params()*.

The *header_prefix* can be used in a number of ways. It specifies a simple string that will be printed before the header line of the output file. One handy way to use this is to specify header_prefix='#' so that gnuplot will ignore the header line automatically. Another use-case would be to specify a descriptive line containing details of the current run. Examples of each of these cases are given above.

If *r0_file* is left at the default of None, then the current state of the system at the execution of the analyze.msd command is used to initialize $\vec{r}_0$.

disable()
> Disable the analyzer.
>
> Examples:
>
> ```
> my_analyzer.disable()
> ```
>
> Executing the disable command will remove the analyzer from the system. Any *hoomd.run()* command executed after disabling an analyzer will not use that analyzer during the simulation. A disabled analyzer can be re-enabled with *enable()*.

enable()
> Enables the analyzer
>
> Examples:
>
> ```
> my_analyzer.enable()
> ```
>
> See *disable()*.

restore_state()
> Restore the state information from the file used to initialize the simulations

set_params(*delimiter=None*)
> Change the parameters of the msd analysis

>> **Parameters delimiter** (`str`) – New delimiter between columns in the output file (if specified).

> Examples:

```
msd.set_params(delimiter=',');
```

set_period(*period*)
> Changes the period between analyzer executions

>> **Parameters period** (`int`) – New period to set (in time steps)

> Examples:

```
analyzer.set_period(100)
analyzer.set_period(1)
```

> While the simulation is running (`hoomd.run()`, the action of each analyzer is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

2.20.2 deprecated.dump

Overview

deprecated.dump.pos	Writes simulation snapshots in the POS format
deprecated.dump.xml	Writes simulation snapshots in the HOOMD XML format.

Details

Deprecated trajectory file writers.

class hoomd.deprecated.dump.**pos**(*filename*, *period=None*, *unwrap_rigid=False*, *phase=0*, *addInfo=None*)
> Writes simulation snapshots in the POS format

> **Parameters**

>> - **filename** (`str`) – File name to write

>> - **period** (`int`) – (optional) Number of time steps between file dumps

>> - **unwrap_rigid** (`bool`) – When False, (the default) individual particles are written inside the simulation box which breaks up rigid bodies near box boundaries. When True, particles belonging to the same rigid body will be unwrapped so that the body is continuous. The center of mass of the body remains in the simulation box, but some particles may be written just outside it.

>> - **phase** (`int`) – When -1, start on the current time step. When >= 0, execute on steps where *(step + phase) % period == 0*.

>> - **addInfo** (*callable*) – A user-defined python function that returns a string of additional information when it is called. This information will be printed in the pos file beneath the shape definitions. The information returned by addInfo may dynamically change over the course of the simulation; addInfo is a function of the simulation timestep only.

Deprecated since version 2.0.

The file is opened on initialization and a new frame is appended every a period steps.

> **Warning:** *pos* is not restart compatible. It always overwrites the file on initialization.

Examples:

```
dump.pos(filename="dump.pos", period=1000)
pos = dump.pos(filename="particles.pos", period=1e5)
```

disable()
> Disable the analyzer.
>
> Examples:
>
> ```
> my_analyzer.disable()
> ```
>
> Executing the disable command will remove the analyzer from the system. Any *hoomd.run()* command executed after disabling an analyzer will not use that analyzer during the simulation. A disabled analyzer can be re-enabled with *enable()*.

enable()
> Enables the analyzer
>
> Examples:
>
> ```
> my_analyzer.enable()
> ```
>
> See *disable()*.

restore_state()
> Restore the state information from the file used to initialize the simulations

set_def(*typ*, *shape*)
> Set a pos def string for a given type
>
> > **Parameters**
> >
> > - **typ** (*str*) – Type name to set shape def
> >
> > - **shape** (*str*) – Shape def string to set

set_period(*period*)
> Changes the period between analyzer executions
>
> > **Parameters** **period** (*int*) – New period to set (in time steps)
>
> Examples:
>
> ```
> analyzer.set_period(100)
> analyzer.set_period(1)
> ```
>
> While the simulation is running (*hoomd.run()*, the action of each analyzer is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

class hoomd.deprecated.dump.**xml**(*group*, *filename='dump'*, *period=None*, *time_step=None*, *phase=0*, *restart=False*, ***params*)
> Writes simulation snapshots in the HOOMD XML format.
>
> > **Parameters**

- **group** (*hoomd.group*) – Group of particles to dump
- **filename** (*str*) – (optional) Base of the file name
- **period** (*int*) – (optional) Number of time steps between file dumps
- **params** – (optional) Any number of parameters that set_params() accepts
- **time_step** (*int*) – (optional) Time step to write into the file (overrides the current simulation step). time_step is ignored for periodic updates
- **phase** (*int*) – When -1, start on the current time step. When >= 0, execute on steps where &(step + phase) % period == 0*.
- **restart** (*bool*) – When True, write only *filename* and don't save previous states.

Deprecated since version 2.0: GSD is the new default file format for HOOMD-blue. It can store everything that an XML file can in an efficient binary format that is easy to access. See *hoomd.dump.gsd*.

Every *period* time steps, a new file will be created. The state of the particles in *group* at that time step is written to the file in the HOOMD XML format. All values are written in native HOOMD-blue units, see *Units* for more information.

If you only need to store a subset of the system, you can save file size and time spent analyzing data by specifying a group to write out. *xml* will write out all of the particles in *group* in ascending tag order. When the group is not *hoomd.group.all()*, *xml* will not write the topology fields (bond, angle, dihedral, improper, constraint).

Examples:

```
deprecated.dump.xml(group=group.all(), filename="atoms.dump", period=1000)
xml = deprecated.dump.xml(group=group.all(), filename="particles", period=1e5)
xml = deprecated.dump.xml(group=group.all(), filename="test.xml", vis=True)
xml = deprecated.dump.xml(group=group.all(), filename="restart.xml", all=True,
→restart=True, period=10000, phase=0);
xml = deprecated.dump.xml(group=group.type('A'), filename="A", period=1e3)
```

If period is set and restart is False, a new file will be created every *period* steps. The time step at which the file is created is added to the file name in a fixed width format to allow files to easily be read in order. I.e. the write at time step 0 with `filename="particles"` produces the file `particles.0000000000.xml`.

If period is set and restart is True, *xml* will write a temporary file and then move it to *filename*. This stores only the most recent state of the simulation in the written file. It is useful for writing jobs that are restartable - see *Restartable jobs*. Note that this causes high metadata traffic on lustre filesystems and may cause your account to be blocked at some supercomputer centers. Use *hoomd.dump.gsd* for efficient restart files.

By default, only particle positions are output to the dump files. This can be changed with set_params(), or by specifying the options in the *xml* command.

If *period* is not specified, then no periodic updates will occur. Instead, the file *filename* is written immediately. *time_step* is passed on to write()

disable()
> Disable the analyzer.

> Examples:

```
my_analyzer.disable()
```

> Executing the disable command will remove the analyzer from the system. Any *hoomd.run()* command executed after disabling an analyzer will not use that analyzer during the simulation. A disabled analyzer can be re-enabled with *enable()*.

enable()
> Enables the analyzer

> Examples:

```
my_analyzer.enable()
```

> See *disable()*.

restore_state()
> Restore the state information from the file used to initialize the simulations

set_params(*all=None*, *vis=None*, *position=None*, *image=None*, *velocity=None*, *mass=None*, *diameter=None*, *type=None*, *body=None*, *bond=None*, *angle=None*, *dihedral=None*, *improper=None*, *constraint=None*, *acceleration=None*, *charge=None*, *orientation=None*, *angmom=None*, *inertia=None*, *vizsigma=None*)
> Change xml write parameters.

> > **Parameters**

> > - **all** (*bool*) – (if True) Enables the output of all optional parameters below

> > - **vis** (*bool*) – (if True) Enables options commonly used for visualization. - Specifically, vis=True sets position, mass, diameter, type, body, bond, angle, dihedral, improper, charge

> > - **position** (*bool*) – (if set) Set to True/False to enable/disable the output of particle positions in the xml file

> > - **image** (*bool*) – (if set) Set to True/False to enable/disable the output of particle images in the xml file

> > - **velocity** (*bool*) – (if set) Set to True/False to enable/disable the output of particle velocities in the xml file

> > - **mass** (*bool*) – (if set) Set to True/False to enable/disable the output of particle masses in the xml file

> > - **diameter** (*bool*) – (if set) Set to True/False to enable/disable the output of particle diameters in the xml file

> > - **type** (*bool*) – (if set) Set to True/False to enable/disable the output of particle types in the xml file

> > - **body** (*bool*) – (if set) Set to True/False to enable/disable the output of the particle bodies in the xml file

> > - **bond** (*bool*) – (if set) Set to True/False to enable/disable the output of bonds in the xml file

> > - **angle** (*bool*) – (if set) Set to True/False to enable/disable the output of angles in the xml file

> > - **dihedral** (*bool*) – (if set) Set to True/False to enable/disable the output of dihedrals in the xml file

> > - **improper** (*bool*) – (if set) Set to True/False to enable/disable the output of impropers in the xml file

> > - **constraint** (*bool*) – (if set) Set to True/False to enable/disable the output of constraints in the xml file

> > - **acceleration** (*bool*) – (if set) Set to True/False to enable/disable the output of particle accelerations in the xml

- **charge** (*bool*) – (if set) Set to True/False to enable/disable the output of particle charge in the xml

- **orientation** (*bool*) – (if set) Set to True/False to enable/disable the output of particle orientations in the xml file

- **angmom** (*bool*) – (if set) Set to True/False to enable/disable the output of particle angular momenta in the xml file

- **inertia** (*bool*) – (if set) Set to True/False to enable/disable the output of particle moments of inertia in the xml file

- **vizsigma** (*bool*) – (if set) Set to a floating point value to include as vizsigma in the xml file

Examples:

```
xml.set_params(type=False)
xml.set_params(position=False, type=False, velocity=True)
xml.set_params(type=True, position=True)
xml.set_params(bond=True)
xml.set_params(all=True)
```

> **Attention:** The simulation topology (bond, angle, dihedral, improper, constraint) cannot be output when the group for *xml* is not *hoomd.group.all*. An error will be raised.

set_period (*period*)

Changes the period between analyzer executions

> **Parameters period** (*int*) – New period to set (in time steps)

Examples:

```
analyzer.set_period(100)
analyzer.set_period(1)
```

While the simulation is running (*hoomd.run()*), the action of each analyzer is executed every *period* time steps. Changing the period does not change the phase set when the analyzer was first created.

write (*filename*, *time_step=None*)

Write a file at the current time step.

> **Parameters**
>
> - **filename** (*str*) – File name to write to
>
> - **time_step** (*int*) – (if set) Time step value to write out to the file

The periodic file writes can be temporarily overridden and a file with any file name written at the current time step.

When *time_step* is None, the current system time step is written to the file. When specified, *time_step* overrides this value.

Examples:

```
xml.write(filename="start.xml")
xml.write(filename="start.xml", time_step=0)
```

write_restart ()

> Write a restart file at the current time step.
>
> This only works when dump.xml() is in **restart** mode. write_restart() writes out a restart file at the current time step. Put it at the end of a script to ensure that the system state is written out before exiting.

2.20.3 deprecated.init

Overview

deprecated.init.create_random	Generates N randomly positioned particles of the same type.
deprecated.init.create_random_polymers	Generates any number of randomly positioned polymers of configurable types.
deprecated.init.read_xml	## Reads initial system state from an XML file

Details

Deprecated initialization routines.

hoomd.deprecated.init.**create_random**(*N, phi_p=None, name='A', min_dist=0.7, box=None, seed=1, dimensions=3*)

> Generates N randomly positioned particles of the same type.
>
> > **Parameters**
> >
> > - **N** (*int*) – Number of particles to create.
> >
> > - **phi_p** (*float*) – Packing fraction of particles in the simulation box (unitless).
> >
> > - **name** (*str*) – Name of the particle type to create.
> >
> > - **min_dist** (*float*) – Minimum distance particles will be separated by (in distance units).
> >
> > - **box** (*hoomd.data.boxdim*) – Simulation box dimensions.
> >
> > - **seed** (*int*) – Random seed.
> >
> > - **dimensions** (*int*) – The number of dimensions in the simulation.
>
> Deprecated since version 2.0: Random initialization is best left to specific methods tailored by the user for their work.
>
> Either *phi_p* or *box* must be specified. If *phi_p* is provided, it overrides the value of *box*.
>
> Examples:
>
> ```
> init.create_random(N=2400, phi_p=0.20)
> init.create_random(N=2400, phi_p=0.40, min_dist=0.5)
> system = init.create_random(N=2400, box=data.boxdim(L=20))
> ```
>
> When *phi_p* is set, the dimensions of the created box are such that the packing fraction of particles in the box is *phi_p*. The number density e n is related to the packing fraction by $n = 2d/\pi \cdot \phi_P$, where *d* is the dimension, and assumes the particles have a radius of 0.5. All particles are created with the same type, given by *name*.
>
> The result of *hoomd.deprecated.init.create_random()* can be saved in a variable and later used to read and/or change particle properties later in the script. See *hoomd.data* for more information.

hoomd.deprecated.init.**create_random_polymers**(*box, polymers, separation, seed=1*)

> Generates any number of randomly positioned polymers of configurable types.

2.20. deprecated 411

Parameters

- **box** (*hoomd.data.boxdim*) – Simulation box dimensions
- **polymers** (*list*) – Specification for the different polymers to create (see below)
- **separation** (*dict*) – Separation radii for different particle types (see below)
- **seed** (*int*) – Random seed to use

Deprecated since version 2.0: Random initialization is best left to specific methods tailored by the user for their work.

Any number of polymers can be generated, of the same or different types, as specified in the argument *polymers*. Parameters for each polymer include bond length, particle type list, bond list, and count.

The syntax is best shown by example. The below line specifies that 600 block copolymers A6B7A6 with a bond length of 1.2 be generated:

```
polymer1 = dict(bond_len=1.2, type=['A']*6 + ['B']*7 + ['A']*6,
                bond="linear", count=600)
```

Here is an example for a second polymer, specifying just 100 polymers made of 5 B beads bonded in a branched pattern:

```
polymer2 = dict(bond_len=1.2, type=['B']*5,
                bond=[(0, 1), (1,2), (1,3), (3,4)] , count=100)
```

The *polymers* argument can be given a list of any number of polymer types specified as above. *count* randomly generated polymers of each type in the list will be generated in the system.

In detail:

- bond_len defines the bond length of the generated polymers. This should not necessarily be set to the equilibrium bond length! The generator is dumb and doesn't know that bonded particles can be placed closer together than the separation (see below). Thus bond_len must be at a minimum set at twice the value of the largest separation radius. An error will be generated if this is not the case.

- type is a python list of strings. Each string names a particle type in the order that they will be created in generating the polymer.

- bond can be specified as "linear" in which case the generator connects all particles together with bonds to form a linear chain. bond can also be given a list if python tuples (see example above). - Each tuple in the form of c (a,b) specifies that particle c a of the polymer be bonded to particle c b. These bonds are given the default type name of 'polymer' to be used when specifying parameters to bond forces such as bond.harmonic. - A tuple with three elements (a,b,type) can be used as above, but with a custom name for the bond. For example, a simple branched polymer with different bond types on each branch could be defined like so:

```
bond=[(0,1), (1,2), (2,3,'branchA'), (3,4,'branchA'), (2,5,'branchB'), (5,6,
→'branchB')]
```

separation must contain one entry for each particle type specified in polymers ('A' and 'B' in the examples above). The value given is the separation radius of each particle of that type. The generated polymer system will have no two overlapping particles.

Examples:

```
init.create_random_polymers(box=data.boxdim(L=35),
                            polymers=[polymer1, polymer2],
                            separation=dict(A=0.35, B=0.35));
```

(continues on next page)

```
init.create_random_polymers(box=data.boxdim(L=31),
                            polymers=[polymer1],
                            separation=dict(A=0.35, B=0.35), seed=52);

# create polymers in an orthorhombic box
init.create_random_polymers(box=data.boxdim(Lx=18,Ly=10,Lz=25),
                            polymers=[polymer2],
                            separation=dict(A=0.35, B=0.35), seed=12345);

# create a triclinic box with tilt factors xy=0.1 xz=0.2 yz=0.3
init.create_random_polymers(box=data.boxdim(L=18, xy=0.1, xz=0.2, yz=0.3),
                            polymers=[polymer2],
                            separation=dict(A=0.35, B=0.35));
```

With all other parameters the same, create_random_polymers will always create the same system if seed is the same. Set a different seed (any integer) to create a different random system with the same parameters. Note that different versions of HOOMD e may generate different systems even with the same seed due to programming changes.

Note: For relatively dense systems (packing fraction 0.4 and higher) the simple random generation algorithm may fail to find room for all the particles and print an error message. There are two methods to solve this. First, you can lower the separation radii allowing particles to be placed closer together. Then setup integrate.nve with the limit option set to a relatively small value. A few thousand time steps should relax the system so that the simulation can be continued without the limit or with a different integrator. For extremely troublesome systems, generate it at a very low density and shrink the box with the command update.box_resize to the desired final size.

Note: The polymer generator always generates polymers as if there were linear chains. If you provide a non-linear bond topology, the bonds in the initial configuration will be stretched significantly. This normally doesn't pose a problem for harmonic bonds (bond.harmonic) as the system will simply relax over a few time steps, but can cause the system to blow up with FENE bonds (bond.fene).

---

hoomd.deprecated.init.**read_xml**(*filename*, *restart=None*, *time_step=None*, *wrap_coordinates=False*)
Reads initial system state from an XML file

> **Parameters**
>
> - **filename** (`str`) – File to read
> - **restart** (`str`) – If it exists, read *restart* instead of *filename*.
> - **time_step** (`int`) – (if specified) Time step number to use instead of the one stored in the XML file
> - **wrap_coordinates** (`bool`) – Wrap input coordinates back into the box

Deprecated since version 2.0: GSD is the new default file format for HOOMD-blue. It can store everything that an XML file can in an efficient binary format that is easy to access. See *hoomd.init.read_gsd*.

Examples:

```
deprecated.init.read_xml(filename="data.xml")
deprecated.init.read_xml(filename="init.xml", restart="restart.xml")
```

```
deprecated.init.read_xml(filename="directory/data.xml")
deprecated.init.read_xml(filename="restart.xml", time_step=0)
system = deprecated.init.read_xml(filename="data.xml")
```

All particles, bonds, etc. . . are read from the given XML file, setting the initial condition of the simulation. After this command completes, the system is initialized allowing other commands in hoomd to be run.

For restartable jobs, specify the initial condition in *filename* and the restart file in *restart*. init.read_xml will read the restart file if it exists, otherwise it will read *filename*.

All values are read in native units, see *Units* for more information.

If *time_step* is specified, its value will be used as the initial time step of the simulation instead of the one read from the XML file.

If *wrap_coordinates* is set to True, input coordinates will be wrapped into the box specified inside the XML file. If it is set to False, out-of-box coordinates will result in an error.

2.21 jit

Details

JIT

The JIT module provides *experimental* support to to JIT (just in time) compile C++ code and call it during the simulation. Compiled C++ code will execute at full performance unlike interpreted python code.

Stability

`hoomd.jit` is **unstable**. When upgrading from version 2.x to 2.y (y > x), existing job scripts may need to be updated. **Maintainer:** Joshua A. Anderson, University of Michigan

New in version 2.3.

Modules

2.21.1 jit.external

Overview

jit.external.user

Details

class hoomd.jit.external.**user**(*mc*, *code=None*, *llvm_ir_file=None*, *clang_exec=None*)
Define an external field imposed on all particles in the system.

   Parameters

   - **code** (*str*) – C++ code to compile
   - **llvm_ir_fname** (*str*) – File name of the llvm IR file to load.

- **clang_exec** (*str*) – The Clang executable to use

Potentials in jit.external behave similarly to external fields assigned via hpmc.field.callback. Potentials added using external.user are added to the total energy calculation in *hpmc* integrators. The *user* external field takes C++ code, JIT compiles it at run time and executes the code natively in the MC loop at with full performance. It enables researchers to quickly and easily implement custom energetic interactions without the need to modify and recompile HOOMD.

C++ code

Supply C++ code to the *code* argument and *user* will compile the code and call it to evaluate forces. Compilation assumes that a recent `clang` installation is on your PATH. This is convenient when the energy evaluation is simple or needs to be modified in python. More complex code (i.e. code that requires auxiliary functions or initialization of static data arrays) should be compiled outside of HOOMD and provided via the *llvm_ir_file* input (see below).

The text provided in *code* is the body of a function with the following signature:

```
float eval(const BoxDim& box,
unsigned int type_i,
const vec3<Scalar>& r_i,
const quat<Scalar>& q_i
Scalar diameter,
Scalar charge
)
```

- `vec3` and `quat` are is defined in HOOMDMath.h.
- *box* is the system box.
- *type_i* is the particle type.
- *r_i* is the particle position
- *q_i* the particle orientation.
- *diameter* the particle diameter.
- *charge* the particle charge.
- Your code *must* return a value.

Once initialized, the following log quantities are provided to analyze.log:

- **external_field_jit** – total energy of the field

Example:

```
gravity = """return r_i.z + box.getL().z/2;"""
external = hoomd.jit.external.user(mc=mc, code=gravity)
```

LLVM IR code

You can compile outside of HOOMD and provide a direct link to the LLVM IR file in *llvm_ir_file*. A compatible file contains an extern "C" eval function with this signature:

```
float eval(const BoxDim& box, unsigned int type_i, const vec3<Scalar>& r_i, const
→quat<Scalar>& q_i, Scalar diameter, Scalar charge)
```

vec3 and `quat` is defined in HOOMDMath.h.

Compile the file with clang: `clang -O3 --std=c++11 -DHOOMD_LLVMJIT_BUILD -I /path/to/hoomd/include -S -emit-llvm code.cc` to produce the LLVM IR in `code.ll`.

New in version 2.5.

compile_user(*code*, *clang_exec*, *fn=None*)
> Helper function to compile the provided code into an executable

> **Parameters**

>> • **code** (*str*) – C++ code to compile

>> • **clang_exec** (*str*) – The Clang executable to use

>> • **fn** (*str*) – If provided, the code will be written to a file.

> New in version 2.3.

disable()
> Disables the compute.

> Examples:

```
c.disable()
```

> Executing the disable command will remove the compute from the system. Any *hoomd.run()* command executed after disabling a compute will not be able to log computed values with *hoomd.analyze.log*.

> A disabled compute can be re-enabled with *enable()*.

enable()
> Enables the compute.

> Examples:

```
c.enable()
```

> See *disable()*.

restore_state()
> Restore the state information from the file used to initialize the simulations

2.21.2 jit.patch

Overview

| *jit.patch.user* | Define an arbitrary patch energy. |
| *jit.patch.user_union* | Define an arbitrary patch energy on a union of particles |

Details

class hoomd.jit.patch.**user**(*mc*, *r_cut*, *array_size=1*, *code=None*, *llvm_ir_file=None*, *clang_exec=None*)
> Define an arbitrary patch energy.

> **Parameters**

>> • **r_cut** (*float*) – Particle center to center distance cutoff beyond which all pair interactions are assumed 0.

- **code** (*str*) – C++ code to compile
- **llvm_ir_fname** (*str*) – File name of the llvm IR file to load.
- **clang_exec** (*str*) – The Clang executable to use
- **array_size** (*int*) – Size of array with adjustable elements. (added in version 2.8)

alpha_iso
> Length array_size numpy array containing dynamically adjustable elements defined by the user (added in version 2.8)

>> **Type** numpy.ndarray, float

Patch energies define energetic interactions between pairs of shapes in *hpmc* integrators. Shapes within a cutoff distance of *r_cut* are potentially interacting and the energy of interaction is a function the type and orientation of the particles and the vector pointing from the *i* particle to the *j* particle center.

The *user* patch energy takes C++ code, JIT compiles it at run time and executes the code natively in the MC loop with full performance. It enables researchers to quickly and easily implement custom energetic interactions without the need to modify and recompile HOOMD. Additionally, *user* provides a mechanism, through the *alpha_iso* attribute (numpy array), to adjust user defined potential parameters without the need to recompile the patch energy code.

C++ code

Supply C++ code to the *code* argument and *user* will compile the code and call it to evaluate patch energies. Compilation assumes that a recent `clang` installation is on your PATH. This is convenient when the energy evaluation is simple or needs to be modified in python. More complex code (i.e. code that requires auxiliary functions or initialization of static data arrays) should be compiled outside of HOOMD and provided via the *llvm_ir_file* input (see below).

The text provided in *code* is the body of a function with the following signature:

```
float eval(const vec3<float>& r_ij,
           unsigned int type_i,
           const quat<float>& q_i,
           float d_i,
           float charge_i,
           unsigned int type_j,
           const quat<float>& q_j,
           float d_j,
           float charge_j)
```

- `vec3` and `quat` are defined in HOOMDMath.h.
- *r_ij* is a vector pointing from the center of particle *i* to the center of particle *j*.
- *type_i* is the integer type of particle *i*
- *q_i* is the quaternion orientation of particle *i*
- *d_i* is the diameter of particle *i*
- *charge_i* is the charge of particle *i*
- *type_j* is the integer type of particle *j*
- *q_j* is the quaternion orientation of particle *j*
- *d_j* is the diameter of particle *j*

- *charge_j* is the charge of particle *j*

- Your code *must* return a value.

- When |r_ij| is greater than *r_cut*, the energy *must* be 0. This *r_cut* is applied between the centers of the two particles: compute it accordingly based on the maximum range of the anisotropic interaction that you implement.

Examples:

Static potential parameters

```
square_well = """float rsq = dot(r_ij, r_ij);
                    if (rsq < 1.21f)
                        return -1.0f;
                    else
                        return 0.0f;
            """
patch = hoomd.jit.patch.user(mc=mc, r_cut=1.1, code=square_well)
hoomd.run(1000)
```

Dynamic potential parameters

```
square_well = """float rsq = dot(r_ij, r_ij);
                float r_cut = alpha_iso[0];
                    if (rsq < r_cut*r_cut)
                        return alpha_iso[1];
                    else
                        return 0.0f;
            """
patch = hoomd.jit.patch.user(mc=mc, r_cut=1.1, array_size=2, code=square_well)
patch.alpha_iso[:] = [1.1, 1.5] # [rcut, epsilon]
hoomd.run(1000)
patch.alpha_iso[1] = 2.0
hoomd.run(1000)
```

LLVM IR code

You can compile outside of HOOMD and provide a direct link to the LLVM IR file in *llvm_ir_file*. A compatible file contains an extern "C" eval function with this signature:

```
float eval(const vec3<float>& r_ij,
           unsigned int type_i,
           const quat<float>& q_i,
           float d_i,
           float charge_i,
           unsigned int type_j,
           const quat<float>& q_j,
           float d_j,
           float charge_j)
```

`vec3` and `quat` are defined in HOOMDMath.h.

Compile the file with clang: `clang -O3 --std=c++11 -DHOOMD_LLVMJIT_BUILD -I /path/to/hoomd/include -S -emit-llvm code.cc` to produce the LLVM IR in `code.ll`.

New in version 2.3.

compile_user(*array_size_iso*, *array_size_union*, *code*, *clang_exec*, *fn=None*)
    Helper function to compile the provided code into an executable

> **Parameters**
>
> - **code** (`str`) – C++ code to compile
> - **clang_exec** (`str`) – The Clang executable to use
> - **fn** (`str`) – If provided, the code will be written to a file.
> - **array_size_iso** (`int`) – Size of array with adjustable elements for the isotropic part. (added in version 2.8)
> - **array_size_union** (`int`) – Size of array with adjustable elements for unions of shapes. (added in version 2.8)

    New in version 2.3.

class hoomd.jit.patch.**user_union**(*mc*, *r_cut*, *array_size=1*, *code=None*, *llvm_ir_file=None*, *r_cut_iso=None*, *code_iso=None*, *llvm_ir_file_iso=None*, *array_size_iso=1*, *clang_exec=None*)
    Define an arbitrary patch energy on a union of particles

> **Parameters**
>
> - **r_cut** (`float`) – Constituent particle center to center distance cutoff beyond which all pair interactions are assumed 0.
> - **r_cut_iso** (float, **optional**) – Cut-off for isotropic interaction between centers of union particles
> - **code** (`str`) – C++ code to compile
> - **code_iso** (str, **optional**) – C++ code for isotropic part
> - **llvm_ir_fname** (`str`) – File name of the llvm IR file to load.
> - **llvm_ir_fname_iso** (str, **optional**) – File name of the llvm IR file to load for isotropic interaction
> - **array_size** (`int`) – Size of array with adjustable elements. (added in version 2.8)
> - **array_size_iso** (`int`) – Size of array with adjustable elements for the isotropic part. (added in version 2.8)

alpha_union
    Length array_size numpy array containing dynamically adjustable elements defined by the user for unions of shapes (added in version 2.8)

> **Type** numpy.ndarray, float

alpha_iso
    Length array_size_iso numpy array containing dynamically adjustable elements defined by the user for the isotropic part. (added in version 2.8)

> **Type** numpy.ndarray, float

Example:

```
square_well = """float rsq = dot(r_ij, r_ij);
                if (rsq < 1.21f)
                        return -1.0f;
                else
                        return 0.0f;
```

(continues on next page)

```
            """
patch = hoomd.jit.patch.user_union(r_cut=1.1, code=square_well)
patch.set_params('A',positions=[(0,0,-5.),(0,0,.5)], typeids=[0,0])
```

Example with added isotropic interactions:

```
# square well attraction on constituent spheres
square_well = """float rsq = dot(r_ij, r_ij);
                    float r_cut = alpha_union[0];
                    if (rsq < r_cut*r_cut)
                        return alpha_union[1];
                    else
                        return 0.0f;
                """

# soft repulsion between centers of unions
soft_repulsion = """float rsq = dot(r_ij, r_ij);
                        float r_cut = alpha_iso[0];
                        if (rsq < r_cut*r_cut)
                          return alpha_iso[1];
                        else
                          return 0.0f;
                  """

patch = hoomd.jit.patch.user_union(r_cut=2.5, code=square_well, array_size=2, \
                                    r_cut_iso=5, code_iso=soft_repulsion, array_
↪size_iso=2)
patch.set_params('A',positions=[(0,0,-5.),(0,0,.5)], typeids=[0,0])
# [r_cut, epsilon]
patch.alpha_iso[:] = [2.5, 1.3];
patch.alpha_union[:] = [2.5, -1.7];
```

New in version 2.3.

compile_user (*array_size_iso*, *array_size_union*, *code*, *clang_exec*, *fn=None*)
    Helper function to compile the provided code into an executable

    Parameters

    - **code** (*str*) – C++ code to compile

    - **clang_exec** (*str*) – The Clang executable to use

    - **fn** (*str*) – If provided, the code will be written to a file.

    - **array_size_iso** (*int*) – Size of array with adjustable elements for the isotropic part. (added in version 2.8)

    - **array_size_union** (*int*) – Size of array with adjustable elements for unions of shapes. (added in version 2.8)

    New in version 2.3.

2.22 metal

Details

Metal potentials.

Stability

hoomd.metal is **unstable**. When upgrading from version 2.x to 2.y (y > x), existing job scripts may need to be updated. **Maintainer:** Lin Yang, Alex Travesset, Iowa State University.

Modules

2.22.1 metal.pair

Overview

metal.pair.eam	EAM pair potential.

Details

Metal pair potentials.

class hoomd.metal.pair.**eam**(*file*, *type*, *nlist*)

EAM pair potential.

> **Parameters**
>
> - **file** (*str*) – File name with potential tables in Alloy or FS format
>
> - **type** (*str*) – Type of file potential ('Alloy', 'FS')
>
> - **nlist** (*hoomd.md.nlist*) – Neighbor list (default of None automatically creates a global cell-list based neighbor list)

eam specifies that a EAM (embedded atom method) pair potential should be applied between every non-excluded particle pair in the simulation.

No coefficients need to be set for *eam*. All specifications, including the cutoff radius, form of the potential, etc. are read in from the specified file.

Particle type names must match those referenced in the EAM potential file.

Particle mass (in atomic mass) **must** be set in the input script, users are allowed to set different mass values other than those in the potential file.

Two file formats are supported: *Alloy* and *FS*. They are described in LAMMPS documentation (commands eam/alloy and eam/fs) here: http://lammps.sandia.gov/doc/pair_eam.html and are also described here: http://enpub.fulton.asu.edu/cms/potentials/submain/format.htm

> **Attention:** EAM is **NOT** supported in MPI parallel simulations.

Example:

```
nl = nlist.cell()
eam = pair.eam(file='name.eam.fs', type='FS', nlist=nl)
eam = pair.eam(file='name.eam.alloy', type='Alloy', nlist=nl)
```

disable(*log=False*)
> Disable the force.

>> **Parameters log** (*bool*) – Set to True if you plan to continue logging the potential energy
>> associated with this force.

> Examples:

```
force.disable()
force.disable(log=True)
```

> Executing the disable command will remove the force from the simulation. Any *hoomd.run()* command executed after disabling a force will not calculate or use the force during the simulation. A disabled force can be re-enabled with *enable()*.

> By setting *log* to True, the values of the force can be logged even though the forces are not applied in the simulation. For forces that use cutoff radii, setting *log=True* will cause the correct *r_cut* values to be used throughout the simulation, and therefore possibly drive the neighbor list size larger than it otherwise would be. If *log* is left False, the potential energy associated with this force will not be available for logging.

enable()
> Enable the force.

> Examples:

```
force.enable()
```

> See *disable()*.

get_energy(*group*)
> Get the energy of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the energy for.

>> **Returns** The last computed energy for the members in the group.

> Examples:

```
g = group.all()
energy = force.get_energy(g)
```

get_net_force(*group*)
> Get the force of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the force for.

>> **Returns** The last computed force for the members in the group.

> ### Examples

> g = group.all() force = force.get_net_force(g)

get_net_virial(*group*)
> Get the virial of a particle group.

>> **Parameters group** (*hoomd.group*) – The particle group to query the virial for.

>> **Returns** The last computed virial for the members in the group.

Examples

g = group.all() virial = force.get_net_virial(g)

2.23 Deprecated features

2.23.1 v2.x

Commands and features deprecated in v2.x will be removed in v3.0.

hoomd:

Feature	Replace with
Python 2.7	Python >= 3.6
`static` parameter in *dump.gsd*	`dynamic` parameter
`set_params` and other `set_*` methods	Properties (*under development*)
`context.initialize`	New context API (*under development*)

hoomd.deprecated:

Feature	Replace with
`deprecated.analyze.msd`	Offline analysis: e.g. Freud's msd module.
`deprecated.dump.xml`	*dump.gsd*
`deprecated.dump.pos`	*dump.gsd* with on-demand conversion to `.pos`.
`deprecated.init.read_xml`	*init.read_gsd*
`deprecated.init.create_random`	mBuild, packmol, or user script.
`deprecated.init.create_random_polymers`	mBuild, packmol, or user script.

hoomd.hpmc:

Feature	Replace with
`ignore_overlaps` parameter	*interaction_matrix*
`sphere_union::max_members` parameter	no longer needed
`convex_polyhedron_union`	*convex_spheropolyhedron_union*, `sweep_radius=0`
`setup_pos_writer` member	n/a
`depletant_mode='circumsphere'`	no longer needed
`max_verts` parameter	no longer needed
`depletant_mode` parameter	no longer needed
`ntrial` parameter	no longer needed
`implicit` boolean parameter	set `fugacity` non-zero

hoomd.cgcmm:

Feature	Replace with
`cgcmm.angle.cgcmm`	no longer needed
`cgcmm.pair.cgcmm`	no longer needed

2.24 License

```
BSD 3-Clause License for HOOMD-blue

Copyright (c) 2009-2019 The Regents of the University of Michigan All rights reserved.

Redistribution and use in source and binary forms, with or without
modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice,
   this list of conditions and the following disclaimer.

2. Redistributions in binary form must reproduce the above copyright notice,
   this list of conditions and the following disclaimer in the documentation
   and/or other materials provided with the distribution.

3. Neither the name of the copyright holder nor the names of its contributors
   may be used to endorse or promote products derived from this software without
   specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
(INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
(INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
```

2.25 Credits

2.25.1 HOOMD-blue Developers

The following people contributed to the *hoomd* and *hoomd.md* packages.

Joshua Anderson, University of Michigan - **Lead developer**

Alex Travesset, Iowa State University and Ames Laboratory

Rastko Sknepnek, Northwestern

- integrate.npt
- pair.morse

Carolyn Phillips, University of Michigan

- dihedral.table
- angle.table
- bond.table
- pair.dpdlj
- pair.dpd

- pair.dpd_conservative

- integrate.langevin

- bond.fene

- pair.slj

- Initial testing and debugging of HOOMD on Mac OS X systems

Aaron Keys, University of Michigan

- update.enforce2d and other updates enabling to 2D simulations

- hoomd c++ compilation helper script

- binary restart files

- integrate.mode_minimize_fire

Axel Kohlmeyer, David LeBard, Ben Levine, from the ICMS group at Temple University

- pair.cgcmm

- angle.harmonic

- angle.cgcmm

- dihedral.harmonic

- improper.harmonic

- numerous other small contributions enhancing the usability of HOOMD

Igor Morozov, Andrey Kazennov, Roman Bystryi, Joint Institute for High Temperatures of RAS (Moscow, Russia)

- pair.eam (original implementation)

Philipp Mertmann, Ruhr University Bochum

- charge.pppm

- pair.ewald

Stephen Barr, Princeton University

- charge.pppm

- pair.ewald

Greg van Anders, Benjamin Schultz, University of Michigan

- refactoring of ForceCompute

Eric Irrgang, University of Michigan

- RPM packaging and daily builds

Ross Smith, University of Michigan

- Deb packaging and daily builds

Peter Palm, Jens Glaser, Leipzig University

- group functionality in force.constant

- misc bug fixes

- conversion of bond forces to template evaluator implementation

Jens Glaser, University of Michigan

- integrate.npt anisotropic integration (mkt)

- pair.force_shifted_lj

- Dynamic addition/removal of bonds

- Computation of virial and pressure tensor

- integrate.nph

- Framework for external potentials

- external.periodic

- ParticleData refactoring

- MPI communication

- Optimization of MPI communication for strong scaling

- Neighborlist and pair force performance improvements (multiple threads per particle)

- Enable cell based neighbor list on small boxes

- Testing of angle.table and dihedral.table

- Replicate command

- metadata output

- anisotropic particle integrators

- Gay-Berne pair potential

- pair.reaction_field

- Rewrite of rigid body framework

- Multi-GPU electrostatics (PPPM)

- pair.van_der_waals

- hpmc interaction_matrix

- special_pair framework

- TBB support

- randomize integrator variables

- GPUArray refactoring

Pavani Medapuram, University of Minnesota

- Framework for external potentials

- external.periodic

Brandon D. Smith, University of Michigan

- full double precision compile time option

- integrate.berendsen

- pair.tersoff

Trung Dac Nguyen, University of Michigan

- integrate.nve_rigid

- integrate.bdnvt_rigid

- integrate.nvt_rigid

- integrate.npt_rigid

- integrate.mode_minimize_rigid_fire

- associated rigid body data structures and helper functions

- integrate.nph_rigid

Ryan Marson, University of Michigan

- unwrap_rigid option to dump.dcd

Kevin Silmore, Princeton University

- OPLS dihedral

David Tarjan, University of Virginia

- performance tweaks to the neighbor list and pair force code

Sumedh R. Risbud, James W. Swan, Massachusetts Institute of Technology

- bug fixes for rigid body virial corrections

Michael P. Howard, Princeton University & University of Texas at Austin

- Automatic citation list generator

- Neighbor list memory footprint reduction

- Bounding volume hierarchy (tree) neighbor lists

- Stenciled cell list (stencil) neighbor lists

- Per-type MPI ghost layer communication

- Dynamic load balancing

- Wall potentials extrapolated mode

- XML dump by particle group

- Fix references when disabling/enabling objects

- Misc. bug fixes

- CUDA9+V100 compatibility

- GPU polymorphic object wrapper

- Performance improvements to tree neighbor lists

James Antonaglia, University of Michigan

- pair.mie

Carl Simon Adorf, University of Michigan

- Analyzer callback

- metadata output

- Frenkel-Ladd bug fixes

Paul Dodd, University of Michigan

- pair.compute_energy

Erin Teich, University of Michigan

- addInfo callback to dump.pos

Joseph Berleant, University of Michigan

- fix python 3.4 segfault

Matthew Spellings, University of Michigan

- anisotropic particle integrators
- Gay-Berne, dipole pair potentials
- GTAR file format
- External components in hoomd 2.x

James Proctor, University of Michigan

- Refactor external potential framework
- Wall potentials
- boost python to pybind11 conversion
- boost unit_test to upp11 conversion
- boost signals to Nano::Signals conversion
- Removal of misc boost library calls

Chengyu Dai, University of Michigan

- Rewrite integrate.brownian with 3D rotational updates
- Rewrite integrate.langevin with 3D rotational updates

Isaac Bruss, Chengyu Dai, University of Michigan

- force.active
- update.constraint_ellipsoid

Vyas Ramasubramani, University of Michigan

- init.read_gsd bug fixes
- Reverse communication for MPI
- Enable simulation of floppy bodies that can be integrated separately but are ignored by the NeighborList
- Enabled use of shared memory for Evaluator structs
- Added per-type shape information to anisotropic pair potentials
- Fix cutoff rescaling in Gay-Berne potential

Nathan Horst

- Language and figure clarifying the dihedral angle definition.

Bryan VanSaders, University of Michigan

- constrain.oneD
- Constant stress mode to integrate.npt.
- map_overlaps() in hpmc.
- Torque options to force.constant and force.active

Ludwig Schneider, Georg-August Univeristy Goettingen

- Constant stress flow: hoomd.md.update.mueller_plathe_flow

- Matrix logging and hdf5 logging: hoomd.hdf5.log

Bjørnar Jensen, University of Bergen

- Add Lennard-Jones 12-8 pair potential

- Add Buckingham/exp-6 pair potential

- Add special_pair Coulomb 1-4 scaling

Lin Yang, Alex Travesset, Iowa State University

- metal.pair.eam - reworked implementation

Tim Moore, Vanderbilt University

- angle.cosinesq

- Documentation fixes

Bradley Dice, Avisek Das, University of Michigan

- integrator.randomize_velocities()

Bradley Dice, Simon Adorf, University of Michigan

- SSAGES support

Bradley Dice, University of Michigan

- Documentation improvements

- WSL support

Peter Schwendeman, Jens Glaser, University of Michigan

- NVLINK optimized multi-GPU execution

Alyssa Travitz, University of Michigan

- *get_net_force* implementation

- bond bug fixes

Mike Henry, Boise State University

- Documentation improvements

Pengji Zhou, University of Michigan

- pair.fourier

Patrick Lawton, University of Michigan

- Documentation changes

Luis Rivera-Rivera, University of Michigan

- `hoomd.dump.gsd.dump_shape` implementation

Alex Yang, Vanderbilt University

- `hoomd.md.dihedral.harmonic` update for phase shift

Geert Kapteijns, University of Amsterdam

- Bug fixes.

2.25.2 HPMC developers

The following people contributed to the `hoomd.hpmc` package.

Joshua Anderson, University of Michigan - Lead developer

- Vision
- Initial design
- Code review
- NVT trial move processing (CPU / GPU)
- Sphere shape
- Polygon shape
- Spheropolygon shape
- Simple polygon shape
- Ellipsoid shape - adaptation of Michael's Ellipsoid overlap check
- 2D Xenocollide implementation
- 2D GJKE implementation
- MPI parallel domain decomposition
- Scale distribution function pressure measurement
- POS writer integration
- Bounding box tree generation, query, and optimizations
- BVH implementation of trial move processing
- SSE and AVX intrinsics
- *jit.patch.user* user defined patchy interactions with LLVM runtime compiled code

Eric Irrgang, University of Michigan

- NPT updater
- Convex polyhedron shape
- Convex spheropolyhedron shape
- 3D Xenocollide implementation
- 3D GJKE implementation
- Move size autotuner (in collaboration with Ben Schultz)
- Densest packing compressor (in collaboration with Ben Schultz)
- POS file utilities (in collaboration with Ben Schultz)
- Shape union low-level implementation
- Sphere union shape (in collaboration with Khalid Ahmed)

Ben Schultz, University of Michigan

- Frenkel-Ladd free energy determination
- Move size autotuner (in collaboration with Eric Irrgang)
- Densest packing compressor (in collaboration with Eric Irrgang)

- POS file utilities (in collaboration with Eric Irrgang)
- Assign move size by particle type
- Ellipsoid overlap check bug fixes

Jens Glaser, University of Michigan

- Patchy sphere shape
- General polyhedron shape
- BVH implementation for countOverlaps
- Hybrid BVH/small box trial move processing
- Helped port the Sphinx overlap check
- Dynamic number of particle types support
- Implicit depletants
- *jit.patch.user_union* user defined patchy interactions with LLVM runtime compiled code
- Geometric Cluster Algorithm implementation
- *convex_spheropolyhedron_union* shape class
- *test_overlap* python API

Eric Harper, University of Michigan

- Misc bug fixes to move size by particle type feature
- Initial code for MPI domain decomposition

Khalid Ahmed, University of Michigan

- Ported the Sphinx overlap check
- Sphere union shape (in collaboration with Eric Irrgang)

Elizabeth R Chen, University of Michigan

- Developed the Sphinx overlap check

Carl Simon Adorf, University of Michigan

- meta data output

Samanthule Nola, University of Michigan

- Run time determination of max_verts

Paul Dodd, Erin Teich, University of Michigan

   - External potential framework
   - Wall overlap checks
   - Lattice external potential

  Erin Teich, University of Michigan

   - Convex polyhedron union particle type

Vyas Ramasubramani, University of Michigan

- hpmc.util.tune fixes for tuning by type
- hpmc.update.boxmc fixes for non-orthorhombic box volume moves

---

2.25. Credits 431

- Fixed various bugs with wall overlap checks
- *jit.external.user* implementation
- Refactored depletant integrators

William Zygmunt, Luis Rivera-Rivera, University of Michigan

- Patchy interaction support in HPMC CPU integrators
- GSD state bug fixes

2.25.3 DEM developers

The following people contributed to the `hoomd.dem` package.

Matthew Spellings, University of Michigan - Lead developer Ryan Marson, University of Michigan

2.25.4 MPCD developers

The following people contributed to the `hoomd.mpcd` package.

Michael P. Howard, Princeton University & University of Texas at Austin - **Lead developer**

- Design
- Cell list and properties
- Particle and cell communication
- Basic streaming method
- Slit streaming method
- Slit pore streaming method
- SRD and AT collision rules
- Virtual particle filling framework
- External force framework and block, constant, and sine forces
- Bounce-back integrator framework

2.25.5 Source code

HOOMD: HOOMD-blue is a continuation of the HOOMD project (http://www.ameslab.gov/hoomd/). The code from the original project is used under the following license:

```
Highly Optimized Object-Oriented Molecular Dynamics (HOOMD) Open
Source Software License
Copyright (c) 2008 Ames Laboratory Iowa State University
All rights reserved.

Redistribution and use of HOOMD, in source and binary forms, with or
without modification, are permitted, provided that the following
conditions are met:

* Redistributions of source code must retain the above copyright notice,
this list of conditions and the following disclaimer.
```

Sockets code from VMD is used for the IMDInterface to VMD (http://www.ks.uiuc.edu/Research/vmd/) - Used under the UIUC Open Source License.

Molfile plugin code from VMD is used for generic file format reading and writing - Used under the UIUC Open Source License:

```
THE SOFTWARE IS PROVIDED AS IS, WITHOUT WARRANTY OF ANY KIND, EXPRESS OR
IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY,
FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT.  IN NO EVENT SHALL
THE CONTRIBUTORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR
OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE,
ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR
OTHER DEALINGS WITH THE SOFTWARE.
```

XML parsing is performed with XML.c from http://www.applied-mathematics.net/tools/xmlParser.html - Used under the BSD License:

```
Copyright (c) 2002, Frank Vanden Berghen<br>
All rights reserved.<br>
Redistribution and use in source and binary forms, with or without
modification, are permitted provided that the following conditions are met:

 - Redistributions of source code must retain the above copyright
     notice, this list of conditions and the following disclaimer.
 - Redistributions in binary form must reproduce the above copyright
     notice, this list of conditions and the following disclaimer in the
     documentation and/or other materials provided with the distribution.
 - Neither the name of the Frank Vanden Berghen nor the
     names of its contributors may be used to endorse or promote products
     derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE REGENTS AND CONTRIBUTORS ``AS IS'' AND ANY
EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
DISCLAIMED. IN NO EVENT SHALL THE REGENTS AND CONTRIBUTORS BE LIABLE FOR ANY
DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
(INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND
ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
```

Saru is used for random number generation - Used under the following license:

```
Copyright (c) 2008 Steve Worley < m a t h g e e k@(my last name).com >

Permission to use, copy, modify, and distribute this software for any
purpose with or without fee is hereby granted, provided that the above
copyright notice and this permission notice appear in all copies.

THE SOFTWARE IS PROVIDED "AS IS" AND THE AUTHOR DISCLAIMS ALL WARRANTIES
WITH REGARD TO THIS SOFTWARE INCLUDING ALL IMPLIED WARRANTIES OF
MERCHANTABILITY AND FITNESS. IN NO EVENT SHALL THE AUTHOR BE LIABLE FOR
ANY SPECIAL, DIRECT, INDIRECT, OR CONSEQUENTIAL DAMAGES OR ANY DAMAGES
WHATSOEVER RESULTING FROM LOSS OF USE, DATA OR PROFITS, WHETHER IN AN
ACTION OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, ARISING OUT OF
OR IN CONNECTION WITH THE USE OR PERFORMANCE OF THIS SOFTWARE.
```

Some **CUDA API headers** are included in the HOOMD-blue source code for code compatibility in CPU only builds - Used under the following license:

```
Copyright 1993-2008 NVIDIA Corporation.  All rights reserved.

NOTICE TO USER:

This source code is subject to NVIDIA ownership rights under U.S. and
international Copyright laws.  Users and possessors of this source code
are hereby granted a nonexclusive, royalty-free license to use this code
in individual and commercial software.

NVIDIA MAKES NO REPRESENTATION ABOUT THE SUITABILITY OF THIS SOURCE
CODE FOR ANY PURPOSE.  IT IS PROVIDED "AS IS" WITHOUT EXPRESS OR
IMPLIED WARRANTY OF ANY KIND.  NVIDIA DISCLAIMS ALL WARRANTIES WITH
REGARD TO THIS SOURCE CODE, INCLUDING ALL IMPLIED WARRANTIES OF
MERCHANTABILITY, NONINFRINGEMENT, AND FITNESS FOR A PARTICULAR PURPOSE.
IN NO EVENT SHALL NVIDIA BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL,
OR CONSEQUENTIAL DAMAGES, OR ANY DAMAGES WHATSOEVER RESULTING FROM LOSS
OF USE, DATA OR PROFITS,  WHETHER IN AN ACTION OF CONTRACT, NEGLIGENCE
OR OTHER TORTIOUS ACTION,  ARISING OUT OF OR IN CONNECTION WITH THE USE
OR PERFORMANCE OF THIS SOURCE CODE.

U.S. Government End Users.   This source code is a "commercial item" as
that term is defined at  48 C.F.R. 2.101 (OCT 1995), consisting  of
"commercial computer  software"  and "commercial computer software
documentation" as such terms are  used in 48 C.F.R. 12.212 (SEPT 1995)
and is provided to the U.S. Government only as a commercial end item.
Consistent with 48 C.F.R.12.212 and 48 C.F.R. 227.7202-1 through
227.7202-4 (JUNE 1995), all U.S. Government End Users acquire the
source code with only those rights set forth herein.

Any use of this source code in individual and commercial software must
include, in the user documentation and internal comments to the code,
the above Disclaimer and U.S. Government End Users Notice.
```

FFTs on the CPU reference implementation of PPPM are performed using **kissFFT** from http://sourceforge.net/projects/kissfft/, used under the following license:

```
Copyright (c) 2003-2010 Mark Borgerding

All rights reserved.

Redistribution and use in source and binary forms, with or without modification,
are permitted provided that the following conditions are met:

* Redistributions of source code must retain the above copyright notice, this
list of conditions and the following disclaimer.

* Redistributions in binary form must reproduce the above copyright notice, this
list of conditions and the following disclaimer in the documentation and/or
other materials provided with the distribution.

* Neither the author nor the names of any contributors may be used to endorse or
promote products derived from this software without specific prior written
permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
```

(continues on next page)

```
DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR
ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
(INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
(INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
```

ModernGPU source code is embedded in HOOMD's package and is used for various tasks: http://nvlabs.github.io/moderngpu/:

```
Copyright (c) 2013, NVIDIA CORPORATION.  All rights reserved.
Redistribution and use in source and binary forms, with or without
modification, are permitted provided that the following conditions are met:

    * Redistributions of source code must retain the above copyright
    notice, this list of conditions and the following disclaimer.
    * Redistributions in binary form must reproduce the above copyright
    notice, this list of conditions and the following disclaimer in the
    documentation and/or other materials provided with the distribution.
    * Neither the name of the NVIDIA CORPORATION nor the
    names of its contributors may be used to endorse or promote products
    derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS"
AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE
IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE
ARE DISCLAIMED. IN NO EVENT SHALL NVIDIA CORPORATION BE LIABLE FOR ANY
DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
(INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND
ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
(INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
```

CUB 1.4.1 source code is embedded in HOOMD's package and is used for various tasks: http://nvlabs.github.io/cub/:

```
Copyright (c) 2011, Duane Merrill.  All rights reserved.
Copyright (c) 2011-2015, NVIDIA CORPORATION.  All rights reserved.

Redistribution and use in source and binary forms, with or without
modification, are permitted provided that the following conditions are met:
    * Redistributions of source code must retain the above copyright
        notice, this list of conditions and the following disclaimer.
    * Redistributions in binary form must reproduce the above copyright
        notice, this list of conditions and the following disclaimer in the
        documentation and/or other materials provided with the distribution.
    * Neither the name of the NVIDIA CORPORATION nor the
        names of its contributors may be used to endorse or promote products
        derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
DISCLAIMED. IN NO EVENT SHALL NVIDIA CORPORATION BE LIABLE FOR ANY
DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
```

```
(INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND
ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
(INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
```

Eigen 3.2.5 (http://eigen.tuxfamily.org/) is embedded in HOOMD's package and is made available under the Mozilla Public License v.2.0 (http://mozilla.org/MPL/2.0/). Its linear algebra routines are used for dynamic load balancing. Source code is available through the [downloads](http://glotzerlab.engin.umich.edu/hoomd-blue/download.html).

A constrained least-squares problem is solved for dynamic load balancing using **BVLSSolver**, which is embedded in HOOMD's package and is made available under the following license:

```
Copyright (c) 2015, Michael P. Howard. All rights reserved.

Redistribution and use in source and binary forms, with or without
modification, are permitted provided that the following conditions are met:
    1. Redistributions of source code must retain the above copyright
       notice, this list of conditions and the following disclaimer.

    2. Redistributions in binary form must reproduce the above copyright
       notice, this list of conditions and the following disclaimer in the
       documentation and/or other materials provided with the distribution.

    3. Neither the name of the copyright holder nor the names of its
       contributors may be used to endorse or promote products derived from
       this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED.
IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT,
INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING,
BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA,
OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY,
WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE)
ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY
OF SUCH DAMAGE.
```

libgetar is used to read and write GTAR files. Used under the MIT license:

```
Copyright (c) 2014-2016 The Regents of the University of Michigan

Permission is hereby granted, free of charge, to any person obtaining a copy
of this software and associated documentation files (the "Software"), to deal
in the Software without restriction, including without limitation the rights
to use, copy, modify, merge, publish, distribute, sublicense, and/or sell
copies of the Software, and to permit persons to whom the Software is
furnished to do so, subject to the following conditions:

The above copyright notice and this permission notice shall be included in all
copies or substantial portions of the Software.

THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR
IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY,
FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE
AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER
```

```
LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM,
OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE
SOFTWARE.
```

pybind11 is used to provide python bindings for C++ classes. Used under the BSD license:

```
Copyright (c) 2016 Wenzel Jakob <wenzel.jakob@epfl.ch>, All rights reserved.

Redistribution and use in source and binary forms, with or without
modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this
   list of conditions and the following disclaimer.

2. Redistributions in binary form must reproduce the above copyright notice,
   this list of conditions and the following disclaimer in the documentation
   and/or other materials provided with the distribution.

3. Neither the name of the copyright holder nor the names of its contributors
   may be used to endorse or promote products derived from this software
   without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE
FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL
DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR
SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER
CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY,
OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE
OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

You are under no obligation whatsoever to provide any bug fixes, patches, or
upgrades to the features, functionality or performance of the source code
("Enhancements") to anyone; however, if you choose to make your Enhancements
available either publicly, or directly to the author of this software, without
imposing a separate written license agreement for such Enhancements, then you
hereby grant the following license: a non-exclusive, royalty-free perpetual
license to install, use, modify, prepare derivative works, incorporate into
other computer software, distribute, and sublicense such enhancements or
derivative works thereof, in binary and source code form.
```

cereal is used to serialize C++ objects for transmission over MPI. Used under the BSD license:

```
Copyright (c) 2014, Randolph Voorhies, Shane Grant
All rights reserved.

Redistribution and use in source and binary forms, with or without
modification, are permitted provided that the following conditions are met:
    * Redistributions of source code must retain the above copyright
      notice, this list of conditions and the following disclaimer.
    * Redistributions in binary form must reproduce the above copyright
      notice, this list of conditions and the following disclaimer in the
      documentation and/or other materials provided with the distribution.
    * Neither the name of cereal nor the
      names of its contributors may be used to endorse or promote products
```

```
      derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
DISCLAIMED. IN NO EVENT SHALL RANDOLPH VOORHIES OR SHANE GRANT BE LIABLE FOR ANY
DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
(INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND
ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
(INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
```

Random123 is used to generate random numbers and is used under the following license:

```
Copyright 2010-2012, D. E. Shaw Research.
All rights reserved.

Redistribution and use in source and binary forms, with or without
modification, are permitted provided that the following conditions are
met:

* Redistributions of source code must retain the above copyright
  notice, this list of conditions, and the following disclaimer.

* Redistributions in binary form must reproduce the above copyright
  notice, this list of conditions, and the following disclaimer in the
  documentation and/or other materials provided with the distribution.

* Neither the name of D. E. Shaw Research nor the names of its
  contributors may be used to endorse or promote products derived from
  this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS
"AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT
LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR
A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT
OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL,
SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT
LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE,
DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY
THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
(INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE
OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
```

A CUDA [neighbor](https://github.com/mphoward/neighbor) search library is used under the Modified BSD license:

```
Copyright (c) 2018-2019, Michael P. Howard. All rights reserved.

Redistribution and use in source and binary forms, with or without modification,
are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this
list of conditions and the following disclaimer.

2. Redistributions in binary form must reproduce the above copyright notice,
this list of conditions and the following disclaimer in the documentation and/or
```

```
other materials provided with the distribution.

3. Neither the name of the copyright holder nor the names of its contributors
may be used to endorse or promote products derived from this software without
specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
(INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
(INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
```

2.25.6 Libraries

HOOMD-blue links to the following libraries:

- python - Used under the Python license (http://www.python.org/psf/license/)
- cuFFT - Used under the NVIDIA CUDA toolkit license (http://docs.nvidia.com/cuda/eula/index.html)

2.26 Index

- genindex
- modindex

h

Symbols

H

I