ESPResSo++ Documentation

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Welcome to the homepage of the ESPResSo++ project

ESPResSo++ is an extensible, flexible, fast and parallel simulation software for soft matter research. It is a highly versatile software package for the scientific simulation and analysis of coarse-grained atomistic or bead-spring models as they are used in soft matter research.

ESPResSo and ESPResSo++ have common roots and share parts of the developer/user community. However their development is independent and they are different software packages.

ESPResSo++ is free, open-source software published under the GNU General Public License (GPL).

Please cite this, if you used ESPResSo++ in your research J. D. Halverson, T. Brandes, O. Lenz, A. Arnold, S. Bevc, V. Starchenko, K. Kremer, T. Stuehn, D. Reith, "ESPResSo++: A Modern Multiscale Simulation Package for Soft Matter Systems", Computer Physics Communications, 184 (2013), pp. 1129-1149 DOI: 10.1016/j.cpc.2012.12.004 Online access: http://dx.doi.org/10.1016/j.cpc.2012.12.004

Recent publications where ESPResSo++ was used

CHAPTER

ONE

OVERVIEW

- highly modularized object oriented and efficient C++ code
- parallelized with MPI
- python user interface
- classical MD simulations with short and long ranged pair, angular or dihedral interactions
- efficient Adaptive Resolution Scheme (AdResS) implementation
- multisystem integrator (e.g. for parallel tempering)
- reads input files of GROMACS, LAMMPS, and ESPResSo

CHAPTER

TWO

INSTALLATION

The first step in the installation of ESPResSo++ is to download the latest release from the following location:

https://github.com/espressopp/espressopp/releases

On the command line type:

```
tar -xzf espressopp-1.9.3.tgz
```

This will create a subdirectory espressopp-1.9.3

Enter this subdirectory

```
cd espressopp-1.9.3
```

Create the Makefiles using the cmake command. If you don't have it yet, you have to install it first. It is available for all major Linux distributions and also for Mac OS X. (ubuntu,debian: "apt-get install cmake" or get it from http://www.cmake.org)

```
cmake .
```

(the space and dot after *cmake* are necessary)

If cmake doesn't finish successfully (e.g. it didn't find all the libraries) you can tell cmake manually, where to find them by typing:

```
ccmake .
```

This will open an interactive page where all configuration information can be specified. Alternatively, if cmake . complains on missing BOOST or MPI4PY libraries and you had not installed them, you can try

```
cmake . -DEXTERNAL_BOOST=OFF -DEXTERNAL_MPI4PY=OFF
```

In this case, ESPResSo++ will try to use internal Boost and mpi4py libraries.

After successfully building all the Makefiles you should build ESPResSo++ with:

```
make
```

(This will take several minutes)

Before beeing able to use the espressopp module in Python you need to source the ESPRC file:

```
source ESPRC
```

(This sets all corresponding environment variables to point to the module, e.g. PYTHONPATH) You have to source this file every time you want to work with espressopp. It would advisable to e.g. source the file in your .bashrc file ("source <path_to_espressopp>/ESPRC")

In order to use matplotlib.pyplot for graphical output get the open source code from:

http://sourceforge.net/projects/matplotlib

and follow the installation instructions of your distribution.

CHAPTER

THREE

TUTORIAL

3.1 Basic System Setup

ESPResSo++ is implemented as a python module that has to be imported at the beginning of every script:

```
>>> import espressopp
```

ESPResSo++ uses an object called *System* to store some global variables and is also used to keep the connection between some other important modules. We create it with:

```
>>> system          = espressopp.System()
```

Starting a new simulation with ESPResSo++ we should have an idea about what we want to simulate. E.g. how big should the simulation box be or what is the density of the system or what are the interactions and the interaction ranges between our particles.

Let us start with the size of the simulation box:

```
>>> box             = (10, 10, 10)
```

In many cases you will need a random number generator (e.G. to couple to a temperature bath or to randomly position particles in the simulation box). ESPResSo++ provides its own random number generator (for the experts: see boost/random.hpp) so let's use it:

```
>>> rng             = espressopp.esutil.RNG()
```

Our simulation box needs some boundary conditions. We want to use periodic boundary conditions:

```
>>> bc              = espressopp.bc.OrthorhombicBC(rng, box)
```

We tell our system object about this:

```
>>> system.bc       = bc
>>> system.rng      = rng
```

Now we need to decide which parallelization scheme for the particle storage we want to use. In the current version of ESPResSo++ there is only one storage scheme implemented which is *domain decomposition*. Further parallelized storages (e.g. *atom decomposition* or *force decomposition*) will be implemented in future versions.

The *domain decomposition* storage needs to know how many CPUs (or cores, if there are multicore CPUs) are available for the simulation and how to assign the CPUs to the different domains of our simulation box. Moreover the storage needs to know the maximum interaction range of the particles. In a simple Lennard-Jones fluid this could for example be $r_{cut} = 2^{\frac{1}{6}}$. This value together with the *skin* value determines the minimal size for the so called *linked cells* which are used to speed up Verlet list rebuilds (see Frenkel&Smit or Allen&Tildesley for the details).

```
>>> maxcutoff       = pow(2.0, 1.0/6.0)
>>> skin            = 0.4
```

Tell the system about it:

```
>>> system.skin     = skin
```

In the most simple case, if you want to use only one CPU, the *nodeGrid* and the *cellGrid* could look like this:

```
>>> nodeGrid        = (1,1,1)
>>> cellGrid        = (2,2,2)
```

In general you don't need to take care of that yourself. Just use the corresponding ESPResSo++ routines to calculate a reasonable *nodeGrid* and *cellGrid*:

```
>>> nodeGrid        = espressopp.tools.decomp.nodeGrid(espressopp.MPI.COMM_WORLD.
↪size)
>>> cellGrid        = espressopp.tools.decomp.cellGrid(box, nodeGrid, maxcutoff,␣
↪skin)
```

Now we have all the ingredients we need for the *domain decomposition* storage of our system:

```
>>> ddstorage       = espressopp.storage.DomainDecomposition(system, nodeGrid,␣
↪cellGrid)
```

We initialized the DomainDecomposition object with a pointer to our system. We also have to inform the system about the DomainDecomposition storage:

```
>>> system.storage = ddstorage
```

The next module we need is the *integrator*. This object will do the actual work of integrating Newtons equations of motion. ESPResSo++ implements the well known *velocity Verlet* algorithm (see for example Frenkel&Smit):

```
>>>  integrator      = espressopp.integrator.VelocityVerlet(system)
```

We have to tell the integrator about the basic time step:

```
>>>  dt              = 0.005
>>>  integrator.dt   = dt
```

Let's do some math in between:

Note: For 3D vectors like positions, velocities or forces ESPResSo++ provides a so called *Real3D* type, which simplifies handling and arithmetic operations with vectors. 3D coordinates would typically be defined like this:

```
>>> a = espressopp.Real3D(2.0, 5.0, 6.0)
>>> b = espressopp.Real3D(0.1, 0.0, 0.5)
```

Now you could do things like:

```
>>> c = a + b          # c is a Real3D object
>>> d = a * 1.5        # d is a Real3D object
>>> e = a - b          # e is a Real3D object
>>> f = e.sqr()        # f is a scalar
>>> g = e.abs()        # g is a scalar
```

In order to make defining vectors even more simple include the line

```
>>> from espressopp import Real3D
```

just at the beginning of your script. This allows to define vectors as:

```
>>> vec = Real3D(2.0, 1.5, 5.0)
```

Back to our simulation:

The most simple simulation we can do is integrating Newtons equation of motion for one particle without any external forces. So let's simply add one particle to the storage of our system. Every particle in ESPResSo++ has a unique particle id and a position (this is obligatory).

```
>>> pid = 1
>>> pos = Real3D(2.0, 4.0, 6.0)     # remember to add "from espressopp import Real3D
↪"
>>>                                  # at the beginning of your script
>>> system.storage.addParticle(pid, pos)
```

Of course nothing will happen when we integrate this. The particle will stay where it is. Add some initial velocity to the particle by adding the follow line to the script:

```
>>> system.storage.modifyParticle(pid, 'v', Real3D(1.0, 0, 0))
```

After particles have been modified make sure that this information is distributed to all CPUs:

```
>>> system.storage.decompose()
```

Now we can propagate the particle by calling the integrator:

```
>>> integrator.run(100)
```

Check the result with:

```
>>> print "The new particle position is: ", system.storage.getParticle(pid).pos
```

Let's add some more particles at random positions with random velocities and random mass and random type 0 or 1. The boundary condition object knows about how to create random positions within the simulation box. We can add all the particles at once by creating a particle list first:

```
>>> particle_list = []
>>> num_particles = 9
>>> for k in range(num_particles):
>>>   pid  = 2 + k
>>>   pos  = system.bc.getRandomPos()
>>>   v    = Real3D(system.rng(), system.rng(), system.rng())
>>>   mass = system.rng()
>>>   type = system.rng(2)
>>>   part = [pid, pos, type, v, mass]
>>>   particle_list.append(part)
>>> system.storage.addParticles(particle_list, 'id', 'pos', 'type', 'v', 'mass')
>>> # don't forget the decomposition
>>> system.storage.decompose()
```

To have a look at the overall system there are several possibilities. The easiest way to get a nice picture is by writing out a PDB file and looking at the configuration with some visualization programm (e.g. VMD):

```
>>> filename = "myconf.pdb"
>>> espressopp.tools.pdb.pdbwrite(filename, system)
```

or (if *vmd* is in your search PATH) you could directly connect to VMD by:

```
>>> espressopp.tools.vmd.connect(system)
```

or you could print all particle information to the screen:

```
>>> for k in range(10):
>>>   p = system.storage.getParticle(k+1)
>>>   print p.id, p.type, p.mass, p.pos, p.v, p.f, p.q
```

3.2 Simple Lennard Jones System

Lets just copy and paste the beginning from the "System Setup" tutorial:

```
>>> import espressopp
>>> from espressopp import Real3D
>>>
>>> system         = espressopp.System()
>>> box            = (10, 10, 10)
>>> rng            = espressopp.esutil.RNG()
>>> bc             = espressopp.bc.OrthorhombicBC(rng, box)
>>> system.bc      = bc
>>> system.rng     = rng
>>> maxcutoff      = pow(2.0, 1.0/6.0)
>>> skin           = 0.4
>>> system.skin    = skin
>>> nodeGrid       = (1,1,1)
>>> cellGrid       = (1,1,1)
>>> nodeGrid       = espressopp.tools.decomp.nodeGrid(espressopp.MPI.COMM_WORLD.
 ↪size)
>>> cellGrid       = espressopp.tools.decomp.cellGrid(box, nodeGrid, maxcutoff,␣
 ↪skin)
>>> ddstorage      = espressopp.storage.DomainDecomposition(system, nodeGrid,␣
 ↪cellGrid)
>>> system.storage = ddstorage
>>>
>>> integrator     = espressopp.integrator.VelocityVerlet(system)
>>> dt             = 0.005
>>> integrator.dt  = dt
```

And lets add some random particles:

```
>>> num_particles = 20
>>> particle_list = []
>>> for k in range(num_particles):
>>>   pid  = k + 1
>>>   pos  = system.bc.getRandomPos()
>>>   v    = Real3D(0,0,0)
>>>   mass = system.rng()
>>>   type = 0
>>>   part = [pid, pos, type, v, mass]
>>>   particle_list.append(part)
>>> system.storage.addParticles(particle_list, 'id', 'pos', 'type', 'v', 'mass')
>>> system.storage.decompose()
```

All particles should interact via a Lennard Jones potential:

```
>>> LJPot = espressopp.interaction.LennardJones(epsilon=1.0, sigma=1.0,␣
 ↪cutoff=maxcutoff, shift='auto')
```

shift=True means that the potential will be shifted at the cutoff so that potLJ(cutoff)=0 Next we create a VerletList which will than be used in the interaction: (the Verlet List object needs to know from which system to get its particles and which cutoff to use)

```
>>> verletlist = espressopp.VerletList(system, cutoff=maxcutoff)
```

Now create a non bonded interaction object and add the Lennard Jones potential to that:

```
>>> NonBondedInteraction = espressopp.interaction.
↪VerletListLennardJones(verletlist)
>>> NonBondedInteraction.setPotential(type1=0, type2=0, potential=LJPot)
```

Tell the system about the newly created NonBondedInteraction object:

```
>>> system.addInteraction(NonBondedInteraction)
```

We should set the langevin thermostat in the integrator to cool down the random particle system:

```
>>> langevin             = espressopp.integrator.LangevinThermostat(system)
>>> langevin.gamma       = 1.0
>>> langevin.temperature = 1.0
>>> integrator.addExtension(langevin)
```

and finally let the system run and see how it relaxes or explodes:

```
>>> espressopp.tools.analyse.info(system, integrator)
>>> for k in range(100):
>>>   integrator.run(10)
>>>   espressopp.tools.analyse.info(system, integrator)
```

Due to the random particle positions it may happen, that two or more particles are very close to each other and the resulting repulsive force between them are so high that they 'shoot off' in different directions with very high speed. Usually the numbers are then larger than the computer can deal with. A typical error message you get could look like this:

Note: ERROR: particle 5 has moved to outer space (one or more coordinates are nan)

In order to prevent this, systems that are setup in a random way and thus have strong overlaps between particels have to be "warmed up" before they can be equilibrated.

In ESPResSo++ there are several possible ways of warming up a system. As a first approach one could simply constrain the forces in the integrator. For this purpose ESPResSo++ provides an integrator Extension named CapForces. The two parameters of this Extension are the system and the maximum force that a particle can get. The following python code shows how CapForces can be used. Add it to your Lennard-Jones example just after adding the Langevin Extension:

```
>>> print "starting warmup with force capping ..."
>>> force_capping   = espressopp.integrator.CapForce(system, 1000000.0)
>>> integrator.addExtension(force_capping)
>>> # reduce the time step of the integrator to make the integration numerically␣
↪more stable
>>> integrator.dt = 0.0001
>>> espressopp.tools.analyse.info(system, integrator)
>>> for k in range(10):
>>>   integrator.run(1000)
>>>   espressopp.tools.analyse.info(system, integrator)
```

After the warmup the time step of the integrator can be set to a larger value. The CapForce extension can be disconnected after the warmup to get the original full Lennard-Jones potential back.

```
>>> integrator.dt   = 0.005
>>> integrator.step = 0
>>> force_capping.disconnect()
>>> print "warmup finished - force capping switched off."
```

3.2.1 Task 1:

write a python script that creates a random configuration of 1000 Lennard Jones particles with a number density of 0.85 in a cubic simulation box. Warm up and equilibrate this configuration. Examine the output of the command

```
>>> espressopp.tools.analyse.info(system, integrator)
```

after each integration step. How fast is the energy of the system going down ? How long do you have to warmup ? What are good parameters for dt, force_capping and number of integration steps ?

3.3 Advanced Lennard Jones System

This tutorial needs the matplotlib.pyplot and numpy libraries and also VMD to be installed.

```
>>> import espressopp
```

After importing espressopp we import several other Python packages that we want to use for graphical output of some system parameters (e.g. temperature and energy)

```
>>> import math
>>> import time
>>> import matplotlib
>>> matplotlib.use('TkAgg')
>>> import matplotlib.pyplot as plt
>>> plt.ion()
```

We setup a standard Lennard-Jones system with 1000 particles and a density of 0.85 in a cubic siomulation box. ESPResSo++ provides a "shortcut" to setup such a system:

```
>>> N   = 1000
>>> rho = 0.85
>>> L   = pow(N/rho, 1.0/3)
>>> system, integrator = espressopp.standard_system.LennardJones(N,(L, L, L), dt=0.
↪0001)
```

We also add a Langevin thermostat:

```
>>> langevin = espressopp.integrator.LangevinThermostat(system)
>>> langevin.gamma       = 1.0
>>> langevin.temperature = 1.0
>>> integrator.addExtension(langevin)
```

We do a very short warmup in the beginning to get rid of "extremely" high forces

```
>>> force_capping   = espressopp.integrator.CapForce(system, 1000000.0)
>>> integrator.addExtension(force_capping)
>>> espressopp.tools.analyse.info(system, integrator)
>>> for k in range(10):
>>>   integrator.run(100)
>>>   espressopp.tools.analyse.info(system, integrator)
```

Now let's initialize a graph. So that we can have a realtime-view on what is happening in the simulation:

```
>>> plt.figure()
```

We want to observe temperature and energy of the system:

```
>>> T   = espressopp.analysis.Temperature(system)
>>> E   = espressopp.analysis.EnergyPot(system, per_atom=True)
```

x will be the x-axixs of the graph containg the time. yT and yE will be temperature and energy as y-axes in 2 plots:

```
>>> x    = []
>>> yT   = []
>>> yE   = []
>>> yTmin = 0.0
>>> yEmin = 0.0
>>> x.append(integrator.dt * integrator.step)
>>> yT.append(T.compute())
>>> yE.append(E.compute())
>>> yTmax = max(yT)
>>> yEmax = max(yE)
```

Initialize the two graphs ('ro' means red circles, 'go' means green cirlces, see also pyplot documentation)

```
>>> plt.subplot(211)
>>> gT, = plt.plot(x, yT, 'ro')
>>> plt.subplot(212)
>>> gE, = plt.plot(x, yE, 'go')
```

We also want to observe the configuration with VMD. So we have to connect to vmd. This command will automatically start vmd (vmd has to be found in your PATH environment for this to work)

```
>>> sock = espressopp.tools.vmd.connect(system)
>>> for k in range(200):
>>>   integrator.run(1000)
>>>   espressopp.tools.vmd.imd_positions(system, sock)
```

Update the x-, and y-axes:

```
>>>   x.append(integrator.dt * integrator.step)
>>>   yT.append(T.compute())
>>>   yE.append(E.compute())
>>>   yTmax = max(yT)
>>>   yEmax = max(yE)
```

Plot the temperature graph

```
>>>   plt.subplot(211)
>>>   plt.axis([x[0], x[-1], yTmin, yTmax*1.2 ])
>>>   gT.set_ydata(yT)
>>>   gT.set_xdata(x)
>>>   plt.draw()
```

Plot the energy graph

```
>>>   plt.subplot(212)
>>>   plt.axis([x[0], x[-1], yEmin, yEmax*1.2 ])
>>>   gE.set_ydata(yE)
>>>   gE.set_xdata(x)
>>>   plt.draw()
```

In the end save the equilibrated configurations as .eps and .pdf files

```
>>> plt.savefig('mypyplot.eps')
>>> plt.savefig('mypyplot.pdf')
```

3.4 Polymer Melt

We first import espressopp and then define all the parameters of the simulation:

```
>>> import espressopp
>>> num_chains          = 10
>>> monomers_per_chain  = 10
>>> L                   = 10
>>> box                 = (L, L, L)
>>> bondlen             = 0.97
>>> rc                  = pow(2, 1.0/6.0)
>>> skin                = 0.3
>>> dt                  = 0.005
>>> epsilon             = 1.0
>>> sigma               = 1.0
```

Like in the simple Lennard Jones tutorial we setup the system and the integrator. First the system with the excluded volume interaction (WCA, Lennard Jones type)

```
>>> system         = espressopp.System()
>>> system.rng     = espressopp.esutil.RNG()
>>> system.bc      = espressopp.bc.OrthorhombicBC(system.rng, box)
>>> system.skin    = skin
>>> nodeGrid       = espressopp.tools.decomp.nodeGrid(espressopp.MPI.COMM_WORLD.
↪size)
>>> cellGrid       = espressopp.tools.decomp.cellGrid(box, nodeGrid, rc, skin)
>>> system.storage = espressopp.storage.DomainDecomposition(system, nodeGrid,␣
↪cellGrid)
>>> interaction    = espressopp.interaction.VerletListLennardJones(espressopp.
↪VerletList(system, cutoff=rc))
>>> potLJ          = espressopp.interaction.LennardJones(epsilon, sigma, rc)
>>> interaction.setPotential(type1=0, type2=0, potential=potLJ)
>>> system.addInteraction(interaction)
```

Then the integrator with the Langevin extension

```
>>> integrator     = espressopp.integrator.VelocityVerlet(system)
>>> integrator.dt  = dt
>>> thermostat     = espressopp.integrator.LangevinThermostat(system)
>>> thermostat.gamma  = 1.0
>>> thermostat.temperature = temperature
>>> integrator.addExtension(thermostat)
```

Know we add the particles. Keep in mind that we want to create a polymer melt. This means that particles are "bonded" in chains. We setup each polymer chain as a random walk.

```
>>> props    = ['id', 'type', 'mass', 'pos', 'v']
>>> vel_zero = espressopp.Real3D(0.0, 0.0, 0.0)
```

In providing bonding information for the particles we "setup" the bonded chains. For this we use the FixedPairList object that needs to know where and in which storage the particles can be found:

```
>>> bondlist = espressopp.FixedPairList(system.storage)
>>> pid      = 1
>>> type     = 0
>>> mass     = 1.0
>>> chain    = []
```

ESPResSo++ provides a function that will return position and bond information of a random walk. You have to provide a start ID (particle id) and a starting position which we will get from the random position generator of the boundary condition object:

```
>>> for i in range(num_chains):
>>>   startpos = system.bc.getRandomPos()
>>>   positions, bonds = espressopp.tools.topology.polymerRW(pid, startpos,␣
↪monomers_per_chain, bondlen)
```

```
>>>   for k in range(monomers_per_chain):
>>>     part = [pid + k, type, mass, positions[k], vel_zero]
>>>     chain.append(part)
>>>   pid += monomers_per_chain
>>>   type += 1
>>>   system.storage.addParticles(chain, *props)
>>>   system.storage.decompose()
>>>   chain = []
>>>   bondlist.addBonds(bonds)
```

Note: try out the command

```
>>> espressopp.tools.topology.polymerRW(pid, startpos, monomers_per_chain, bondlen)
```

to see what it returns

Don't forget to distribute the particles and the bondlist to the CPUs in the end:

```
>>> system.storage.decompose()
```

Finally add the information about the bonding potential. In this example we are using a FENE-potential between the bonded particles.

```
>>> potFENE    = espressopp.interaction.FENE(K=30.0, r0=0.0, rMax=1.5)
>>> interFENE = espressopp.interaction.FixedPairListFENE(system, bondlist, potFENE)
>>> system.addInteraction(interFENE)
```

Start the integrator and observe how the system explodes. Like in the random Lennard Jones system, we have the same problem here: particles can strongly overlap and thus will get very high forces accelerating them to infinite (for the computer) speed.

```
>>> espressopp.tools.analyse.info(system, integrator)
>>> for k in range(nsteps):
>>>   integrator.run(isteps)
>>>   espressopp.tools.analyse.info(system, integrator)
>>>   espressopp.tools.analyse.info(system, integrator)
```

3.4.1 Task 2:

Try to warmup and equilibrate a dense polymer melt (density=0.85) by using the warmup methods that you have learned in the Lennard Jones tutorial.

3.4.2 Hint:

During warmup you can slowly switch on the excluded volume interaction by starting with a small epsilon and increasing it during integration: You can do this by continuously overwriting the interaction potential after some time interval.

```
>>> potLJ          = espressopp.interaction.LennardJones(new_epsilon, sigma, rc)
>>> interaction.setPotential(type1=0, type2=0, potential=potLJ)
```

3.5 AddNewPotential

The aim of the tutorial is to implement a new interaction potential in ESPResSo++. We start with the Gromos fourth-power bond-stretching potential, because its functional form is simple and its implementation is somewhat

similar to other potentials already implemented in ESPResSo++. Everything you learn in this tutorial will then be relevent for implementing any other more complicated potential.

Make sure you have a working, compiled version of ESPResSo++ before starting the tutorial.

For those who are not so familiar with C++ or interfacing python and C++, you will find some helpful notes in the appendix.

3.5.1 Steps for adding a new interaction potential

1. Choose the potential and derive the force.
2. Choose the appropriate interaction template from those in `$ESPRESSOHOME/src/interaction`, e.g. `VerletListInteractionTemplate.hpp`, `FixedTripleListInteractionTemplate.hpp`
3. Create the .cpp, .hpp and .py files for your potential, place them in `$ESPRESSOHOME/src/interaction` and modify `$ESPRESSOHOME/src/interaction/bindings.cpp` and `$ESPRESSOHOME/src/interaction/__init__.py`
4. Compile.

These steps are described in more detail below for our tutorial example potential.

3.5.2 Today's tutorial exercise

Step 1

The potential we are implementing today is a two-body bonded potential with the form

$$V(r_{ij}) = \frac{1}{4}k_{ij}(r_{ij}^2 - r_{0,ij}^2)^2$$

noindent where r_{ij} is the distance between particles *i* and *j*. The potential has two input parameters r_0 and k.

Derive the force.

Step 2

This is a 2-body interaction between a predefined (fixed) list of atom pairs. What is the appropriate interaction template to use? Choose one in `$ESPRESSOHOME/src/interaction`

Open the interaction template file. (When you close the file later, close it without saving, or else later on your compile time will be very long, because of the number of dependencies on the interaction template!) Identify the functions `addForces()` and `computeEnergy()`. Many interaction templates also contain functions such as `computeVirial()`, `computeVirialX()` (for calculating the virial in slabs along the x-direction) etc.

Find the function calls:

```
potential->_computeForce(force, dist)
```

in `addForces()` and

```
potential->_computeEnergy(r21)
```

in `computeEnergy()`.

An interaction template can be combined with many different potentials (e.g. harmonic potential, Lennard Jones potential, etc.) Each potential will have its own C++ class containing functions to compute the energy and forces for that particular potential (see e.g. Harmonic.cpp/hpp, LennardJones.cpp/hpp) In turn, each potential can be combined with many different interaction templates.

You don't need to modify the interaction template file today. (Close it without saving!)

Step 3

In this step we create the .cpp, .hpp and .py files for our potential. Let's call the potential FourthPower. The FourthPower.py file will contain the end-user python interface, and in the FourthPower.cpp and FourthPower.hpp files we will create a C++ class for our potential. We will also write a wrapper which will allow the user to call the C++ code from the python interface.

3(a) Interfacing potential class and interaction template

In many cases, it's not necessary to understand the contents of this section in order to implement a new potential. If you like, you can skip directly to Section *3(b) Creating the new potential class*.

Now we need to understand how the interaction template will interface with our new class. This is done via a class template, e.g. in `Potential.hpp`, `AnglePotential.hpp`, `DihedralPotential.hpp` etc.

Still in `$ESPRESSOHOME/src/interaction`, open the file `Potential.hpp`. (When you close the file later, close it without saving, or else later on your compile time will be very long, because of the number of dependencies on the file!)

Find the functions `_computeForce(Real3D& force,const Real3D& dist)` and `_computeEnergy(real dist)` which you identified in the interaction template. Note that `_computeForce(Real3D& force,const Real3D& dist)` calls the function `_computeForceRaw(force,dist,distSqr)` and `_computeEnergy(real dist)` calls `_computeEnergySqr(dist*dist)` which calls `_computeEnergySqrRaw(distSqr)`. The functions `_computeForceRaw()` and `_computeEnergySqrRaw()` are the new functions we need to write for our new potential. They will be member methods of our new C++ class FourthPower.

You don't need to modify anything in `Potential.hpp` today. (Close it without saving!)

3(b) Creating the new potential class

An easy way to implement the new C++ class is to identify a previously implemented potential which somewhat resembles your new potential, e.g. here we could take the Harmonic potential, which is also a 2-body potential, and which has also been interfaced with the FixedPairListInteractionTemplate.

Still in `$ESPRESSOHOME/src/interaction`, copy the files `Harmonic.py`, `Harmonic.cpp` and `Harmonic.hpp` to new files `FourthPower.py`, `FourthPower.cpp` and `FourthPower.hpp`. In the new files, find and replace all occurences of 'Harmonic' with 'FourthPower', and 'HARMONIC' with 'FOURTHPOWER'.

First modify `FourthPower.hpp`.

Note the `#include` statement for `FixedPairListInteractionTemplate.hpp` and `Potential.hpp`, the files you examined in *Step 2* and Step *3(a) Interfacing potential class and interaction template*.

The Harmonic potential had parameters called `K` and `r0`. You can reuse these for the FourthPower potential, along with the setters and getters `setK`, `getK`, `setR0` and `getR0`. For better efficiency, you could also create a new variable which contains the square of `r0`.

Now we need functions `_computeForceRaw()` and `_computeEnergySqrRaw()`, as explained in Step *3(a) Interfacing potential class and interaction template*. Modify these functions to use the functional form of the fourth power potential as derived in *Step 1*. Note that `Real3D dist`, which contains the vector between the two particles, has been defined as $r_{p1} - r_{p2}$ (see `addForces()` in `FixedPairListInteractionTemplate.hpp`).

Next open `Harmonic.py` and `FourthPower.py`.

Here is an example of an end-user's python script to add an interaction using the harmonic potential:

```
harmonicbondslist = espresso.FixedPairList(system.storage)
harmonicbondslist.addBonds(bond_list) #bond_list is a list of tuples␣
↪[(particleindex_i,particleindex_j),...]
harmonic_potential = espresso.interaction.Harmonic(K=10.0, r0=1.0, cutoff = 5.0,␣
↪shift = 0.0)
harmonic_interaction = espresso.interaction.FixedPairListHarmonic(system,␣
↪harmonicbondslist, potential=harmonic_potential)
system.addInteraction(harmonic_interaction)
```

Compare this to the contents of `Harmonic.py` to understand the python source code.

Our new potential FourthPower can be called by the end-user in a similar way. Since the Harmonic and FourthPower potentials have similar input parameters (`K`, `r0`) and both use the FixedPairListInteractionTemplate, you don't need to make any further modifications to the file `FourthPower.py`, besides replacing 'Harmonic' with 'FourthPower'.

Next open `FourthPower.cpp`.

Here you will find the C++/python interface, in the function `registerPython()`. If you want to understand this function, you will find details in *Exposing a C++ class or struct to python using boost*. You don't need to make any further modifications to this file, besides replacing 'Harmonic' with 'FourthPower'.

3(c) Including the new class in espressopp

Finally, update the files `$ESPRESSOHOME/src/interaction/bindings.cpp` and `$ESPRESSOHOME/src/interaction/__init__.py` (for example by copying and modifying all the lines referring to the Harmonic potential so that they now refer to the FourthPower potential). You need to make three modifications: to include the new .hpp file, to call the new registerPython() wrapper, and to import everything in the new python module.

Step 4

Move to the directory `$ESPRESSOHOME`. Update the makefiles and compile using the commands:

```
cmake .
make
```

3.5.3 Advanced exercise

For an interaction potential of your choosing, follow the steps above to implement it, e.g. a non-bonded two-body interaction, probably using `VerletListInteractionTemplate` and based on the `LennardJones` potential, or a bonded three-body interaction, probably using `FixedTripleListInteractionTemplate.hpp` and based on the `AngularHarmonic` potential.

You will probably have to write setters and getters for the parameters in your potential in your .hpp file, and make the corresponding modifications to the function `registerPython()` in the .cpp file and the python user interface in the .py file.

3.6 Appendices

3.6.1 Exposing a C++ class or struct to python using boost

(See http://www.boost.org/doc/libs/1_56_0/libs/python/doc/tutorial/doc/html/python/exposing.html)

Say we have a C++ struct called World:

```
struct World
{
    World(std::string msg): msg(msg) {}                // constructor
    void set(std::string msg) { this->msg = msg; }     // function set
    std::string greet() { return msg; }                // function greet
    std::string msg;                                   // member variable
};
```

Now we write the C++ class wrapper for struct World to expose the constructor and the functions greet and set to python:

```
{
    class_<World>("World", init<std::string>())
        .def("greet", &World::greet)
        .def("set", &World::set)
    ;
}
```

If there are additional constructors we can also expose them using `def()`, e.g. for an additional constructor which takes two doubles:

```
class_<World>("World", init<std::string>())
    .def(init<double, double>())
    .def("greet", &World::greet)
    .def("set", &World::set)
;
```

We can also expose the data members of the C++ class or struct and the associated access (getter and setter) functions using `add_property()`, e.g. for the variable myValue with access functions `getMyValue` and `setMyValue`:

```
.add_property("myValue",&World::getMyValue,&World::setMyValue)
```

C++ classes and structs may be derived from other classes. Say we have the C++ struct myDerivedStruct which is derived from the struct myBaseStruct:

```
struct myBaseStruct { virtual ~myBaseStruct(); };
struct myDerivedStruct : myBaseStruct {};
```

We can wrap the base class myBaseStruct as explained above:

```
<Base>("Base")
   /*...*/
   ;
```

Now when we want to wrap the class myDerivedStruct, we tell boost that it is derived from the base class myBaseStruct:

```
class_<myDerivedStruct, bases<myBaseStruct> >("myDerivedStruct")
    /*...*/
    ;
```

3.6.2 C++ templates

See http://www.cplusplus.com/doc/oldtutorial/templates/

3.6.3 typedef

typedef declaration allows you to create an alias that can be used anywhere in place of a (possibly complex) type name

```
typedef DataType AliasName;
```

3.6.4 Python notes

Syntax for classes in python

(See also https://docs.python.org/2/tutorial/classes.html)

Here is a python class called DerivedClassName which is derived from two other base classes (BaseClassName1 and BaseClassName1), is initialised with two variables x and y which have default values 1 and 2, and contains a function myFunction.

```
class DerivedClassName(BaseClassName1, BaseClassName2):
    """docstring"""           #a way of providing some documentation for the class
    def __init__(self,x=1,y=2): #takes two variable which have default values 1␣
↪and 2
        self.x = x
        self.y = y
    def myFunction(self):
        return self.x * self.y
```

PMI

PMI = parallel method invocation. For more details see the file `$ESPRESSOHOME/src/pmi.py`

3.7 Adaptive Resolution Scheme (AdResS)

3.8 Thermodynamic integration

3.8.1 Theoretical explanation

Thermodynamic integration (TI) is a method used to calculate the free energy difference between two states A and B. For the theoretical background, see e.g. http://www.alchemistry.org. In this tutorial, we show how to perform TI calculations with ESPResSo++. We calculate the free energy of solvation of methanol in water. The complete python script is available in the ESPResSo+ source code under `examples/thd_integration_solvation`

To do TI, we define states A and B, with potentials U^A and U^B. We then construct a pathway of intermediate states between A and B by defining a parameter λ that takes values between 0 and 1 and writing the system potential U as a function of λ, U^A and U^B. The free energy difference between the states A and B is then given by

$$\Delta A = \int_0^1 \left\langle \frac{dU(\lambda)}{d\lambda} \right\rangle_\lambda \mathrm{d}\lambda$$

In practise, we discretise λ and perform a series of MD simulations with different λ values between 0 and 1, sampling $\frac{dU(\lambda)}{d\lambda}$ in each simulation.

To calculate the solvation free energy of methanol in water, we use a box of water containing one methanol molecule. We simulate desolvation via two separate TI calculations. (Note that the procedure described here is decoupling, and solute-solute interactions will be treated differently if you're doing annihilation instead of decoupling, see Note 1.)

Step 1: free energy change for switching off the Coulombic interactions

State A: methanol has full non-bonded (Coulomb and Lennard Jones) interactions with the solvent

State B: methanol has only Lennard Jones interactions with the solvent

---

Step 2: free energy change for switching off the Lennard Jones interactions

State A: methanol has only Lennard Jones interactions with the solvent

State B: methanol has no interaction with the solvent

Step 1 can be done using a linear function of λ:

$$U(\lambda_C) = (1 - \lambda_C)U_C^A + U_{unaffected}$$

where U_C^A is the solute-solvent Coulombic interaction in state A. In ESPResSo++ the charges used for state A are the particle charges contained in the particle property `charge`. The charges in state B are zero, so $U_C^B(q)$ does not appear in the expression. (The case where A and B both have non-zero charges is not implemented in ESPResSo++). The term $U_{unaffected}$ is all other parts of the potential that don't change with λ_C including all bonded interactions, any solute-solute Coulombic interactions, solvent-solvent Coulombic interactions and all Lennard-Jones interactions. The parameter λ_C goes from 0 to 1 in Step 1.

Step 2 must be done using a softcore potential because of the singularity in the Lennard-Jones potential at $r_{ij} = 0$.

$$\begin{aligned} U(\lambda_L) &= \sum_{i,j} U_L(r_{ij}, \lambda_L) + U_{unaffected} \\ U_L(r_{ij}, \lambda_L) &= (1 - \lambda_L)U_H^A(r_A) + \lambda_L U_H^B(r_B) \\ r_A &= (\alpha\sigma_A^6\lambda^p + r_{ij}^6)^{1/6} \\ r_B &= (\alpha\sigma_B^6(1 - \lambda)^p + r_{ij}^6)^{1/6} \end{aligned}$$

The terms $U_H^A(r_A)$ and $U_H^B(r_B)$ are the normal Lennard-Jones 12-6 hardcore potentials:

$$U_H^A(r_A) = 4.0\epsilon_A(\frac{\sigma_A}{r_A}^{12} - \frac{\sigma_A}{r_A}^{6})$$

The sum $\sum_{i,j} U_L(r_{ij}, \lambda_L)$ is over all solute-solvent interactions. The term $U_{unaffected}$ is all other parts of the potential that don't change with λ_L including any solute-solute Lennard-Jones interactions and solvent-solvent Lennard-Jones interactions, which are treated using standard hardcore Lennard-Jones. (In this particular example of methanol, there are no solute-solute Lennard-Jones interactions). Finally α and p are adjustable parameters of the softcore potential.

The ESPResSo++ C++ code allows for different values of ϵ_A, ϵ_B, σ_A and σ_B for every pair of atomtypes interacting via this potential. In this example, we will set ϵ_B to 0 (we are switching off the Lennard-Jones interaction). The parameter λ_L goes from 0 to 1 in Step 2.

3.8.2 ESPResSo++ code

We must perform many separate simulations, each with a different λ value. It is convenient to define a list of λ values in the python script and use an index to access a different element of the list in each separate simulation. The script for the first simulation contains these lines:

```
# Parameters for Thermodynamic Integration
stateBIndices = [1,2,3,4,5,6] #indices of the methanol atoms
lambdaVectorCoul = [0.00, 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.
↪50,
```

```
                    0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 0.95, 1.00, 1.
↪000,
                    1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000,
                    1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000,
                    1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000,
                    1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000, 1.000,
                    1.000, 1.000, 1.000]
lambdaVectorVdwl = [0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.
↪00,
                    0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.
↪025,
                    0.050, 0.075, 0.100, 0.125, 0.150, 0.175, 0.200, 0.225, 0.250,
                    0.275, 0.300, 0.325, 0.350, 0.375, 0.400, 0.425, 0.450, 0.475,
                    0.500, 0.525, 0.550, 0.575, 0.600, 0.625, 0.650, 0.675, 0.700,
                    0.725, 0.750, 0.775, 0.800, 0.825, 0.850, 0.875, 0.900, 0.925,
                    0.950, 0.975, 1.000]
lambdaIndex = 0
lambdaTICoul = lambdaVectorCoul[lambdaIndex]
lambdaTIVdwl = lambdaVectorVdwl[lambdaIndex]
```

The list `lambdaVectorCoul` contains the values of λ_C and the list `lambdaVectorVdwl` contains the values of λ_L. The total number of simulations to do Step 1 and Step 2 will be `len(lambdaVectorCoul)` or `len(lambdaVectorVdwl)`. We must make a copy of the python script for each simulation, changing each time the value of `lambdaIndex`.

Next we set up the Coulombic interactions, assuming we already have created a `system` and a `verletlist`. The electrostatics method used is generalised reaction field.

```
#atTypes - list of all atomtypes (integers) used in the pairs interacting via this␣
↪potential
#epsilon1,epsilon2,kappa - reaction field parameters
#annihilate=False means decoupling is used (see Note 1)
#ftpl - a FixedTupleListAdResS object (see AdResS tutorial)
#for non-AdResS simulations, simply set adress=False, and the parameter ftpl is␣
↪not needed
qq_adres_interaction = gromacs.setCoulombInteractionsTI(system, verletlist,␣
↪nbCutoff,
                                                        atTypes, epsilon1=1, epsilon2=80,
                                                        kappa=0, lambdaTI=lambdaTICoul,
                                                        pidlist=stateBIndices,
                                                        annihilate=False, adress=True,␣
↪ftpl=ftpl)
```

Now we set up the softcore Lennard Jones interaction.

```
#atomtypeparameters - dictionary of format {atomtype: {'eps': epsilon, 'sig':␣
↪sigma}}
#                     where atomtype is integer and epsilon and sigma are real
#defaults - dictionary containing a key 'combinationrule' with value 1 if the␣
↪contents
#           of atomtypeparameters need to be converted from c6,c12 format to
#           epsilon,sigma format; can also be an empty dictionary if no conversion␣
↪needed
#sigmaSC, alphaSC, powerSC - parameters of the softcore potential
alphaSC = 0.5
powerSC = 1.0
epsilonB = 0.0
sigmaSC = 0.3
lj_adres_interaction = gromacs.setLennardJonesInteractionsTI(system, defaults,
                                          atomtypeparameters, verletlist, nbCutoff,
                                          epsilonB=epsilonB, sigmaSC=sigmaSC,␣
↪alphaSC=alphaSC,
                                          powerSC=powerSC, lambdaTI=lambdaTIVdwl,
```

```
                                        pidlist=stateBIndices, annihilate=False,
                                        adress=True, ftpl=ftpl)
```

We open an output file. In the first line we write the values of λ_C and λ_L for this simulation.

```
dhdlF = open("dhdl.xvg","a")
dhdlF.write("#(coul-lambda, vdw-lambda) = ("+str(lambdaTICoul)+",
↪"+str(lambdaTIVdwl)+")\n")
```

During the MD run, every x number of MD steps, we return to the python level and calculate the derivatives of the energies with respect to λ.

```
dhdlCoul = qq_adres_interaction.computeEnergyDeriv()
dhdlVdwl = lj_adres_interaction.computeEnergyDeriv()
dhdlF.write(str(time)+" "+str(dhdlCoul)+" "+str(dhdlVdwl)+"\n")
```

After all simulations, we can now average $\frac{dU(\lambda)}{d\lambda}$ for each value of λ_C or λ_L, integrate over λ_C and λ_L, add the values ΔA_C and ΔA_L, and take the negative (because the procedure described here is desolvation and we want the free energy of solvation).

3.8.3 Some notes

1. This example given here uses decoupling (solute-solvent interactions are a function of λ, solute-solute interactions are not affected by changes in λ). In ESPResSo++ it is also possible to do annihilation, where both solute-solvent and solute-solute interactions are a function of λ, by setting `annihilate=True` when creating the non-bonded interactions.
2. The procedure described here is desolvation. To get the free energy of solvation, we take the negative of the value obtained after integration.
3. The example Python code snippets here use the helper functions `gromacs.setLennardJonesInteractionsTI` and `gromacs.setCoulombInteractionsTI` contained in `$ESPRESSOHOME/src/tools/convert/gromacs.py`, but this is not necessary. You can do TI with ESPResSo++ without the Gromacs parser by directly calling `espresso.interaction.LennardJonesSoftcoreTI` and `espresso.interaction.ReactionFieldGeneralizedTI`. See the documentation of these two classes.

CHAPTER

FOUR

USER INTERFACE

4.1 Version - Object

Return version information of espressopp module

Example:

```
>>> version     = espressopp.Version()
>>> print "Name                   = ", version.name
>>> print "Major version number   = ", version.major
>>> print "Minor version number   = ", version.minor
>>> print "Git revision = ", version.gitrevision
>>> print "boost version          = ", version.boostversion
>>> print "Patchlevel             = ", version.patchlevel
>>> print "Compilation date       = ", version.date
>>> print "Compilation time       = ", version.time
```

to print a full version info string:

```
>>> print version.info()
```

espressopp.**Version**()

4.2 PMI - Parallel Method Invocation

PMI allows users to write serial Python scripts that use functions and classes that are executed in parallel.

PMI is intended to be used in data-parallel environments, where several threads run in parallel and can communicate via MPI.

In PMI mode, a single thread of control (a python script that runs on the *controller*, i.e. the MPI root task) can invoke arbitrary functions on all other threads (the *workers*) in parallel via *call()*, *invoke()* and *reduce()*. When the function on the workers return, the control is returned to the controller.

This model is equivalent to the "Fork-Join execution model" used e.g. in OpenMP.

PMI also allows to create parallel instances of object classes via *create()*, i.e. instances that have a corresponding object instance on all workers. *call()*, *invoke()* and *reduce()* can be used to call arbitrary methods of these instances.

to execute arbitrary code on all workers, *exec_()* can be used, and to import python modules to all workers, use 'import_()'.

4.2.1 Main program

On the workers, the main program of a PMI script usually consists of a single call to the function *startWorkerLoop()*. On the workers, this will start an infinite loop on the workers that waits to receive the next PMI call,

while it will immediately return on the controller. On the workers, the loop ends only, when one of the commands *finalizeWorkers()* or *stopWorkerLoop()* is issued on the controller. A typical PMI main program looks like this:

```
>>> # compute 2*factorial(42) in parallel
>>> import pmi
>>>
>>> # start the worker loop
>>> # on the controller, this function returns immediately
>>> pmi.startWorkerLoop()
>>>
>>> # Do the parallel computation
>>> pmi.import_('math')
>>> pmi.reduce('lambda a,b: a+b', 'math.factorial', 42)
>>>
>>> # exit all workers
>>> pmi.finalizeWorkers()
```

Instead of using *finalizeWorkers()* at the end of the script, you can call *registerAtExit()* anywhere else, which will cause *finalizeWorkers()* to be called when the python interpreter exits.

Alternatively, it is possible to use PMI in an SPMD-like fashion, where each call to a PMI command on the controller must be accompanied by a corresponding call on the worker. This can be either a simple call to *receive()* that accepts any PMI command, or a call to the identical PMI command. In that case, the arguments of the call to the PMI command on the workers are ignored. In this way, it is possible to write SPMD scripts that profit from the PMI communication patterns.

```
>>> # compute 2*factorial(42) in parallel
>>> import pmi
>>>
>>> pmi.exec_('import math')
>>> pmi.reduce('lambda a,b: a+b', 'math.factorial', 42)
```

To start the worker loop, the command *startWorkerLoop()* can be issued on the workers. To stop the worker loop, *stopWorkerLoop()* can be issued on the controller, which will end the worker loop without exiting the workers.

4.2.2 Controller commands

These commands can be called in the controller script. When any of these commands is issued on a worker during the worker loop, a *UserError* is raised.

- *call()*, *invoke()*, *reduce()* to call functions and methods in parallel
- *create()* to create parallel object instances
- *exec_()* and *import_()* to execute arbitrary python code in parallel and to import classes and functions into the global namespace of pmi.
- *sync()* to make sure that all deleted PMI objects have been deleted.
- *finalizeWorkers()* to stop and exit all workers
- *registerAtExit()* to make sure that finalizeWorkers() is called when python exits on the controller
- *stopWorkerLoop()* to interrupt the worker loop an all workers and to return control to the single workers

4.2.3 Worker commands

These commands can be called on a worker.

- *startWorkerLoop()* to start the worker loop
- *receive()* to receive a single PMI command

- *call()*, *invoke()*, *reduce()*, *create()* and *exec_()* to receive a single corresponding PMI command. Note that these commands will ignore any arguments when called on a worker.

4.2.4 PMI Proxy metaclass

The *Proxy* metaclass can be used to easily generate front-end classes to distributed PMI classes. . . .

4.2.5 Useful constants and variables

The pmi module defines the following useful constants and variables:

- *isController* is True when used on the controller, False otherwise
- *isWorker* = not isController
- *ID* is the rank of the MPI task
- *CONTROLLER* is the rank of the Controller (normally the MPI root)
- *workerStr* is a string describing the thread ('Worker #' or 'Controller')
- *inWorkerLoop* is True, if PMI currently executes the worker loop on the workers.

espressopp.pmi.**exec_**(**args*)
Controller command that executes arbitrary python code on all (active) workers.

exec_() allows to execute arbitrary Python code on all workers. It can be used to define classes and functions on all workers. Modules should not be imported via exec_(), instead import_() should be used.

Each element of args should be string that is executed on all workers.

Example:

```
>>> pmi.exec_('import hello')
>>> hw = pmi.create('hello.HelloWorld')
```

espressopp.pmi.**import_**(**args*)
Controller command that imports python modules on all (active) workers.

Each element of args should be a module name that is imported to all workers.

Example:

```
>>> pmi.import_('hello')
>>> hw = pmi.create('hello.HelloWorld')
```

espressopp.pmi.**create**(*cls=None*, **args*, ***kwds*)
Controller command that creates an object on all workers.

cls describes the (new-style) class that should be instantiated. args are the arguments to the constructor of the class. Only classes that are known to PMI can be used, that is, classes that have been imported to pmi via *exec_()* or *import_()*.

Example:

```
>>> pmi.exec_('import hello')
>>> hw = pmi.create('hello.HelloWorld')
>>> print(hw)
MPI process #0: Hello World!
MPI process #1: Hello World!
...
```

Alternative: Note that in this case the class has to be imported to the calling module *and* via PMI.

```
>>> import hello
>>> pmi.exec_('import hello')
>>> hw = pmi.create(hello.HelloWorld)
>>> print(hw)
MPI process #0: Hello World!
MPI process #1: Hello World!
...
```

espressopp.pmi.**call**(**args*, ***kwds*)
Call a function on all workers, returning only the return value on the controller.

function denotes the function that is to be called, args and kwds are the arguments to the function. If kwds contains keys that start with with the prefix '__pmictr_', they are stripped of the prefix and are passed only to the controller. If the function should return any results, it will be locally returned. Only functions that are known to PMI can be used, that is functions that have been imported to pmi via *exec_()* or *import_()*.

Example:

```
>>> pmi.exec_('import hello')
>>> hw = pmi.create('hello.HelloWorld')
>>> pmi.call(hw.hello)
>>> # equivalent:
>>> pmi.call('hello.HelloWorld', hw)
```

Note, that you can use only functions that are know to PMI when *call()* is called, i.e. functions in modules that have been imported via *exec_()*.

espressopp.pmi.**invoke**(**args*, ***kwds*)
Invoke a function on all workers, gathering the return values into a list.

function denotes the function that is to be called, args and kwds are the arguments to the function. If kwds contains keys that start with with the prefix '__pmictr_', they are stripped of the prefix and are passed only to the controller.

On the controller, invoke() returns the results of the different workers as a list. On the workers, invoke returns None. Only functions that are known to PMI can be used, that is functions that have been imported to pmi via *exec_()* or *import_()*.

Example:

```
>>> pmi.exec_('import hello')
>>> hw = pmi.create('hello.HelloWorld')
>>> messages = pmi.invoke(hw.hello())
>>> # alternative:
>>> messages = pmi.invoke('hello.HelloWorld.hello', hw)
```

espressopp.pmi.**reduce**(**args*, ***kwds*)
Invoke a function on all workers, reducing the return values to a single value.

reduceOp is the (associative) operator that is used to process the return values, function denotes the function that is to be called, args and kwds are the arguments to the function. If kwds contains keys that start with with the prefix '__pmictr_', they are stripped of the prefix and are passed only to the controller.

reduce() reduces the results of the different workers into a single value via the operation reduceOp. reduceOp is assumed to be associative. Both reduceOp and function have to be known to PMI, that is they must have been imported to pmi via *exec_()* or *import_()*.

Example:

```
>>> pmi.exec_('import hello')
>>> pmi.exec_('joinstr=lambda a,b: "\n".join(a,b)')
>>> hw = pmi.create('hello.HelloWorld')
>>> print(pmi.reduce('joinstr', hw.hello()))
>>> # equivalent:
```

```
>>> print(
...   pmi.reduce('lambda a,b: "\n".join(a,b)',
...              'hello.HelloWorld.hello', hw)
...              )
```

espressopp.pmi.**sync**()
Controller command that deletes the PMI objects on the workers that have already been deleted on the controller.

espressopp.pmi.**receive**(*expected=None*)
Worker command that receives and handles the next PMI command.

This function waits to receive and handle a single PMI command. If expected is not None and the received command does not equal expected, raise a *UserError*.

espressopp.pmi.**startWorkerLoop**()
Worker command that starts the main worker loop.

This function starts a loop that expects to receive PMI commands until *stopWorkerLoop()* or *finalizeWorkers()* is called on the controller.

espressopp.pmi.**finalizeWorkers**()
Controller command that stops and exits all workers.

espressopp.pmi.**stopWorkerLoop**(*doExit=False*)
Controller command that stops all workers.

If doExit is set, the workers exit afterwards.

espressopp.pmi.**registerAtExit**()
Controller command that registers the function *finalizeWorkers()* via atexit.

class espressopp.pmi.**Proxy**(*name*, *bases*, *dict*)
A metaclass to be used to create frontend serial objects.

exception espressopp.pmi.**UserError**(*msg*)
Raised when PMI has encountered a user error.

4.3 System - Object

The main purpose of this class is to store pointers to some important other classes and thus make them available to C++. In a way the System class can be viewed as a container for system wide global variables. If you need to run more than one system at the same time you can combine several systems with the help of the Multisystem class.

4.3.1 In detail the System class holds pointers to:

- the *storage* (e.g. DomainDecomposition)
- the boundary conditions *bc* for the system (e.g. OrthorhombicBC)
- a random number generator *rng* which is for example used by a thermostat
- the *skin* which is needed for the Verlet lists and the cell grid
- a list of short range interactions that apply to the system these interactions are added with the *addInteraction()* method of the System

Example (not complete):

```
>>> LJSystem       = espressopp.System()
>>> LJSystem.bc    = espressopp.bc.OrthorhombicBC(rng, boxsize)
>>> LJSystem.rng
```

```
>>> LJSystem.skin = 0.4
>>> LJSystem.addInteraction(interLJ)
```

espressopp.**System**()

espressopp.System.**addInteraction**(*interaction*, *name*)

Parameters

- **interaction** –
- **name** (*string*) – The optional name of the interaction.

Return type bool

espressopp.System.**getInteraction**(*number*)

Parameters **number** –

Return type

espressopp.System.**getNumberOfInteractions**()

Return type

espressopp.System.**removeInteraction**(*number*)

Parameters **number** –

Return type

espressopp.System.**removeInteractionByName**(*self*, *name*)

Parameters **name** (*str*) – The name of the interaction to remove.

espressopp.System.**scaleVolume**(**args*)

Parameters ***args** –

Return type

espressopp.System.**setTrace**(*switch*)

Parameters **switch** –

4.4 BC - Boundary Condition Object

This is the abstract base class for all boundary condition objects. It cannot be used directly. All derived classes implement at least the following methods:

- *getMinimumImageVector(pos1, pos2)*
- *getFoldedPosition(pos, imageBox)*
- *getUnfoldedPosition(pos, imageBox)*
- *getRandomPos()*

pos, *pos1* and *pos2* are particle coordinates (type: (*float*, *float*, *float*)). *imageBox* (type: (*int*, *int*, *int*)) specifies the

espressopp.bc.BC.**getFoldedPosition**(*pos*, *imageBox*)

Parameters

- **pos** –
- **imageBox** – (default: None)

Return type

espressopp.bc.BC.**getMinimumImageVector**(*pos1*, *pos2*)

Parameters

- **pos1** –
- **pos2** –

Return type

espressopp.bc.BC.**getRandomPos**()

Return type

espressopp.bc.BC.**getUnfoldedPosition**(*pos*, *imageBox*)

Parameters

- **pos** –
- **imageBox** –

Return type

4.5 OrthorhombicBC - Object

Like all boundary condition objects, this class implements all the methods of the base class **BC** , which are described in detail in the documentation of the abstract class **BC**.

The OrthorhombicBC class is responsible for the orthorhombic boundary condition. Currently only periodic boundary conditions are supported.

Example:

```
>>> boxsize = (Lx, Ly, Lz)
>>> bc = espressopp.bc.OrthorhombicBC(rng, boxsize)
```

espressopp.bc.**OrthorhombicBC**(*rng*, *boxL*)

Parameters

- **rng** –
- **boxL** (*real*) – (default: 1.0)

espressopp.bc.OrthorhombicBC.**setBoxL**(*boxL*)

Parameters **boxL** –

4.6 Storage - Storage Object

This is the base class for all storage objects. All derived classes implement at least the following methods:

- *decompose()*

  Send all particles to their corresponding cell/cpu

- *addParticle(pid, pos)*:

  Add a particle to the storage

- *removeParticle(pid)*:

  Remove a particle with id number *pid* from the storage.

  ```
  >>> system.storage.removeParticle(4)
  ```

There is an example in *examples* folder

- *getParticle(pid)*:

  Get a particle object. This can be used to get specific particle information:

```
>>> particle = system.storage.getParticle(15)
>>> print "Particle ID is       : ", particle.id
>>> print "Particle position is : ", particle.pos
```

  you cannot use this particle object to modify particle data. You have to use the modifyParticle command for that (see below).

- *addAdrParticle(pid, pos, last_pos)*:

  Add an AdResS Particle to the storage

- *setFixedTuplesAdress(fixed_tuple_list)*:

- *addParticles(particle_list, *properties)*:

  This routine adds particles with certain properties to the storage.

  param particleList list of particles (and properties) to be added

  param properties property strings

  Each particle in the list must be itself a list where each entry corresponds to the property specified in properties.

  Example:

```
>>> addParticles([[id, pos, type, ... ], ...], 'id', 'pos', 'type', ...
 ↪)
```

- *modifyParticle(pid, property, value, decompose='yes')*

  This routine allows to modify any properties of an already existing particle.

  Example:

```
>>> modifyParticle(pid, 'pos', Real3D(new_x, new_y, new_z))
```

- *removeAllParticles()*:

  This routine removes all particles from the storage.

- 'system':

  The property 'system' returns the System object of the storage.

Examples:

```
>>> s.storage.addParticles([[1, espressopp.Real3D(3,3,3)], [2, espressopp.
 ↪Real3D(4,4,4)]],'id','pos')
>>> s.storage.decompose()
>>> s.storage.modifyParticle(15, 'pos', Real3D(new_x, new_y, new_z))
```

espressopp.storage.Storage.**addAdrATParticle**(*pid*, **args*)

Parameters

- **pid** –
- ***args** –

Return type

espressopp.storage.Storage.**addParticle**(*pid*, *pos*)

Parameters

- **pid** –
- **pos** –

Return type

espressopp.storage.Storage.**addParticles**(*particleList*, **properties*)

Parameters

- **particleList** –
- ***properties** –

Return type

espressopp.storage.Storage.**clearSavedPositions**()

Return type

espressopp.storage.Storage.**getParticle**(*pid*)

Parameters **pid** –

Return type

espressopp.storage.Storage.**getRealParticleIDs**()

Return type

espressopp.storage.Storage.**modifyParticle**(*pid*, *property*, *value*)

Parameters

- **pid** –
- **property** –
- **value** –

Return type

espressopp.storage.Storage.**particleExists**(*pid*)

Parameters **pid** –

Return type

espressopp.storage.Storage.**printRealParticles**()

Return type

espressopp.storage.Storage.**removeAllParticles**()

Return type

espressopp.storage.Storage.**removeParticle**(*pid*)

Parameters **pid** –

Return type

espressopp.storage.Storage.**restorePositions**()

Return type

espressopp.storage.Storage.**savePositions**(*idList*)

Parameters **idList** –

Return type

espressopp.storage.Storage.**setFixedTuplesAdress**(*fixedtuples*)

Parameters **fixedtuples** –

4.7 BerendsenBarostat - Berendsen barostat Object

This is the Berendsen barostat implementation according to the original paper *[Berendsen84]*. If Berendsen barostat is defined (as a property of integrator) then at the each run the system size and the particle coordinates will be scaled by scaling parameter μ according to the formula:

$$\mu = [1 - \Delta t/\tau(P_0 - P)]^{1/3}$$

where Δt - integration timestep, τ - time parameter (coupling parameter), P_0 - external pressure and P - instantaneous pressure.

Example:

```
>>> berendsenP = espressopp.integrator.BerendsenBarostat(system)
>>> berendsenP.tau = 0.1
>>> berendsenP.pressure = 1.0
>>> integrator.addExtension(berendsenP)
```

!IMPORTANT In order to run *npt* simulation one should separately define thermostat as well (e.g. Berendsen-Thermostat).

Definition:

In order to define the Berendsen barostat

```
>>> berendsenP = espressopp.integrator.BerendsenBarostat(system)
```

one should have the System defined.

Properties:

- *berendsenP.tau*

  The property 'tau' defines the time parameter τ.

- *berendsenP.pressure*

  The property 'pressure' defines the external pressure P_0.

Setting the integration property:

```
>>> integrator.addExtension(berendsenP)
```

It will define Berendsen barostat as a property of integrator.

One more example:

```
>>> berendsen_barostat = espressopp.integrator.BerendsenBarostat(system)
>>> berendsen_barostat.tau = 10.0
>>> berendsen_barostat.pressure = 3.5
>>> integrator.addExtension(berendsen_barostat)
```

Canceling the barostat:

If one do not need the pressure regulation in system anymore or need to switch the ensamble or whatever :)

```
>>> # define barostat with parameters
>>> berendsen = espressopp.integrator.BerendsenBarostat(system)
>>> berendsen.tau = 0.8
>>> berendsen.pressure = 15.0
>>> integrator.addExtension(berendsen)
>>> ...
>>> # some runs
>>> ...
>>> # disconnect Berendsen barostat
```

```
>>> berendsen.disconnect()
>>> # the next runs will not include the system size and particle␣
↪coordinates scaling
```

Connecting the barostat back after the disconnection

```
>>> berendsen.connect()
```

References:

espressopp.integrator.**BerendsenBarostat**(*system*)

Parameters **system** –

4.8 BerendsenThermostat - Berendsen thermostat Object

This is the Berendsen thermostat implementation according to the original paper *[Berendsen84]*. If Berendsen thermostat is defined (as a property of integrator) then at the each run the system size and the particle coordinates will be scaled by scaling parameter λ according to the formula:

$$\lambda = [1 + \Delta t/\tau_T(T_0/T - 1)]^{1/2}$$

where Δt - integration timestep, τ_T - time parameter (coupling parameter), T_0 - external temperature and T - instantaneous temperature.

Example:

```
>>> berendsenT = espressopp.integrator.BerendsenThermostat(system)
>>> berendsenT.tau = 1.0
>>> berendsenT.temperature = 1.0
>>> integrator.addExtension(berendsenT)
```

Definition:

In order to define the Berendsen thermostat

```
>>> berendsenT = espressopp.integrator.BerendsenThermostat(system)
```

one should have the System defined.

Properties:

- *berendsenT.tau*

  The property 'tau' defines the time parameter τ_T.

- *berendsenT.temperature*

  The property 'temperature' defines the external temperature T_0.

Setting the integration property:

```
>>> integrator.addExtension(berendsenT)
```

It will define Berendsen thermostat as a property of integrator.

One more example:

```
>>> berendsen_thermostat = espressopp.integrator.BerendsenThermostat(system)
>>> berendsen_thermostat.tau = 0.1
>>> berendsen_thermostat.temperature = 3.2
>>> integrator.addExtension(berendsen_thermostat)
```

Canceling the thermostat:

```
>>> # define thermostat with parameters
>>> berendsen = espressopp.integrator.BerendsenThermostat(system)
>>> berendsen.tau = 2.0
>>> berendsen.temperature = 5.0
>>> integrator.addExtension(berendsen)
>>> ...
>>> # some runs
>>> ...
>>> # disconnect Berendsen thermostat
>>> berendsen.disconnect()
```

Connecting the thermostat back after the disconnection

```
>>> berendsen.connect()
```

espressopp.integrator.**BerendsenThermostat**(*system*)

Parameters **system** –

4.9 LangevinBarostat - Langevin-Hoover barostat Object

This is the barostat implementation to perform Langevin dynamics in a Hoover style extended system according to the paper *[Quigley04]*. It includes corrections of Hoover approach which were introduced by Martyna et al *[Martyna94]*. If LangevinBarostat is defined (as a property of integrator) the integration equations will be modified. The volume of system V is introduced as a dynamical variable:

$$\dot{\boldsymbol{r}}_i = \frac{\boldsymbol{p}_i}{m_i} + \frac{p_\epsilon}{W}\boldsymbol{r}_i$$

$$\dot{\boldsymbol{p}}_i = -\bigtriangledown_{\boldsymbol{r}_i}\Phi - (1+\frac{n}{N_f})\frac{p_\epsilon}{W}\boldsymbol{p}_i - \gamma\boldsymbol{p}_i + \boldsymbol{R}_i$$

$$\dot{V} = dVp_\epsilon/W$$

$$\dot{p}_\epsilon = nV(X - P_{ext}) + \frac{n}{N_f}\sum_{i=1}^{N}\frac{\boldsymbol{p}_i^2}{m_i} - \gamma_p p_\epsilon + R_p$$

where volume has a fictitious mass W and associated momentum p_ϵ, γ_p - friction coefficient, P_{ext} - external pressure and X - instantaneous pressure without white noise contribution from thermostat, n - dimension, N_f - degrees of freedom (if there are no constrains and N is the number of particles in system $N_f = nN$). R_p - values which are drawn from Gaussian distribution of zero mean and unit variance scaled by

$$\sqrt{\frac{2k_BTW\gamma_p}{\Delta t}}$$

!IMPORTANT Terms $-\gamma\boldsymbol{p}_i + \boldsymbol{R}_i$ correspond to the termostat. They are not included here and will not be calculated if the Langevin Thermostat is not defined.

Example:

```
>>> rng = espressopp.esutil.RNG()
>>> langevinP = espressopp.integrator.LangevinBarostat(system, rng,␣
↪desiredTemperature)
>>> langevinP.gammaP = 0.05
>>> langevinP.pressure = 1.0
>>> langevinP.mass = pow(10.0, 4)
>>> integrator.addExtension(langevinP)
```

!IMPORTANT This barostat is supposed to be run in a couple with thermostat in order to simulate the *npt* ensamble, because the term R_p needs the temperature as a parameter.

Definition:

In order to define the Langevin-Hoover barostat

```
>>> langevinP = espressopp.integrator.LangevinBarostat(system, rng,␣
↪desiredTemperature)
```

one should have the System and *RNG* defined and know the desired temperature.

Properties:

- *langevinP.gammaP*

  The property 'gammaP' defines the friction coefficient γ_p.

- *langevinP.pressure*

  The property 'pressure' defines the external pressure P_{ext}.

- *langevinP.mass*

  The property 'mass' defines the fictitious mass W.

Methods:

- *setMassByFrequency(frequency)*

  Set the proper *langevinP.mass* using expression $W = dNk_bT/\omega_b^2$, where frequency, ω_b, is the frequency of required volume fluctuations. The value of ω_b should be less then the lowest frequency which appears in the NVT temperature spectrum *[Quigley04]* in order to match the canonical distribution. d - dimensions, N - number of particles, k_b - Boltzmann constant, T - desired temperature.

NOTE The *langevinP.mass* can be set both directly and using the (*setMassByFrequency(frequency)*)

Adding to the integration:

```
>>> integrator.addExtension(langevinP)
```

It will define Langevin-Hoover barostat as a property of integrator.

One more example:

```
>>> rngBaro = espressopp.esutil.RNG()
>>> lP = espressopp.integrator.LangevinBarostat(system, rngBaro,␣
↪desiredTemperature)
>>> lP.gammaP = .5
>>> lP.pressure = 1.0
>>> lP.mass = pow(10.0, 5)
>>> integrator.addExtension(lP)
```

Canceling the barostat:

If one do not need the pressure regulation in system anymore or need to switch the ensamble or whatever :)

```
>>> # define barostat with parameters
>>> rngBaro = espressopp.esutil.RNG()
>>> lP = espressopp.integrator.LangevinBarostat(system, rngBaro,␣
↪desiredTemperature)
>>> lP.gammaP = .5
>>> lP.pressure = 1.0
>>> lP.mass = pow(10.0, 5)
>>> integrator.langevinBarostat = lP
>>> ...
>>> # some runs
>>> ...
>>> # disconnect barostat
>>> langevinBarostat.disconnect()
>>> # the next runs will not include the modification of␣
↪integration equations
```

Connecting the barostat back after the disconnection

```
>>> langevinBarostat.connect()
```

References:

espressopp.integrator.**LangevinBarostat**(*system*, *rng*, *temperature*)

Parameters

- **system** –
- **rng** –
- **temperature** –

4.10 CoulombRSpace - Coulomb potential and interaction Objects (*R* space part)

$$\sum_{i=1}^{N} \sum_{\substack{j>i \\ r_{ij}<k_{max}}} \frac{q_i q_j}{r_{ij}} erfc(\alpha r_{ij}) - \frac{\alpha}{\sqrt{\pi}} \sum_{i=1}^{N} q_i^2$$

This is the *R* space part of potential of Coulomb long range interaction according to the Ewald summation technique. Good explanation of Ewald summation could be found here *[Allen89]*, *[Deserno98]*.

Example:

```
>>> vl = espressopp.VerletList(system, rspacecutoff+skin)
>>> coulombR_pot = espressopp.interaction.CoulombRSpace(coulomb_prefactor, alpha,␣
↪rspacecutoff)
>>> coulombR_int = espressopp.interaction.VerletListCoulombRSpace(vl)
>>> coulombR_int.setPotential(type1=0, type2=0, potential = coulombR_pot)
>>> system.addInteraction(coulombR_int)
```

!IMPORTANT Coulomb interaction needs k-space part as well EwaldKSpace.

Definition:

It provides potential object *CoulombRSpace* and interaction object *VerletListCoulombRSpace*

The *potential* is based on parameters: Coulomb prefactor (coulomb_prefactor), Ewald parameter (alpha), and the cutoff in R space (rspacecutoff).

```
>>> coulombR_pot = espressopp.interaction.CoulombRSpace(coulomb_
↪prefactor, alpha, rspacecutoff)
```

Potential Properties:

- *coulombR_pot.prefactor*

  The property 'prefactor' defines the Coulomb prefactor.

- *coulombR_pot.alpha*

  The property 'alpha' defines the Ewald parameter *alpha*.

- *coulombR_pot.cutoff*

  The property 'cutoff' defines the cutoff in R space.

The *interaction* is based on the Verlet list (*VerletList*)

```
>>> vl = espressopp.VerletList(system, rspacecutoff+skin)
>>> coulombR_int = espressopp.interaction.VerletListCoulombRSpace(vl)
```

It should include at least one potential

```
>>> coulombR_int.setPotential(type1=0, type2=0, potential = coulombR_pot)
```

Interaction Methods:

- *setPotential(type1, type2, potential)*

  This method sets the *potential* for the particles of *type1* and *type2*. It could be a bunch of potentials for the different particle types.

- *getVerletListLocal()*

  Access to the local Verlet list.

Adding the interaction to the system:

```
>>> system.addInteraction(coulombR_int)
```

espressopp.interaction.**CoulombRSpace**(*prefactor*, *alpha*, *cutoff*)

Parameters

- **prefactor** (*real*) – (default: 1.0)
- **alpha** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)

espressopp.interaction.**VerletListCoulombRSpace**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListCoulombRSpace.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListCoulombRSpace.**getVerletList**()

Return type A Python list of lists.

espressopp.interaction.VerletListCoulombRSpace.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

4.11 CoulombKSpaceEwald - Coulomb potential and interaction Objects (*K* space part)

$$\frac{1}{2\pi V} \sum_{\substack{m\in\mathbb{Z}^3 \\ 0<|m|<k_{max}}} \frac{exp(-\frac{\pi^2}{\alpha^2}m'^2)}{m'^2} \left| \sum_{i=1}^{N} q_i \cdot exp(2\pi i r_i \cdot m') \right|^2$$

This is the *K* space part of potential of Coulomb long range interaction according to the Ewald summation technique. Good explanation of Ewald summation could be found here *[Allen89]*, *[Deserno98]*.

Example:

```
>>> ewaldK_pot = espressopp.interaction.CoulombKSpaceEwald(system, coulomb_
↪prefactor, alpha, kspacecutoff)
>>> ewaldK_int = espressopp.interaction.CellListCoulombKSpaceEwald(system.storage,␣
↪ewaldK_pot)
>>> system.addInteraction(ewaldK_int)
```

!IMPORTANT Coulomb interaction needs *R* space part as well CoulombRSpace.

Definition:

It provides potential object *CoulombKSpaceEwald* and interaction object *CellListCoulombKSpaceEwald* based on all particles list.

The *potential* is based on the system information (System) and parameters: Coulomb prefactor (coulomb_prefactor), Ewald parameter (alpha), and the cutoff in K space (kspacecutoff).

```
>>> ewaldK_pot = espressopp.interaction.CoulombKSpaceEwald(system,␣
↪coulomb_prefactor, alpha, kspacecutoff)
```

Potential Properties:

- *ewaldK_pot.prefactor*

  The property 'prefactor' defines the Coulomb prefactor.

- *ewaldK_pot.alpha*

  The property 'alpha' defines the Ewald parameter $alpha$.

- *ewaldK_pot.kmax*

  The property 'kmax' defines the cutoff in *K* space.

The *interaction* is based on the all particles list. It needs the information from Storage and *K* space part of potential.

```
>>> ewaldK_int = espressopp.interaction.CellListCoulombKSpaceEwald(system.
↪storage, ewaldK_pot)
```

Interaction Methods:

- *getPotential()*

  Access to the local potential.

Adding the interaction to the system:

```
>>> system.addInteraction(ewaldK_int)
```

References:

espressopp.interaction.**CoulombKSpaceEwald**(*system*, *prefactor*, *alpha*, *kmax*)

Parameters

- **system** –
- **prefactor** –
- **alpha** –
- **kmax** –

espressopp.interaction.**CellListCoulombKSpaceEwald**(*storage*, *potential*)

Parameters

- **storage** –

- **potential** –

espressopp.interaction.CellListCoulombKSpaceEwald.**getFixedPairList**()

Return type A Python list of lists.

espressopp.interaction.CellListCoulombKSpaceEwald.**getPotential**()

Return type

4.12 decomp.py - Auxiliary python functions

- *nodeGrid(n)*:

  It determines how the processors are distributed and how the cells are arranged. *n* - number of processes

- *cellGrid(box_size, node_grid, rc, skin)*:

  It returns an appropriate grid of cells.

- *tuneSkin(system, integrator, minSkin=0.01, maxSkin=1.2, precision=0.001)*:

  It tunes the skin size for the current system

- *printTimeVsSkin(system, integrator, minSkin=0.01, maxSkin=1.5, skinStep = 0.01)*:

  It prints time of running versus skin size in the range [minSkin, maxSkin] with the step skinStep

4.13 espressopp

4.13.1 espressopp.Exceptions

espressopp.**Error**(*msg*)

Parameters **msg** –

espressopp.**ParticleDoesNotExistHere**(*msg*)

Parameters **msg** –

espressopp.**UnknownParticleProperty**(*msg*)

Parameters **msg** –

espressopp.**MissingFixedPairList**(*msg*)

Parameters **msg** –

4.13.2 espressopp.FixedPairDistList

espressopp.**FixedPairDistList**(*storage*)

Parameters **storage** –

espressopp.FixedPairDistList.**add**(*pid1*, *pid2*)

Parameters

- **pid1** –
- **pid2** –

Return type

espressopp.FixedPairDistList.**addPairs**(*bondlist*)

Parameters **bondlist** –

Return type

espressopp.FixedPairDistList.**getDist**(*pid1*, *pid2*)

Parameters

- **pid1** –
- **pid2** –

Return type

espressopp.FixedPairDistList.**getPairs**()

Return type

espressopp.FixedPairDistList.**getPairsDist**()

Return type

espressopp.FixedPairDistList.**size**()

Return type

4.13.3 espressopp.FixedPairList

espressopp.**FixedPairList**(*storage*)

Parameters **storage** –

espressopp.FixedPairList.**add**(*pid1*, *pid2*)

Parameters

- **pid1** –
- **pid2** –

Return type

espressopp.FixedPairList.**addBonds**(*bondlist*)

Parameters **bondlist** –

Return type

espressopp.FixedPairList.**getBonds**()

Return type

espressopp.FixedPairList.**getLongtimeMaxBond**()

Return type

espressopp.FixedPairList.**resetLongtimeMaxBond**()

Return type

espressopp.FixedPairList.**size**()

Return type

4.13.4 FixedPairListAdress - Object

The FixedPairListAdress is the Fixed Pair List to be used for AdResS or H-AdResS simulations. When creating the FixedPairListAdress one has to provide the storage and the tuples. Afterwards the bonds can be added. In the example "bonds" is a python list of the form ((pid1, pid2), (pid3, pid4), ...) where each inner pair defines a bond between the particles with the given particle ids.

Example - creating the FixedPairListAdress and adding bonds:

```
>>> ftpl = espressopp.FixedTupleList(system.storage)
>>> fpl = espressopp.FixedPairListAdress(system.storage, ftpl)
>>> fpl.addBonds(bonds)
```

espressopp.**FixedPairListAdress**(*storage*, *fixedtupleList*)

Parameters

- **storage** –
- **fixedtupleList** –

espressopp.FixedPairListAdress.**add**(*pid1*, *pid2*)

Parameters

- **pid1** –
- **pid2** –

Return type

espressopp.FixedPairListAdress.**addBonds**(*bondlist*)

Parameters **bondlist** –

Return type

espressopp.FixedPairListAdress.**getBonds**()

Return type

4.13.5 espressopp.FixedQuadrupleAngleList

espressopp.**FixedQuadrupleAngleList**(*storage*)

Parameters **storage** –

espressopp.FixedQuadrupleAngleList.**add**(*pid1*, *pid2*, *pid3*, *pid4*)

Parameters

- **pid1** –
- **pid2** –
- **pid3** –
- **pid4** –

Return type

espressopp.FixedQuadrupleAngleList.**addQuadruples**(*quadruplelist*)

Parameters **quadruplelist** –

Return type

espressopp.FixedQuadrupleAngleList.**getAngle**(*pid1*, *pid2*, *pid3*, *pid4*)

Parameters

- **pid1** –
- **pid2** –
- **pid3** –
- **pid4** –

Return type

espressopp.FixedQuadrupleAngleList.**getQuadruples**()

Return type

espressopp.FixedQuadrupleAngleList.**getQuadruplesAngles**()

Return type

espressopp.FixedQuadrupleAngleList.**size**()

Return type

4.13.6 espressopp.FixedQuadrupleList

espressopp.**FixedQuadrupleList**(*storage*)

Parameters **storage** –

espressopp.FixedQuadrupleList.**add**(*pid1*, *pid2*, *pid3*, *pid4*)

Parameters

- **pid1** –
- **pid2** –
- **pid3** –
- **pid4** –

Return type

espressopp.FixedQuadrupleList.**addQuadruples**(*quadruplelist*)

Parameters **quadruplelist** –

Return type

espressopp.FixedQuadrupleList.**getQuadruples**()

Return type

espressopp.FixedQuadrupleList.**size**()

Return type

4.13.7 espressopp.FixedSingleList

espressopp.**FixedSingleList**(*storage*)

Parameters **storage** –

espressopp.FixedSingleList.**add**(*pid1*)

Parameters **pid1** –

Return type

espressopp.FixedSingleList.**addSingles**(*singlelist*)

Parameters **singlelist** –

Return type

espressopp.FixedSingleList.**getSingles**()

Return type

espressopp.FixedSingleList.**size**()

Return type

4.13.8 espressopp.FixedTripleAngleList

espressopp.**FixedTripleAngleList**(*storage*)

Parameters **storage** –

espressopp.FixedTripleAngleList.**add**(*pid1*, *pid2*, *pid3*)

Parameters

- **pid1** –
- **pid2** –
- **pid3** –

Return type

espressopp.FixedTripleAngleList.**addTriples**(*triplelist*)

Parameters **triplelist** –

Return type

espressopp.FixedTripleAngleList.**getAngle**(*pid1*, *pid2*, *pid3*)

Parameters

- **pid1** –
- **pid2** –
- **pid3** –

Return type

espressopp.FixedTripleAngleList.**getTriples**()

Return type

espressopp.FixedTripleAngleList.**getTriplesAngles**()

Return type

espressopp.FixedTripleAngleList.**size**()

Return type

4.13.9 espressopp.FixedTripleList

espressopp.**FixedTripleList**(*storage*)

Parameters **storage** –

espressopp.FixedTripleList.**add**(*pid1*, *pid2*, *pid3*)

Parameters

- **pid1** –
- **pid2** –
- **pid3** –

Return type

espressopp.FixedTripleList.**addTriples**(*triplelist*)

Parameters **triplelist** –

Return type

espressopp.FixedTripleList.**getTriples**()

Return type

espressopp.FixedTripleList.**size**()

Return type

4.13.10 espressopp.FixedTripleListAdress

espressopp.**FixedTripleListAdress**(*storage*, *fixedtupleList*)

Parameters

- **storage** –
- **fixedtupleList** –

espressopp.FixedTripleListAdress.**add**(*pid1*, *pid2*)

Parameters

- **pid1** –
- **pid2** –

Return type

espressopp.FixedTripleListAdress.**addTriples**(*triplelist*)

Parameters **triplelist** –

Return type

4.13.11 espressopp.FixedTupleList

espressopp.**FixedTupleList**(*storage*)

Parameters **storage** –

espressopp.FixedTupleList.**size**()

Return type

4.13.12 FixedTupleListAdress - Object

The FixedTupleListAdress is important for AdResS and H-AdResS simulations. It is the connection between the atomistic and coarse-grained particles. It defines which atomistic particles belong to which coarse-grained particle. In the following example "tuples" is a python list of the form ((pid_CG1, pidAT11, pidAT12, pidAT13, ...), (pid_CG2, pidAT21, pidAT22, pidAT23, ...), ...). Each inner list (pid_CG1, pidAT11, pidAT12, pidAT13, ...) defines a tuple. The first number is the particle id of the coarse-grained particle while the following numbers are the particle ids of the corresponding atomistic particles.

Example - creating the FixedTupleListAdress:

```
>>> ftpl = espressopp.FixedTupleListAdress(system.storage)
>>> ftpl.addTuples(tuples)
>>> system.storage.setFixedTuples(ftpl)
```

espressopp.**FixedTupleListAdress**(*storage*)

Parameters **storage** –

espressopp.FixedTupleListAdress.**addTuples**(*tuplelist*)

Parameters **tuplelist** –

Return type

4.13.13 espressopp.Int3D

espressopp.**__Int3D**(**args*)

Parameters ***args** –

espressopp.__Int3D.**x**(*v*, *[0*)

Parameters

- **v** –
- **[0** –

Return type

espressopp.__Int3D.**y**(*v*, *[1*)

Parameters

- **v** –
- **[1** –

Return type

espressopp.__Int3D.**z**(*v*, *[2*)

Parameters

- **v** –
- **[2** –

Return type

espressopp.**toInt3DFromVector**(**args*)

Parameters ***args** –

espressopp.**toInt3D**(**args*)

Parameters ***args** –

espressopp.Int3D.**toInt3D**(**args*)
Try to convert the arguments to a Int3D, returns the argument, if it is already a Int3D.

espressopp.Int3D.**toInt3DFromVector**(**args*)
Try to convert the arguments to a Int3D.

This function will only convert to a Int3D if x, y and z are specified.

4.13.14 espressopp.MultiSystem

espressopp.**MultiSystem**()

espressopp.MultiSystem.**beginSystemDefinition**()

Return type

espressopp.MultiSystem.**runAnalysisNPart**()

Return type

espressopp.MultiSystem.**runAnalysisPotential**()

Return type

espressopp.MultiSystem.**runAnalysisTemperature**()

Return type

espressopp.MultiSystem.**runIntegrator**(*niter*)

Parameters **niter** –

Return type

espressopp.MultiSystem.**setAnalysisNPart**(*npart*)

Parameters **npart** –

espressopp.MultiSystem.**setAnalysisPotential**(*potential*)

Parameters **potential** –

espressopp.MultiSystem.**setAnalysisTemperature**(*temperature*)

Parameters **temperature** –

espressopp.MultiSystem.**setIntegrator**(*integrator*)

Parameters **integrator** –

4.13.15 espressopp.ParallelTempering

espressopp.**ParallelTempering**(*NumberOfSystems*, *RNG*)

Parameters

- **NumberOfSystems** (*int*) – (default: 4)
- **RNG** – (default: None)

espressopp.ParallelTempering.**endDefiningSystem**(*n*)

Parameters **n** –

Return type

espressopp.ParallelTempering.**exchange**()

Return type

espressopp.ParallelTempering.**getNumberOfCPUsPerSystem**()

Return type

espressopp.ParallelTempering.**getNumberOfSystems**()

Return type

espressopp.ParallelTempering.**run**(*nsteps*)

Parameters **nsteps** –

Return type

espressopp.ParallelTempering.**setAnalysisE**(*analysisE*)

Parameters **analysisE** –

espressopp.ParallelTempering.**setAnalysisNPart**(*analysisNPart*)

Parameters **analysisNPart** –

espressopp.ParallelTempering.**setAnalysisT**(*analysisT*)

Parameters **analysisT** –

espressopp.ParallelTempering.**setIntegrator**(*integrator*, *thermostat*)

Parameters

- **integrator** –
- **thermostat** –

espressopp.ParallelTempering.**startDefiningSystem**(*n*)

Parameters **n** –

Return type

4.13.16 espressopp.Particle

espressopp.**Particle**(*pid*, *storage*)

Parameters

- **pid** –
- **storage** –

class espressopp.Particle.**ParticleLocal**(*pid*, *storage*)

The local particle.

Throws an exception: * when the particle does not exists locally

TODO: Should throw an exception: * when a ghost particle is to be written * when data is to be read from a ghost that is not available

4.13.17 ParticleAccess - abstract base class for analysis/measurement/io

espressopp.ParticleAccess.**perform_action**()

Return type

4.13.18 espressopp.ParticleGroup

espressopp.**ParticleGroup**(*storage*)

Parameters **storage** –

espressopp.ParticleGroup.**add**(*pid*)

Parameters **pid** –

Return type

espressopp.ParticleGroup.**has**(*pid*)

Parameters **pid** –

Return type

espressopp.ParticleGroup.**show**()

Return type

espressopp.ParticleGroup.**size**()

Return type

4.13.19 espressopp.Real3D

espressopp.**__Real3D**(**args*)

Parameters ***args** –

espressopp.__Real3D.**x**(*v, [0*)

Parameters

- **v** –
- **[0** –

Return type

espressopp.__Real3D.**y**(*v, [1*)

Parameters

- **v** –
- **[1** –

Return type

espressopp.__Real3D.**z**(*v, [2*)

Parameters

- **v** –
- **[2** –

Return type

espressopp.**toReal3DFromVector**(**args*)

Parameters ***args** –

espressopp.**toReal3D**(**args*)

Parameters ***args** –

espressopp.Real3D.**toReal3D**(**args*)
Try to convert the arguments to a Real3D, returns the argument, if it is already a Real3D.

espressopp.Real3D.**toReal3DFromVector**(**args*)
Try to convert the arguments to a Real3D.

This function will only convert to a Real3D if x, y and z are specified.

4.13.20 RealND -

This is the object which represents N-dimensional vector. It is an extended Real3D, basicly, it hase the same functionallity but in N-dimetions. First of all it is usefull for classes in 'espressopp.analysis'.

Description

...

espressopp.**__RealND**(**args*)

Parameters ***args** –

espressopp.**toRealNDFromVector**(**args*)

Parameters ***args** –

espressopp.**toRealND**(**args*)

Parameters ***args** –

espressopp.RealND.**toRealND**(**args*)
Try to convert the arguments to a RealND, returns the argument, if it is already a RealND.

espressopp.RealND.**toRealNDFromVector**(**args*)
Try to convert the arguments to a RealND.

This function will only convert to a RealND if x, y and z are specified.

4.13.21 espressopp.Tensor

espressopp.Tensor.**toTensor**(**args*)
Try to convert the arguments to a Tensor, returns the argument, if it is already a Tensor.

espressopp.Tensor.**toTensorFromVector**(**args*)
Try to convert the arguments to a Tensor.

This function will only convert to a Tensor if x, y and z are specified.

4.13.22 espressopp.VerletList

espressopp.**VerletList**(*system*, *cutoff*, *exclusionlist*)

Parameters

- **system** –
- **cutoff** –
- **exclusionlist** – (default: [])

espressopp.VerletList.**exclude**(*exclusionlist*)

Parameters **exclusionlist** –

Return type

espressopp.VerletList.**getAllPairs**()

Return type

espressopp.VerletList.**localSize**()

Return type

espressopp.VerletList.**totalSize**()

Return type

4.13.23 VerletListAdress - Object

The VerletListAdress is the Verlet List to be used for AdResS or H-AdResS simulations. When creating the VerletListAdress one has to provide the system and specify both cutoff for the CG interaction and adrcutoff for the atomistic interaction. Often, it is important to set the atomistic adrcutoff much bigger than the actual interaction's cutoff would be, since also the atomistic part of the VerletListAdress (adrPairs) is built based on the coarse-grained particle positions. For a much larger coarse-grained cutoff it is for example possible to also set the atomistic cutoff on the same value as the coarse-grained one.

Furthermore, the sizes of the explicit and hybrid region have to be provided (dEx and dHy in the example below) and the center of the atomistic region has to be set (adrCenter). In the current implementation this results in a resolution change along the x-direction of the box. A spherical symmetry can be obtained by only minor code changes.

Bascially the VerListAdress provides 4 lists:

- adrZone: A list which holds all particles in the atomistic and hybrid region
- cgZone: A list which holds all particles in the coarse-grained region
- adrPairs: A list which holds all pairs which have at least one particle in the adrZone, i.e. in the atomistic or hybrid region
- vlPairs: A list which holds all pairs which have both particles in the cgZone, i.e. in the coarse-grained region

Example - creating the VerletListAdress for a slab-type adress region fixed in space (only the x value of adrCenter is used):

```
>>> vl       = espressopp.VerletListAdress(system, cutoff=rc, adrcut=rc, dEx=ex_
↪size, dHy=hy_size, adrCenter=[Lx/2, Ly/2, Lz/2])
```

or

```
>>> vl       = espressopp.VerletListAdress(system, cutoff=rc, adrcut=rc, dEx=ex_
↪size, dHy=hy_size, adrCenter=[Lx/2, Ly/2, Lz/2], sphereAdr=False)
```

Example - creating the VerletListAdress for a spherical adress region centered on adrCenter and fixed in space:

```
>>> vl       = espressopp.VerletListAdress(system, cutoff=rc, adrcut=rc, dEx=ex_
↪size, dHy=hy_size, adrCenter=[Lx/2, Ly/2, Lz/2], sphereAdr=True)
```

Example - creating the VerletListAdress for a spherical adress region centered on a particle and moving with the particle

```
>>> vl       = espressopp.VerletListAdress(system, cutoff=rc, adrcut=rc, dEx=ex_
↪size, dHy=hy_size, pids=[adrCenterPID], sphereAdr=True)
```

espressopp.**VerletListAdress**(*system*, *cutoff*, *adrcut*, *dEx*, *dHy*, *adrCenter*, *pids*, *exclusionlist*, *sphereAdr*)

Parameters

- **system** –
- **cutoff** –
- **adrcut** –
- **dEx** –
- **dHy** –
- **adrCenter** – (default: [])
- **pids** – (default: [])
- **exclusionlist** – (default: [])
- **sphereAdr** – (default: False)

espressopp.VerletListAdress.**addAdrParticles**(*pids*, *rebuild*)

Parameters

- **pids** –
- **rebuild** – (default: True)

Return type

espressopp.VerletListAdress.**exclude**(*exclusionlist*)

Parameters **exclusionlist** –

Return type

espressopp.VerletListAdress.**rebuild**()

Return type

espressopp.VerletListAdress.**totalSize**()

Return type

4.13.24 espressopp.VerletListTriple

espressopp.**VerletListTriple**(*system*, *cutoff*, *exclusionlist*)

Parameters

- **system** –
- **cutoff** –
- **exclusionlist** – (default: [])

espressopp.VerletListTriple.**exclude**(*exclusionlist*)

Parameters **exclusionlist** –

Return type

espressopp.VerletListTriple.**getAllTriples**()

Return type

espressopp.VerletListTriple.**localSize**()

Return type

espressopp.VerletListTriple.**totalSize**()

Return type

4.14 analysis

4.14.1 espressopp.analysis.AllParticlePos

espressopp.analysis.AllParticlePos.**gatherAllPositions**()

Return type

4.14.2 AnalysisBase - abstract base class for analysis/measurement

This abstract base class provides the interface and some basic functionality for classes that do analysis or observable measurements

It provides the following methods:

espressopp.analysis.AnalysisBase.**compute**()
Computes the instant value of the observable.

Return type a python list or a scalar

espressopp.analysis.AnalysisBase.**getAverageValue**()
Returns the average value for the observable and the standard deviation.

Return type a python list

espressopp.analysis.AnalysisBase.**getNumberOfMeasurements**()
counts the number of measurements that have been performed (standalone or in integrator) does _not_ include measurements that have been done using "compute()"

Return type

espressopp.analysis.AnalysisBase.**performMeasurement**()
Computes the observable and updates average and standard deviation

Return type

espressopp.analysis.AnalysisBase.**reset**()
Resets average and standard deviation

Return type

4.14.3 espressopp.analysis.Autocorrelation

espressopp.analysis.**Autocorrelation**(*system*)

Parameters **system** –

espressopp.analysis.Autocorrelation.**clear**()

Return type

espressopp.analysis.Autocorrelation.**compute**()

Return type

espressopp.analysis.Autocorrelation.**gather**(*value*)

Parameters **value** –

Return type

4.14.4 espressopp.analysis.CenterOfMass

espressopp.analysis.**CenterOfMass**(*system*)

Parameters **system** –

4.14.5 espressopp.analysis.ConfigsParticleDecomp

espressopp.analysis.**ConfigsParticleDecomp**(*system*)

Parameters **system** –

espressopp.analysis.ConfigsParticleDecomp.**clear**()

Return type

espressopp.analysis.ConfigsParticleDecomp.**compute**()

Return type

espressopp.analysis.ConfigsParticleDecomp.**gather**()

Return type

espressopp.analysis.ConfigsParticleDecomp.**gatherFromFile**(*filename*)

Parameters **filename** –

Return type

4.14.6 Configurations - Configurations Object

- *gather()* add configuration to trajectory
- *clear()* clear trajectory
- *back()* get last configuration of trajectory
- *capacity* maximum number of configurations in trajectory further adding (*gather()*) configurations results in erasing oldest configuration before adding new one capacity=0 means: infinite capacity (until memory is full)

- *size* number of stored configurations

usage:

storing trajectory

```
>>> configurations = espressopp.Configurations(system)
>>> configurations.gather()
>>> for k in range(100):
>>>   integrator.run(100)
>>>   configurations.gather()
```

accessing trajectory data:

iterate over all stored configurations:

```
>>> for conf in configurations:
```

iterate over all particles stored in configuration:

```
>>>   for pid in conf
>>>     particle_coords = conf[pid]
>>>     print pid, particle_coords
```

access particle with id <pid> of stored configuration <n>:

```
>>> print "particle coord: ",configurations[n][pid]
```

espressopp.analysis.**Configurations**(*system*)

Parameters **system** –

espressopp.analysis.Configurations.**back**()

Return type

espressopp.analysis.Configurations.**clear**()

Return type

espressopp.analysis.Configurations.**gather**()

Return type

4.14.7 ConfigurationsExt - ConfigurationsExt Object

- *gather()* add configuration to trajectory
- *clear()* clear trajectory
- *back()* get last configuration of trajectory
- *capacity* maximum number of configurations in trajectory further adding (*gather()*) configurations results in erasing oldest configuration before adding new one capacity=0 means: infinite capacity (until memory is full)
- *size* number of stored configurations

usage:

storing trajectory

```
>>> configurations = espressopp.ConfigurationsExt(system)
>>> configurations.gather()
>>> for k in range(100):
>>>   integrator.run(100)
>>>   configurations.gather()
```

accessing trajectory data:

iterate over all stored configurations:

```
>>> for conf in configurations:
```

iterate over all particles stored in configuration:

```
>>>   for pid in conf
>>>     particle_coords = conf[pid]
>>>     print pid, particle_coords
```

access particle with id <pid> of stored configuration <n>:

```
>>> print "particle coord: ",configurations[n][pid]
```

espressopp.analysis.**ConfigurationsExt**(*system*)

Parameters **system** –

espressopp.analysis.ConfigurationsExt.**back**()

Return type

espressopp.analysis.ConfigurationsExt.**clear**()

Return type

espressopp.analysis.ConfigurationsExt.**gather**()

Return type

4.14.8 espressopp.analysis.Energy

espressopp.analysis.**EnergyPot**(*system*, *per_atom*)

Parameters

- **system** –
- **per_atom** – (default: False)

espressopp.analysis.EnergyPot.**compute**()

Return type

espressopp.analysis.**EnergyKin**(*system*, *per_atom*)

Parameters

- **system** –
- **per_atom** – (default: False)

espressopp.analysis.EnergyKin.**compute**()

Return type

espressopp.analysis.**EnergyTot**(*system*, *per_atom*)

Parameters

- **system** –
- **per_atom** – (default: False)

espressopp.analysis.EnergyTot.**compute**()

Return type

4.14.9 espressopp.analysis.IntraChainDistSq

espressopp.analysis.**IntraChainDistSq**(*system*, *fpl*)

Parameters

- **system** –
- **fpl** –

espressopp.analysis.IntraChainDistSq.**compute**()

Return type

4.14.10 LBOutput - abstract base class for analysis / output in LB simulations

Abstract base class for arbitrary output from LB simulations. At the moment, the implemented realisations are:

- *espressopp.analysis.LBOutputScreen* to output local density rho and v_z component of the velocity as a function of the coordinate x.
- *espressopp.analysis.LBOutputVzInTime* to output velocity component v_z of a specific lattice site (the value used at the moment is $0.25 * N_i, 0, 0$) in time.
- *espressopp.analysis.LBOutputVzOfX* to output simulation progress and control flux conservation when using MD to LB coupling.

Note: Other types of output classes are possible. It is a subject of user requests.

4.14.11 LBOutputScreen - controls screen output in LB-simulations

Child class derived from the abstract class *espressopp.analysis.LBOutput*. It computes and outputs to the screen the simulation progress (finished step) and controls mass flux conservation when using MD-to-LB coupling. Ideally, the sum of mass fluxes should be zero, i.e. $j_{LB} + j_{MD} = 0$.

espressopp.analysis.**LBOutputScreen**(*system*, *latticeboltzmann*)

Parameters

- **system** – system object defined earlier in the python-script
- **latticeboltzmann** – lattice boltzmann object defined earlier in the python-script

Note: this class should be called from external analysis class *espressopp.integrator.ExtAnalyze* with specified periodicity of invokation and after this added to the integrator. See an example for details.

Example to call the profiler:

```
>>> # initialise profiler (for example with the name outputScreen) with system and
>>> # lattice boltzmann objects as parameters:
>>> outputScreen = espressopp.analysis.LBOutputScreen(system,lb)
>>>
>>> # initialise external analysis object (for example extAnalysisNum1) with
>>> # previously created profiler and periodicity of invocation in steps:
>>> extAnalysisNum1=espressopp.integrator.ExtAnalyze(outputScreen,100)
>>>
>>> # add the external analysis object as an extension to the integrator
>>> integrator.addExtension(extAnalysisNum1)
```

espressopp.analysis.**LBOutputScreen**(*system*, *latticeboltzmann*)

Parameters

- **system** –
- **latticeboltzmann** –

4.14.12 LBOutputVzInTime - controls output of the velocity component on a site in time

Child class derived from the abstract class *espressopp.analysis.LBOutput*. It computes and outputs the velocity component v_z in time on a specific lattice site (the value used at the moment is $0.25 * N_i, 0, 0$).

espressopp.analysis.**LBOutputVzInTime**(*system*, *latticeboltzmann*)

Parameters

- **system** – system object defined earlier in the python-script
- **latticeboltzmann** – lattice boltzmann object defined earlier in the python-script

Note: this class should be called from external analysis class *espressopp.integrator.ExtAnalyze* with specified periodicity of invokation and after this added to the integrator. See an example for details.

Example to call the profiler:

```
>>> # initialise profiler (for example with the name outputVzInTime) with system␣
 ↪and
>>> # lattice boltzmann objects as parameters:
>>> outputVzInTime = espressopp.analysis.LBOutputVzInTime(system,lb)
>>>
>>> # initialise external analysis object (for example extAnalysisNum2) with
>>> # previously created profiler and periodicity of invocation in steps:
>>> extAnalysisNum2=espressopp.integrator.ExtAnalyze(outputVzInTime,100)
>>>
>>> # add the external analysis object as an extension to the integrator
>>> integrator.addExtension(extAnalysisNum2)
```

espressopp.analysis.**LBOutputVzInTime**(*system*, *latticeboltzmann*)

Parameters

- **system** –
- **latticeboltzmann** –

4.14.13 LBOutputVzOfX - controls output of the velocity component profile

Child class derived from the abstract class *espressopp.analysis.LBOutput*. It computes and outputs simulation progress (finished step) and controls flux conservation when using MD to LB coupling.

espressopp.analysis.**LBOutputVzOfX**(*system*, *latticeboltzmann*)

Parameters

- **system** – system object defined earlier in the python-script
- **latticeboltzmann** – lattice boltzmann object defined earlier in the python-script

Note: this class should be called from external analysis class *espressopp.integrator.ExtAnalyze* with specified periodicity of invokation and after this added to the integrator. See an example for details.

Example to call the profiler:

```
>>> # initialise profiler (for example with the name outputVzOfX) with system and
>>> # lattice boltzmann objects as parameters:
>>> outputVzOfX = espressopp.analysis.LBOutputVzOfX(system,lb)
>>>
>>> # initialise external analysis object (for example extAnalysisNum3) with
>>> # previously created profiler and periodicity of invocation in steps:
>>> extAnalysisNum3=espressopp.integrator.ExtAnalyze(outputVzOfX,100)
>>>
>>> # add the external analysis object as an extension to the integrator
>>> integrator.addExtension(extAnalysisNum3)
```

espressopp.analysis.**LBOutputVzOfX**(*system*, *latticeboltzmann*)

Parameters

- **system** –
- **latticeboltzmann** –

4.14.14 espressopp.analysis.MaxPID

espressopp.analysis.**MaxPID**(*system*)

Parameters **system** –

4.14.15 espressopp.analysis.MeanSquareDispl

espressopp.analysis.**MeanSquareDispl**(*system*, *chainlength*)

Parameters

- **system** –
- **chainlength** – (default: None)

espressopp.analysis.MeanSquareDispl.**computeG2**()

Return type

espressopp.analysis.MeanSquareDispl.**computeG3**()

Return type

espressopp.analysis.MeanSquareDispl.**strange**()

Return type

4.14.16 espressopp.analysis.NPart

espressopp.analysis.**NPart**(*system*)

Parameters **system** –

4.14.17 espressopp.analysis.NeighborFluctuation

espressopp.analysis.**NeighborFluctuation**(*system*, *radius*)

Parameters

- **system** –
- **radius** –

4.14.18 espressopp.analysis.Observable

espressopp.analysis.Observable.**compute**()

Return type

4.14.19 espressopp.analysis.OrderParameter

espressopp.analysis.**OrderParameter**(*system*, *cutoff*, *angular_momentum*, *do_cluster_analysis*, *include_surface_particles*, *ql_low*, *ql_high*)

Parameters

- **system** –
- **cutoff** –
- **angular_momentum** (*int*) – (default: 6)
- **do_cluster_analysis** – (default: False)
- **include_surface_particles** – (default: False)
- **ql_low** – (default: -1.0)
- **ql_high** (*real*) – (default: 1.0)

4.14.20 espressopp.analysis.ParticleRadiusDistribution

espressopp.analysis.**ParticleRadiusDistribution**(*system*)

Parameters **system** –

4.14.21 espressopp.analysis.PotentialEnergy

The object that computes potential energy of different interactions.

espressopp.analysis.**PotentialEnergy**(*system*, *potential*, *compute_method=None*)

Parameters

- **system** (espressopp.System) – The system object
- **interaction** (espressopp.interaction.Interaction) – The interaction object.
- **compute_method** (*str*) – If set to *ALL* (default) then compute total potential energies, if set to *CG* then compute only coarse-grained part (if feasible), if set to *AT* then compute only atomitic part of potential energy.

4.14.22 espressopp.analysis.Pressure

espressopp.analysis.**Pressure**(*system*)

Parameters **system** –

4.14.23 PressureTensor - Analysis

This class computes the pressure tensor of the system. It can be used as standalone class in python as well as in combination with the integrator extension ExtAnalyze.

Standalone Usage:

```
>>> pt = espressopp.analysis.PressureTensor(system)
>>> print "pressure tensor of current configuration = ", pt.compute()
```

or

```
>>> pt = espressopp.analysis.PressureTensor(system)
>>> for k in range(100):
>>>     integrator.run(100)
>>>     pt.performMeasurement()
>>> print "average pressure tensor = ", pt.getAverageValue()
```

Usage in integrator with ExtAnalyze:

```
>>> pt           = espressopp.analysis.PressureTensor(system)
>>> extension_pt = espressopp.integrator.ExtAnalyze(pt , interval=100)
>>> integrator.addExtension(extension_pt)
>>> integrator.run(10000)
>>> pt_ave = pt.getAverageValue()
>>> print "average Pressure Tensor = ", pt_ave[:6]
>>> print "          std deviation = ", pt_ave[6:]
>>> print "number of measurements  = ", pt.getNumberOfMeasurements()
```

The following methods are supported:

- **performMeasurement()** computes the pressure tensor and updates average and standard deviation
- **reset()** resets average and standard deviation to 0
- **compute()** computes the instant pressure tensor, return value: [xx, yy, zz, xy, xz, yz]
- **getAverageValue()** returns the average pressure tensor and the standard deviation, return value: [xx, yy, zz, xy, xz, yz, +-xx, +-yy, +-zz, +-xy, +-xz, +-yz]
- **getNumberOfMeasurements()** counts the number of measurements that have been computed (standalone or in integrator) does _not_ include measurements that have been done using "compute()"

espressopp.analysis.**PressureTensor**(*system*)

Parameters **system** –

4.14.24 PressureTensorLayer - Analysis

This class computes the pressure tensor of the system in layer h0. It can be used as standalone class in python as well as in combination with the integrator extension ExtAnalyze.

Standalone Usage:

```
>>> pt = espressopp.analysis.PressureTensorLayer(system, h0, dh)
>>> print "pressure tensor of current configuration = ", pt.compute()
```

or

```
>>> pt = espressopp.analysis.PressureTensorLayer(system)
>>> for k in range(100):
>>>     integrator.run(100)
>>>     pt.performMeasurement()
>>> print "average pressure tensor = ", pt.getAverageValue()
```

Usage in integrator with ExtAnalyze:

```
>>> pt           = espressopp.analysis.PressureTensorLayer(system)
>>> extension_pt = espressopp.integrator.ExtAnalyze(pt , interval=100)
>>> integrator.addExtension(extension_pt)
>>> integrator.run(10000)
>>> pt_ave = pt.getAverageValue()
>>> print "average Pressure Tensor = ", pt_ave[:6]
>>> print "          std deviation = ", pt_ave[6:]
>>> print "number of measurements  = ", pt.getNumberOfMeasurements()
```

The following methods are supported:

- **performMeasurement()** computes the pressure tensor and updates average and standard deviation
- **reset()** resets average and standard deviation to 0
- **compute()** computes the instant pressure tensor in layer h0, return value: [xx, yy, zz, xy, xz, yz]
- **getAverageValue()** returns the average pressure tensor and the standard deviation, return value: [xx, yy, zz, xy, xz, yz, +-xx, +-yy, +-zz, +-xy, +-xz, +-yz]
- **getNumberOfMeasurements()** counts the number of measurements that have been computed (standalone or in integrator) does _not_ include measurements that have been done using "compute()"

espressopp.analysis.**PressureTensorLayer**(*system*, *h0*, *dh*)

Parameters

- **system** –
- **h0** –
- **dh** –

4.14.25 PressureTensorMultiLayer - Analysis

This class computes the pressure tensor of the system in *n* layers. Layers are perpendicular to Z direction and are equidistant(distance is Lz/n). It can be used as standalone class in python as well as in combination with the integrator extension ExtAnalyze.

Standalone Usage:

```
>>> pt = espressopp.analysis.PressureTensorMultiLayer(system, n, dh)
>>> for i in range(n):
>>>     print "pressure tensor in layer %d: %s" % ( i, pt.compute())
```

or

```
>>> pt = espressopp.analysis.PressureTensorMultiLayer(system, n, dh)
>>> for k in range(100):
>>>     integrator.run(100)
>>>     pt.performMeasurement()
>>> for i in range(n):
>>>     print "average pressure tensor in layer %d: %s" % ( i, pt.compute())
```

Usage in integrator with ExtAnalyze:

```
>>> pt           = espressopp.analysis.PressureTensorMultiLayer(system, n, dh)
>>> extension_pt = espressopp.integrator.ExtAnalyze(pt , interval=100)
>>> integrator.addExtension(extension_pt)
>>> integrator.run(10000)
>>> pt_ave = pt.getAverageValue()
>>> for i in range(n):
>>>   print "average Pressure Tensor = ", pt_ave[i][:6]
>>>   print "          std deviation = ", pt_ave[i][6:]
>>> print "number of measurements  = ", pt.getNumberOfMeasurements()
```

The following methods are supported:

- **performMeasurement()** computes the pressure tensor and updates average and standard deviation
- **reset()** resets average and standard deviation to 0
- **compute()** computes the instant pressure tensor in *n* layers, return value: [xx, yy, zz, xy, xz, yz]
- **getAverageValue()** returns the average pressure tensor and the standard deviation, return value: [xx, yy, zz, xy, xz, yz, +-xx, +-yy, +-zz, +-xy, +-xz, +-yz]
- **getNumberOfMeasurements()** counts the number of measurements that have been computed (standalone or in integrator) does _not_ include measurements that have been done using "compute()"

espressopp.analysis.**PressureTensorMultiLayer**(*system*, *n*, *dh*)

Parameters

- **system** –
- **n** –
- **dh** –

4.14.26 espressopp.analysis.RDFatomistic

espressopp.analysis.**RDFatomistic**(*system*, *type1*, *type2*, *_span*)

Parameters

- **system** –
- **type1** –
- **type2** –
- **_span** –

espressopp.analysis.RDFatomistic.**compute**(*rdfN*)

Parameters **rdfN** –

Return type

4.14.27 espressopp.analysis.RadialDistrF

espressopp.analysis.**RadialDistrF**(*system*)

Parameters **system** –

espressopp.analysis.RadialDistrF.**compute**(*rdfN*)

Parameters **rdfN** –

Return type

4.14.28 espressopp.analysis.StaticStructF

espressopp.analysis.**StaticStructF**(*system*)

Parameters **system** –

espressopp.analysis.StaticStructF.**compute**(*nqx*, *nqy*, *nqz*, *bin_factor*, *ofile*)

Parameters

- **nqx** –
- **nqy** –
- **nqz** –
- **bin_factor** –
- **ofile** – (default: None)

Return type

espressopp.analysis.StaticStructF.**computeSingleChain**(*nqx*, *nqy*, *nqz*, *bin_factor*, *chainlength*, *ofile*)

Parameters

- **nqx** –
- **nqy** –
- **nqz** –
- **bin_factor** –
- **chainlength** –
- **ofile** – (default: None)

Return type

4.14.29 espressopp.analysis.SystemMonitor

SystemMonitor prints and logs to file values obtained from Observables like temperature, pressure or potential energy.

espressopp.analysis.**SystemMonitor**(*system*, *integrator*, *output*)

Parameters

- **system** (espressopp.System) – The system object.
- **integrator** (espressopp.integrator.MDIntegrator) – The MD integrator.
- **output** (espressopp.analysis.SystemMonitorOutputCSV) – The output object.

espressopp.analysis.SystemMonitor.**add_observable**(*name*, *observable*, *is_visible*)
The function adds new observable to SystemMonitor.

Parameters

- **name** (*str*) – The name of observable
- **observable** – The observable, eg. espressopp.analysis.PotentialEnergy
- **is_visible** (*bool*) – If set to True then values will be print on console.

espressopp.analysis.SystemMonitor.**info**()
The method print out on console the values of observables.

CSV Output

The output of SystemMonitor to CSV files.

espressopp.analysis.**SystemMonitorOutputCSV** (*file_name*, *delimiter*)

Parameters

- **file_name** (*str*) – The name of CSV file.
- **delimiter** (*str*) – The field delimiter, by default it is tabulator.

Example

```
>>> interaction = espressopp.interaction.VerletListLennardJones(verletlist)
>>> interaction.setPotential(type1=0, type2=0,
                             potential=espressopp.interaction.
↪LennardJones(epsilon=1.0, sigma=1.0,
                                                                    ␣
↪cutoff=2.0))
>>> system_monitor_csv = espressopp.analysis.SystemMonitorOutputCSV('out.csv')
>>> system_monitor = espressopp.analysis.SystemMonitor(
        system, integrator, espressopp.analysis.SystemMonitorOutputCSV('out.csv'))
>>> system_monitor.add_observable('pot', espressopp.analysis.
↪PotentialEnergy(system, interaction))
>>> ext_analysis = espressopp.integrator.ExtAnalyze(system_monitor, 10)
>>> integrator.addExtension(ext_analysis)
```

4.14.30 espressopp.analysis.PotentialEnergy

The object that computes potential energy of different interactions.

espressopp.analysis.**PotentialEnergy** (*system*, *potential*, *compute_method=None*)

Parameters

- **system** (espressopp.System) – The system object
- **interaction** (espressopp.interaction.Interaction) – The interaction object.
- **compute_method** (*str*) – If set to *ALL* (default) then compute total potential energies, if set to *CG* then compute only coarse-grained part (if feasible), if set to *AT* then compute only atomitic part of potential energy.

4.14.31 espressopp.analysis.Temperature

espressopp.analysis.**Temperature** (*system*)

Parameters **system** –

4.14.32 espressopp.analysis.Test

espressopp.analysis.**Test** (*system*)

Parameters **system** –

4.14.33 espressopp.analysis.TotalVelocity

espressopp.analysis.**TotalVelocity**(*system*)

Parameters **system** (espressopp.System) – The system object.

espressopp.analysis.TotalVelocity.**compute**()
Compute the total velocity of the system.

rtype float

espressopp.analysis.TotalVelocity.**reset**()
Subtract the total velocity of the system from every particle.

Examples

Reset the velocity

```
>>> total_velocity = espressopp.analysis.TotalVelocity(system)
>>> total_velocity.reset()
```

Extension to integrator

This extension can also be attached to integrator and run *reset()* every *n-th* steps.

```
>>> total_velocity = espressopp.analysis.TotalVelocity(system)
>>> ext_remove_com = espressopp.analysis.ExtAnalyze(total_velocity, 10)
>>> integrator.addExtension(ext_remove_com)
```

4.14.34 espressopp.analysis.Velocities

espressopp.analysis.**Velocities**(*system*)

Parameters **system** –

espressopp.analysis.Velocities.**clear**()

Return type

espressopp.analysis.Velocities.**gather**()

Return type

4.14.35 espressopp.analysis.VelocityAutocorrelation

espressopp.analysis.**VelocityAutocorrelation**(*system*)

Parameters **system** –

4.14.36 espressopp.analysis.Viscosity

espressopp.analysis.**Viscosity**(*system*)

Parameters **system** –

espressopp.analysis.Viscosity.**compute**(*t0*, *dt*, *T*)

Parameters

- **t0** –

- **dt** –
- **T** –

Return type

espressopp.analysis.Viscosity.**gather**()

Return type

4.14.37 espressopp.analysis.XDensity

espressopp.analysis.**XDensity**(*system*)

Parameters **system** –

espressopp.analysis.XDensity.**compute**(*rdfN*)

Parameters **rdfN** –

Return type

4.14.38 espressopp.analysis.XPressure

espressopp.analysis.**XPressure**(*system*)

Parameters **system** –

espressopp.analysis.XPressure.**compute**(*N*)

Parameters **N** –

Return type

4.15 bc

4.16 check

4.16.1 espressopp.check.System

4.17 esutil

4.17.1 espressopp.esutil.GammaVariate

espressopp.esutil.**GammaVariate**(*alpha*, *beta*)

Parameters

- **alpha** –
- **beta** –

4.17.2 espressopp.esutil.Grid

4.17.3 espressopp.esutil.NormalVariate

espressopp.esutil.**NormalVariate**(*mean*, *sigma*)

Parameters

- **mean** (*real*) – (default: 0.0)
- **sigma** (*real*) – (default: 1.0)

4.17.4 espressopp.esutil.RNG

4.17.5 espressopp.esutil.UniformOnSphere

4.17.6 espressopp.esutil.collectives

espressopp.esutil.**locateItem**(*here*)

Parameters **here** –

espressopp.esutil.collectives.**locateItem**(*here*)

locate the node with here=True (e.g. indicating that data of a distributed storage is on the local node). This is a collective SPMD function.

here is a boolean value, which should be True on at most one node. Returns on the controller the number of the node with here=True, or an KeyError exception if no node had the item, i.e. had here=True.

4.18 external

Homogeneous Transformation Matrices and Quaternions.

A library for calculating 4x4 matrices for translating, rotating, reflecting, scaling, shearing, projecting, orthogonalizing, and superimposing arrays of 3D homogeneous coordinates as well as for converting between rotation matrices, Euler angles, and quaternions. Also includes an Arcball control object and functions to decompose transformation matrices.

Authors Christoph Gohlke, Laboratory for Fluorescence Dynamics, University of California, Irvine

Version 2011.01.25

4.18.1 Requirements

- Python 2.6 or 3.1
- Numpy 1.5
- transformations.c 2010.04.10 (optional implementation of some functions in C)

4.18.2 Notes

The API is not stable yet and is expected to change between revisions.

This Python code is not optimized for speed. Refer to the transformations.c module for a faster implementation of some functions.

Documentation in HTML format can be generated with epydoc.

Matrices (M) can be inverted using numpy.linalg.inv(M), concatenated using numpy.dot(M0, M1), or used to transform homogeneous coordinates (v) using numpy.dot(M, v) for shape (4, *) “point of arrays”, respectively numpy.dot(v, M.T) for shape (*, 4) “array of points”.

Use the transpose of transformation matrices for OpenGL glMultMatrixd().

Calculations are carried out with numpy.float64 precision.

Vector, point, quaternion, and matrix function arguments are expected to be “array like”, i.e. tuple, list, or numpy arrays.

Return types are numpy arrays unless specified otherwise.

Angles are in radians unless specified otherwise.

Quaternions w+ix+jy+kz are represented as [w, x, y, z].

A triple of Euler angles can be applied/interpreted in 24 ways, which can be specified using a 4 character string or encoded 4-tuple:

Axes 4-string: e.g. 'sxyz' or 'ryxy'

- first character : rotations are applied to 's'tatic or 'r'otating frame
- remaining characters : successive rotation axis 'x', 'y', or 'z'

Axes 4-tuple: e.g. (0, 0, 0, 0) or (1, 1, 1, 1)

- inner axis: code of axis ('x':0, 'y':1, 'z':2) of rightmost matrix.
- parity : even (0) if inner axis 'x' is followed by 'y', 'y' is followed by 'z', or 'z' is followed by 'x'. Otherwise odd (1).
- repetition : first and last axis are same (1) or different (0).
- frame : rotations are applied to static (0) or rotating (1) frame.

4.18.3 References

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4.18.4 Examples

```
>>> alpha, beta, gamma = 0.123, -1.234, 2.345
>>> origin, xaxis, yaxis, zaxis = (0, 0, 0), (1, 0, 0), (0, 1, 0), (0, 0, 1)
>>> I = identity_matrix()
>>> Rx = rotation_matrix(alpha, xaxis)
>>> Ry = rotation_matrix(beta, yaxis)
>>> Rz = rotation_matrix(gamma, zaxis)
>>> R = concatenate_matrices(Rx, Ry, Rz)
>>> euler = euler_from_matrix(R, 'rxyz')
>>> numpy.allclose([alpha, beta, gamma], euler)
True
>>> Re = euler_matrix(alpha, beta, gamma, 'rxyz')
>>> is_same_transform(R, Re)
True
>>> al, be, ga = euler_from_matrix(Re, 'rxyz')
>>> is_same_transform(Re, euler_matrix(al, be, ga, 'rxyz'))
True
>>> qx = quaternion_about_axis(alpha, xaxis)
>>> qy = quaternion_about_axis(beta, yaxis)
>>> qz = quaternion_about_axis(gamma, zaxis)
>>> q = quaternion_multiply(qx, qy)
>>> q = quaternion_multiply(q, qz)
>>> Rq = quaternion_matrix(q)
>>> is_same_transform(R, Rq)
True
>>> S = scale_matrix(1.23, origin)
>>> T = translation_matrix((1, 2, 3))
>>> Z = shear_matrix(beta, xaxis, origin, zaxis)
>>> R = random_rotation_matrix(numpy.random.rand(3))
>>> M = concatenate_matrices(T, R, Z, S)
>>> scale, shear, angles, trans, persp = decompose_matrix(M)
>>> numpy.allclose(scale, 1.23)
True
>>> numpy.allclose(trans, (1, 2, 3))
True
>>> numpy.allclose(shear, (0, math.tan(beta), 0))
True
>>> is_same_transform(R, euler_matrix(axes='sxyz', *angles))
True
>>> M1 = compose_matrix(scale, shear, angles, trans, persp)
>>> is_same_transform(M, M1)
True
>>> v0, v1 = random_vector(3), random_vector(3)
>>> M = rotation_matrix(angle_between_vectors(v0, v1), vector_product(v0, v1))
>>> v2 = numpy.dot(v0, M[:3,:3].T)
>>> numpy.allclose(unit_vector(v1), unit_vector(v2))
True
```

class espressopp.external.transformations.**Arcball**(*initial=None*)

Virtual Trackball Control.

```
>>> ball = Arcball()
>>> ball = Arcball(initial=numpy.identity(4))
>>> ball.place([320, 320], 320)
>>> ball.down([500, 250])
>>> ball.drag([475, 275])
>>> R = ball.matrix()
>>> numpy.allclose(numpy.sum(R), 3.90583455)
True
>>> ball = Arcball(initial=[1, 0, 0, 0])
>>> ball.place([320, 320], 320)
>>> ball.setaxes([1,1,0], [-1, 1, 0])
>>> ball.setconstrain(True)
```

```
>>> ball.down([400, 200])
>>> ball.drag([200, 400])
>>> R = ball.matrix()
>>> numpy.allclose(numpy.sum(R), 0.2055924)
True
>>> ball.next()
```

down(*point*)
Set initial cursor window coordinates and pick constrain-axis.

drag(*point*)
Update current cursor window coordinates.

getconstrain()
Return state of constrain to axis mode.

matrix()
Return homogeneous rotation matrix.

next(*acceleration=0.0*)
Continue rotation in direction of last drag.

place(*center*, *radius*)
Place Arcball, e.g. when window size changes.

center [sequence[2]] Window coordinates of trackball center.

radius [float] Radius of trackball in window coordinates.

setaxes(**axes*)
Set axes to constrain rotations.

setconstrain(*constrain*)
Set state of constrain to axis mode.

espressopp.external.transformations.**angle_between_vectors**(*v0*, *v1*, *directed=True*, *axis=0*)
Return angle between vectors.

If directed is False, the input vectors are interpreted as undirected axes, i.e. the maximum angle is pi/2.

```
>>> a = angle_between_vectors([1, -2, 3], [-1, 2, -3])
>>> numpy.allclose(a, math.pi)
True
>>> a = angle_between_vectors([1, -2, 3], [-1, 2, -3], directed=False)
>>> numpy.allclose(a, 0)
True
>>> v0 = [[2, 0, 0, 2], [0, 2, 0, 2], [0, 0, 2, 2]]
>>> v1 = [[3], [0], [0]]
>>> a = angle_between_vectors(v0, v1)
>>> numpy.allclose(a, [0., 1.5708, 1.5708, 0.95532])
True
>>> v0 = [[2, 0, 0], [2, 0, 0], [0, 2, 0], [2, 0, 0]]
>>> v1 = [[0, 3, 0], [0, 0, 3], [0, 0, 3], [3, 3, 3]]
>>> a = angle_between_vectors(v0, v1, axis=1)
>>> numpy.allclose(a, [1.5708, 1.5708, 1.5708, 0.95532])
True
```

espressopp.external.transformations.**arcball_constrain_to_axis**(*point*, *axis*)
Return sphere point perpendicular to axis.

espressopp.external.transformations.**arcball_map_to_sphere**(*point*, *center*, *radius*)
Return unit sphere coordinates from window coordinates.

espressopp.external.transformations.**arcball_nearest_axis**(*point*, *axes*)
Return axis, which arc is nearest to point.

espressopp.external.transformations.**clip_matrix**(*left*, *right*, *bottom*, *top*, *near*, *far*, *perspective=False*)
Return matrix to obtain normalized device coordinates from frustrum.

The frustrum bounds are axis-aligned along x (left, right), y (bottom, top) and z (near, far).

Normalized device coordinates are in range [-1, 1] if coordinates are inside the frustrum.

If perspective is True the frustrum is a truncated pyramid with the perspective point at origin and direction along z axis, otherwise an orthographic canonical view volume (a box).

Homogeneous coordinates transformed by the perspective clip matrix need to be dehomogenized (devided by w coordinate).

```
>>> frustrum = numpy.random.rand(6)
>>> frustrum[1] += frustrum[0]
>>> frustrum[3] += frustrum[2]
>>> frustrum[5] += frustrum[4]
>>> M = clip_matrix(perspective=False, *frustrum)
>>> numpy.dot(M, [frustrum[0], frustrum[2], frustrum[4], 1.0])
array([-1., -1., -1.,  1.])
>>> numpy.dot(M, [frustrum[1], frustrum[3], frustrum[5], 1.0])
array([ 1.,  1.,  1.,  1.])
>>> M = clip_matrix(perspective=True, *frustrum)
>>> v = numpy.dot(M, [frustrum[0], frustrum[2], frustrum[4], 1.0])
>>> v / v[3]
array([-1., -1., -1.,  1.])
>>> v = numpy.dot(M, [frustrum[1], frustrum[3], frustrum[4], 1.0])
>>> v / v[3]
array([ 1.,  1., -1.,  1.])
```

espressopp.external.transformations.**compose_matrix**(*scale=None*, *shear=None*, *angles=None*, *translate=None*, *perspective=None*)
Return transformation matrix from sequence of transformations.

This is the inverse of the decompose_matrix function.

Sequence of transformations: scale : vector of 3 scaling factors shear : list of shear factors for x-y, x-z, y-z axes angles : list of Euler angles about static x, y, z axes translate : translation vector along x, y, z axes perspective : perspective partition of matrix

```
>>> scale = numpy.random.random(3) - 0.5
>>> shear = numpy.random.random(3) - 0.5
>>> angles = (numpy.random.random(3) - 0.5) * (2*math.pi)
>>> trans = numpy.random.random(3) - 0.5
>>> persp = numpy.random.random(4) - 0.5
>>> M0 = compose_matrix(scale, shear, angles, trans, persp)
>>> result = decompose_matrix(M0)
>>> M1 = compose_matrix(*result)
>>> is_same_transform(M0, M1)
True
```

espressopp.external.transformations.**concatenate_matrices**(**matrices*)
Return concatenation of series of transformation matrices.

```
>>> M = numpy.random.rand(16).reshape((4, 4)) - 0.5
>>> numpy.allclose(M, concatenate_matrices(M))
True
>>> numpy.allclose(numpy.dot(M, M.T), concatenate_matrices(M, M.T))
True
```

espressopp.external.transformations.**decompose_matrix**(*matrix*)

Return sequence of transformations from transformation matrix.

matrix [array_like] Non-degenerative homogeneous transformation matrix

Return tuple of: scale : vector of 3 scaling factors shear : list of shear factors for x-y, x-z, y-z axes angles : list of Euler angles about static x, y, z axes translate : translation vector along x, y, z axes perspective : perspective partition of matrix

Raise ValueError if matrix is of wrong type or degenerative.

```
>>> T0 = translation_matrix((1, 2, 3))
>>> scale, shear, angles, trans, persp = decompose_matrix(T0)
>>> T1 = translation_matrix(trans)
>>> numpy.allclose(T0, T1)
True
>>> S = scale_matrix(0.123)
>>> scale, shear, angles, trans, persp = decompose_matrix(S)
>>> scale[0]
0.123
>>> R0 = euler_matrix(1, 2, 3)
>>> scale, shear, angles, trans, persp = decompose_matrix(R0)
>>> R1 = euler_matrix(*angles)
>>> numpy.allclose(R0, R1)
True
```

espressopp.external.transformations.**euler_from_matrix**(*matrix*, *axes='sxyz'*)

Return Euler angles from rotation matrix for specified axis sequence.

axes : One of 24 axis sequences as string or encoded tuple

Note that many Euler angle triplets can describe one matrix.

```
>>> R0 = euler_matrix(1, 2, 3, 'syxz')
>>> al, be, ga = euler_from_matrix(R0, 'syxz')
>>> R1 = euler_matrix(al, be, ga, 'syxz')
>>> numpy.allclose(R0, R1)
True
>>> angles = (4.0*math.pi) * (numpy.random.random(3) - 0.5)
>>> for axes in _AXES2TUPLE.keys():
...    R0 = euler_matrix(axes=axes, *angles)
...    R1 = euler_matrix(axes=axes, *euler_from_matrix(R0, axes))
...    if not numpy.allclose(R0, R1): print(axes, "failed")
```

espressopp.external.transformations.**euler_from_quaternion**(*quaternion*, *axes='sxyz'*)

Return Euler angles from quaternion for specified axis sequence.

```
>>> angles = euler_from_quaternion([0.99810947, 0.06146124, 0, 0])
>>> numpy.allclose(angles, [0.123, 0, 0])
True
```

espressopp.external.transformations.**euler_matrix**(*ai*, *aj*, *ak*, *axes='sxyz'*)

Return homogeneous rotation matrix from Euler angles and axis sequence.

ai, aj, ak : Euler's roll, pitch and yaw angles axes : One of 24 axis sequences as string or encoded tuple

```
>>> R = euler_matrix(1, 2, 3, 'syxz')
>>> numpy.allclose(numpy.sum(R[0]), -1.34786452)
True
>>> R = euler_matrix(1, 2, 3, (0, 1, 0, 1))
>>> numpy.allclose(numpy.sum(R[0]), -0.383436184)
True
>>> ai, aj, ak = (4.0*math.pi) * (numpy.random.random(3) - 0.5)
>>> for axes in _AXES2TUPLE.keys():
```

```
...     R = euler_matrix(ai, aj, ak, axes)
>>> for axes in _TUPLE2AXES.keys():
...     R = euler_matrix(ai, aj, ak, axes)
```

espressopp.external.transformations.**identity_matrix**()

Return 4x4 identity/unit matrix.

```
>>> I = identity_matrix()
>>> numpy.allclose(I, numpy.dot(I, I))
True
>>> numpy.sum(I), numpy.trace(I)
(4.0, 4.0)
>>> numpy.allclose(I, numpy.identity(4, dtype=numpy.float64))
True
```

espressopp.external.transformations.**inverse_matrix**(*matrix*)

Return inverse of square transformation matrix.

```
>>> M0 = random_rotation_matrix()
>>> M1 = inverse_matrix(M0.T)
>>> numpy.allclose(M1, numpy.linalg.inv(M0.T))
True
>>> for size in range(1, 7):
...     M0 = numpy.random.rand(size, size)
...     M1 = inverse_matrix(M0)
...     if not numpy.allclose(M1, numpy.linalg.inv(M0)): print(size)
```

espressopp.external.transformations.**is_same_transform**(*matrix0*, *matrix1*)

Return True if two matrices perform same transformation.

```
>>> is_same_transform(numpy.identity(4), numpy.identity(4))
True
>>> is_same_transform(numpy.identity(4), random_rotation_matrix())
False
```

espressopp.external.transformations.**orthogonalization_matrix**(*lengths*, *angles*)

Return orthogonalization matrix for crystallographic cell coordinates.

Angles are expected in degrees.

The de-orthogonalization matrix is the inverse.

```
>>> O = orthogonalization_matrix((10., 10., 10.), (90., 90., 90.))
>>> numpy.allclose(O[:3, :3], numpy.identity(3, float) * 10)
True
>>> O = orthogonalization_matrix([9.8, 12.0, 15.5], [87.2, 80.7, 69.7])
>>> numpy.allclose(numpy.sum(O), 43.063229)
True
```

espressopp.external.transformations.**projection_from_matrix**(*matrix*, *pseudo=False*)

Return projection plane and perspective point from projection matrix.

Return values are same as arguments for projection_matrix function: point, normal, direction, perspective, and pseudo.

```
>>> point = numpy.random.random(3) - 0.5
>>> normal = numpy.random.random(3) - 0.5
>>> direct = numpy.random.random(3) - 0.5
>>> persp = numpy.random.random(3) - 0.5
>>> P0 = projection_matrix(point, normal)
>>> result = projection_from_matrix(P0)
```

```
>>> P1 = projection_matrix(*result)
>>> is_same_transform(P0, P1)
True
>>> P0 = projection_matrix(point, normal, direct)
>>> result = projection_from_matrix(P0)
>>> P1 = projection_matrix(*result)
>>> is_same_transform(P0, P1)
True
>>> P0 = projection_matrix(point, normal, perspective=persp, pseudo=False)
>>> result = projection_from_matrix(P0, pseudo=False)
>>> P1 = projection_matrix(*result)
>>> is_same_transform(P0, P1)
True
>>> P0 = projection_matrix(point, normal, perspective=persp, pseudo=True)
>>> result = projection_from_matrix(P0, pseudo=True)
>>> P1 = projection_matrix(*result)
>>> is_same_transform(P0, P1)
True
```

espressopp.external.transformations.**projection_matrix**(*point*, *normal*, *direction=None*, *perspective=None*, *pseudo=False*)

Return matrix to project onto plane defined by point and normal.

Using either perspective point, projection direction, or none of both.

If pseudo is True, perspective projections will preserve relative depth such that Perspective = dot(Orthogonal, PseudoPerspective).

```
>>> P = projection_matrix((0, 0, 0), (1, 0, 0))
>>> numpy.allclose(P[1:, 1:], numpy.identity(4)[1:, 1:])
True
>>> point = numpy.random.random(3) - 0.5
>>> normal = numpy.random.random(3) - 0.5
>>> direct = numpy.random.random(3) - 0.5
>>> persp = numpy.random.random(3) - 0.5
>>> P0 = projection_matrix(point, normal)
>>> P1 = projection_matrix(point, normal, direction=direct)
>>> P2 = projection_matrix(point, normal, perspective=persp)
>>> P3 = projection_matrix(point, normal, perspective=persp, pseudo=True)
>>> is_same_transform(P2, numpy.dot(P0, P3))
True
>>> P = projection_matrix((3, 0, 0), (1, 1, 0), (1, 0, 0))
>>> v0 = (numpy.random.rand(4, 5) - 0.5) * 20.0
>>> v0[3] = 1.0
>>> v1 = numpy.dot(P, v0)
>>> numpy.allclose(v1[1], v0[1])
True
>>> numpy.allclose(v1[0], 3.0-v1[1])
True
```

espressopp.external.transformations.**quaternion_about_axis**(*angle*, *axis*)

Return quaternion for rotation about axis.

```
>>> q = quaternion_about_axis(0.123, (1, 0, 0))
>>> numpy.allclose(q, [0.99810947, 0.06146124, 0, 0])
True
```

espressopp.external.transformations.**quaternion_conjugate**(*quaternion*)

Return conjugate of quaternion.

```
>>> q0 = random_quaternion()
>>> q1 = quaternion_conjugate(q0)
>>> q1[0] == q0[0] and all(q1[1:] == -q0[1:])
True
```

espressopp.external.transformations.**quaternion_from_euler**(*ai*, *aj*, *ak*, *axes='sxyz'*)

Return quaternion from Euler angles and axis sequence.

ai, aj, ak : Euler's roll, pitch and yaw angles axes : One of 24 axis sequences as string or encoded tuple

```
>>> q = quaternion_from_euler(1, 2, 3, 'ryxz')
>>> numpy.allclose(q, [0.435953, 0.310622, -0.718287, 0.444435])
True
```

espressopp.external.transformations.**quaternion_from_matrix**(*matrix*, *isprecise=False*)

Return quaternion from rotation matrix.

If isprecise=True, the input matrix is assumed to be a precise rotation matrix and a faster algorithm is used.

```
>>> q = quaternion_from_matrix(identity_matrix(), True)
>>> numpy.allclose(q, [1., 0., 0., 0.])
True
>>> q = quaternion_from_matrix(numpy.diag([1., -1., -1., 1.]))
>>> numpy.allclose(q, [0, 1, 0, 0]) or numpy.allclose(q, [0, -1, 0, 0])
True
>>> R = rotation_matrix(0.123, (1, 2, 3))
>>> q = quaternion_from_matrix(R, True)
>>> numpy.allclose(q, [0.9981095, 0.0164262, 0.0328524, 0.0492786])
True
>>> R = [[-0.545, 0.797, 0.260, 0], [0.733, 0.603, -0.313, 0],
...      [-0.407, 0.021, -0.913, 0], [0, 0, 0, 1]]
>>> q = quaternion_from_matrix(R)
>>> numpy.allclose(q, [0.19069, 0.43736, 0.87485, -0.083611])
True
>>> R = [[0.395, 0.362, 0.843, 0], [-0.626, 0.796, -0.056, 0],
...      [-0.677, -0.498, 0.529, 0], [0, 0, 0, 1]]
>>> q = quaternion_from_matrix(R)
>>> numpy.allclose(q, [0.82336615, -0.13610694, 0.46344705, -0.29792603])
True
>>> R = random_rotation_matrix()
>>> q = quaternion_from_matrix(R)
>>> is_same_transform(R, quaternion_matrix(q))
True
```

espressopp.external.transformations.**quaternion_imag**(*quaternion*)

Return imaginary part of quaternion.

```
>>> quaternion_imag([3.0, 0.0, 1.0, 2.0])
[0.0, 1.0, 2.0]
```

espressopp.external.transformations.**quaternion_inverse**(*quaternion*)

Return inverse of quaternion.

```
>>> q0 = random_quaternion()
>>> q1 = quaternion_inverse(q0)
>>> numpy.allclose(quaternion_multiply(q0, q1), [1, 0, 0, 0])
True
```

espressopp.external.transformations.**quaternion_matrix**(*quaternion*)

Return homogeneous rotation matrix from quaternion.

```
>>> M = quaternion_matrix([0.99810947, 0.06146124, 0, 0])
>>> numpy.allclose(M, rotation_matrix(0.123, (1, 0, 0)))
True
>>> M = quaternion_matrix([1, 0, 0, 0])
>>> numpy.allclose(M, identity_matrix())
True
>>> M = quaternion_matrix([0, 1, 0, 0])
>>> numpy.allclose(M, numpy.diag([1, -1, -1, 1]))
True
```

espressopp.external.transformations.**quaternion_multiply**(*quaternion1*, *quaternion0*)

Return multiplication of two quaternions.

```
>>> q = quaternion_multiply([4, 1, -2, 3], [8, -5, 6, 7])
>>> numpy.allclose(q, [28, -44, -14, 48])
True
```

espressopp.external.transformations.**quaternion_real**(*quaternion*)

Return real part of quaternion.

```
>>> quaternion_real([3.0, 0.0, 1.0, 2.0])
3.0
```

espressopp.external.transformations.**quaternion_slerp**(*quat0*, *quat1*, *fraction*, *spin=0*, *shortestpath=True*)

Return spherical linear interpolation between two quaternions.

```
>>> q0 = random_quaternion()
>>> q1 = random_quaternion()
>>> q = quaternion_slerp(q0, q1, 0.0)
>>> numpy.allclose(q, q0)
True
>>> q = quaternion_slerp(q0, q1, 1.0, 1)
>>> numpy.allclose(q, q1)
True
>>> q = quaternion_slerp(q0, q1, 0.5)
>>> angle = math.acos(numpy.dot(q0, q))
>>> numpy.allclose(2.0, math.acos(numpy.dot(q0, q1)) / angle) or
↪numpy.allclose(2.0, math.acos(-numpy.dot(q0, q1)) / angle)
True
```

espressopp.external.transformations.**random_quaternion**(*rand=None*)

Return uniform random unit quaternion.

rand: array like or None Three independent random variables that are uniformly distributed between 0 and 1.

```
>>> q = random_quaternion()
>>> numpy.allclose(1.0, vector_norm(q))
True
>>> q = random_quaternion(numpy.random.random(3))
>>> len(q.shape), q.shape[0]==4
(1, True)
```

espressopp.external.transformations.**random_rotation_matrix**(*rand=None*)

Return uniform random rotation matrix.

rnd: array like Three independent random variables that are uniformly distributed between 0 and 1 for each returned quaternion.

```
>>> R = random_rotation_matrix()
>>> numpy.allclose(numpy.dot(R.T, R), numpy.identity(4))
True
```

espressopp.external.transformations.**random_vector**(*size*)

Return array of random doubles in the half-open interval [0.0, 1.0).

```
>>> v = random_vector(10000)
>>> numpy.all(v >= 0.0) and numpy.all(v < 1.0)
True
>>> v0 = random_vector(10)
>>> v1 = random_vector(10)
>>> numpy.any(v0 == v1)
False
```

espressopp.external.transformations.**reflection_from_matrix**(*matrix*)

Return mirror plane point and normal vector from reflection matrix.

```
>>> v0 = numpy.random.random(3) - 0.5
>>> v1 = numpy.random.random(3) - 0.5
>>> M0 = reflection_matrix(v0, v1)
>>> point, normal = reflection_from_matrix(M0)
>>> M1 = reflection_matrix(point, normal)
>>> is_same_transform(M0, M1)
True
```

espressopp.external.transformations.**reflection_matrix**(*point*, *normal*)

Return matrix to mirror at plane defined by point and normal vector.

```
>>> v0 = numpy.random.random(4) - 0.5
>>> v0[3] = 1.0
>>> v1 = numpy.random.random(3) - 0.5
>>> R = reflection_matrix(v0, v1)
>>> numpy.allclose(2., numpy.trace(R))
True
>>> numpy.allclose(v0, numpy.dot(R, v0))
True
>>> v2 = v0.copy()
>>> v2[:3] += v1
>>> v3 = v0.copy()
>>> v2[:3] -= v1
>>> numpy.allclose(v2, numpy.dot(R, v3))
True
```

espressopp.external.transformations.**rotation_from_matrix**(*matrix*)

Return rotation angle and axis from rotation matrix.

```
>>> angle = (random.random() - 0.5) * (2*math.pi)
>>> direc = numpy.random.random(3) - 0.5
>>> point = numpy.random.random(3) - 0.5
>>> R0 = rotation_matrix(angle, direc, point)
>>> angle, direc, point = rotation_from_matrix(R0)
>>> R1 = rotation_matrix(angle, direc, point)
>>> is_same_transform(R0, R1)
True
```

espressopp.external.transformations.**rotation_matrix**(*angle*, *direction*, *point=None*)

Return matrix to rotate about axis defined by point and direction.

```
>>> R = rotation_matrix(math.pi/2.0, [0, 0, 1], [1, 0, 0])
>>> numpy.allclose(numpy.dot(R, [0, 0, 0, 1]), [ 1., -1.,  0.,  1.])
```

```
True
>>> angle = (random.random() - 0.5) * (2*math.pi)
>>> direc = numpy.random.random(3) - 0.5
>>> point = numpy.random.random(3) - 0.5
>>> R0 = rotation_matrix(angle, direc, point)
>>> R1 = rotation_matrix(angle-2*math.pi, direc, point)
>>> is_same_transform(R0, R1)
True
>>> R0 = rotation_matrix(angle, direc, point)
>>> R1 = rotation_matrix(-angle, -direc, point)
>>> is_same_transform(R0, R1)
True
>>> I = numpy.identity(4, numpy.float64)
>>> numpy.allclose(I, rotation_matrix(math.pi*2, direc))
True
>>> numpy.allclose(2., numpy.trace(rotation_matrix(math.pi/2,
...                                                direc, point)))
True
```

espressopp.external.transformations.**scale_from_matrix**(*matrix*)

Return scaling factor, origin and direction from scaling matrix.

```
>>> factor = random.random() * 10 - 5
>>> origin = numpy.random.random(3) - 0.5
>>> direct = numpy.random.random(3) - 0.5
>>> S0 = scale_matrix(factor, origin)
>>> factor, origin, direction = scale_from_matrix(S0)
>>> S1 = scale_matrix(factor, origin, direction)
>>> is_same_transform(S0, S1)
True
>>> S0 = scale_matrix(factor, origin, direct)
>>> factor, origin, direction = scale_from_matrix(S0)
>>> S1 = scale_matrix(factor, origin, direction)
>>> is_same_transform(S0, S1)
True
```

espressopp.external.transformations.**scale_matrix**(*factor*, *origin=None*, *direction=None*)

Return matrix to scale by factor around origin in direction.

Use factor -1 for point symmetry.

```
>>> v = (numpy.random.rand(4, 5) - 0.5) * 20.0
>>> v[3] = 1.0
>>> S = scale_matrix(-1.234)
>>> numpy.allclose(numpy.dot(S, v)[:3], -1.234*v[:3])
True
>>> factor = random.random() * 10 - 5
>>> origin = numpy.random.random(3) - 0.5
>>> direct = numpy.random.random(3) - 0.5
>>> S = scale_matrix(factor, origin)
>>> S = scale_matrix(factor, origin, direct)
```

espressopp.external.transformations.**shear_from_matrix**(*matrix*)

Return shear angle, direction and plane from shear matrix.

```
>>> angle = (random.random() - 0.5) * 4*math.pi
>>> direct = numpy.random.random(3) - 0.5
>>> point = numpy.random.random(3) - 0.5
>>> normal = numpy.cross(direct, numpy.random.random(3))
>>> S0 = shear_matrix(angle, direct, point, normal)
>>> angle, direct, point, normal = shear_from_matrix(S0)
>>> S1 = shear_matrix(angle, direct, point, normal)
```

```
>>> is_same_transform(S0, S1)
True
```

espressopp.external.transformations.**shear_matrix**(*angle*, *direction*, *point*, *normal*)

Return matrix to shear by angle along direction vector on shear plane.

The shear plane is defined by a point and normal vector. The direction vector must be orthogonal to the plane's normal vector.

A point P is transformed by the shear matrix into P" such that the vector P-P" is parallel to the direction vector and its extent is given by the angle of P-P'-P", where P' is the orthogonal projection of P onto the shear plane.

```
>>> angle = (random.random() - 0.5) * 4*math.pi
>>> direct = numpy.random.random(3) - 0.5
>>> point = numpy.random.random(3) - 0.5
>>> normal = numpy.cross(direct, numpy.random.random(3))
>>> S = shear_matrix(angle, direct, point, normal)
>>> numpy.allclose(1.0, numpy.linalg.det(S))
True
```

espressopp.external.transformations.**superimposition_matrix**(*v0*, *v1*, *scaling=False*, *usesvd=True*)

Return matrix to transform given vector set into second vector set.

v0 and v1 are shape (3, *) or (4, *) arrays of at least 3 vectors.

If usesvd is True, the weighted sum of squared deviations (RMSD) is minimized according to the algorithm by W. Kabsch [8]. Otherwise the quaternion based algorithm by B. Horn [9] is used (slower when using this Python implementation).

The returned matrix performs rotation, translation and uniform scaling (if specified).

```
>>> v0 = numpy.random.rand(3, 10)
>>> M = superimposition_matrix(v0, v0)
>>> numpy.allclose(M, numpy.identity(4))
True
>>> R = random_rotation_matrix(numpy.random.random(3))
>>> v0 = ((1,0,0), (0,1,0), (0,0,1), (1,1,1))
>>> v1 = numpy.dot(R, v0)
>>> M = superimposition_matrix(v0, v1)
>>> numpy.allclose(v1, numpy.dot(M, v0))
True
>>> v0 = (numpy.random.rand(4, 100) - 0.5) * 20.0
>>> v0[3] = 1.0
>>> v1 = numpy.dot(R, v0)
>>> M = superimposition_matrix(v0, v1)
>>> numpy.allclose(v1, numpy.dot(M, v0))
True
>>> S = scale_matrix(random.random())
>>> T = translation_matrix(numpy.random.random(3)-0.5)
>>> M = concatenate_matrices(T, R, S)
>>> v1 = numpy.dot(M, v0)
>>> v0[:3] += numpy.random.normal(0.0, 1e-9, 300).reshape(3, -1)
>>> M = superimposition_matrix(v0, v1, scaling=True)
>>> numpy.allclose(v1, numpy.dot(M, v0))
True
>>> M = superimposition_matrix(v0, v1, scaling=True, usesvd=False)
>>> numpy.allclose(v1, numpy.dot(M, v0))
True
>>> v = numpy.empty((4, 100, 3), dtype=numpy.float64)
>>> v[:, :, 0] = v0
>>> M = superimposition_matrix(v0, v1, scaling=True, usesvd=False)
```

```
>>> numpy.allclose(v1, numpy.dot(M, v[:, :, 0]))
True
```

espressopp.external.transformations.**translation_from_matrix**(*matrix*)
Return translation vector from translation matrix.

```
>>> v0 = numpy.random.random(3) - 0.5
>>> v1 = translation_from_matrix(translation_matrix(v0))
>>> numpy.allclose(v0, v1)
True
```

espressopp.external.transformations.**translation_matrix**(*direction*)
Return matrix to translate by direction vector.

```
>>> v = numpy.random.random(3) - 0.5
>>> numpy.allclose(v, translation_matrix(v)[:3, 3])
True
```

espressopp.external.transformations.**unit_vector**(*data*, *axis=None*, *out=None*)
Return ndarray normalized by length, i.e. eucledian norm, along axis.

```
>>> v0 = numpy.random.random(3)
>>> v1 = unit_vector(v0)
>>> numpy.allclose(v1, v0 / numpy.linalg.norm(v0))
True
>>> v0 = numpy.random.rand(5, 4, 3)
>>> v1 = unit_vector(v0, axis=-1)
>>> v2 = v0 / numpy.expand_dims(numpy.sqrt(numpy.sum(v0*v0, axis=2)), 2)
>>> numpy.allclose(v1, v2)
True
>>> v1 = unit_vector(v0, axis=1)
>>> v2 = v0 / numpy.expand_dims(numpy.sqrt(numpy.sum(v0*v0, axis=1)), 1)
>>> numpy.allclose(v1, v2)
True
>>> v1 = numpy.empty((5, 4, 3), dtype=numpy.float64)
>>> unit_vector(v0, axis=1, out=v1)
>>> numpy.allclose(v1, v2)
True
>>> list(unit_vector([]))
[]
>>> list(unit_vector([1.0]))
[1.0]
```

espressopp.external.transformations.**vector_norm**(*data*, *axis=None*, *out=None*)
Return length, i.e. eucledian norm, of ndarray along axis.

```
>>> v = numpy.random.random(3)
>>> n = vector_norm(v)
>>> numpy.allclose(n, numpy.linalg.norm(v))
True
>>> v = numpy.random.rand(6, 5, 3)
>>> n = vector_norm(v, axis=-1)
>>> numpy.allclose(n, numpy.sqrt(numpy.sum(v*v, axis=2)))
True
>>> n = vector_norm(v, axis=1)
>>> numpy.allclose(n, numpy.sqrt(numpy.sum(v*v, axis=1)))
True
>>> v = numpy.random.rand(5, 4, 3)
>>> n = numpy.empty((5, 3), dtype=numpy.float64)
>>> vector_norm(v, axis=1, out=n)
>>> numpy.allclose(n, numpy.sqrt(numpy.sum(v*v, axis=1)))
True
```

```
>>> vector_norm([])
0.0
>>> vector_norm([1.0])
1.0
```

espressopp.external.transformations.**vector_product**(*v0*, *v1*, *axis=0*)

Return vector perpendicular to vectors.

```
>>> v = vector_product([2, 0, 0], [0, 3, 0])
>>> numpy.allclose(v, [0, 0, 6])
True
>>> v0 = [[2, 0, 0, 2], [0, 2, 0, 2], [0, 0, 2, 2]]
>>> v1 = [[3], [0], [0]]
>>> v = vector_product(v0, v1)
>>> numpy.allclose(v, [[0, 0, 0, 0], [0, 0, 6, 6], [0, -6, 0, -6]])
True
>>> v0 = [[2, 0, 0], [2, 0, 0], [0, 2, 0], [2, 0, 0]]
>>> v1 = [[0, 3, 0], [0, 0, 3], [0, 0, 3], [3, 3, 3]]
>>> v = vector_product(v0, v1, axis=1)
>>> numpy.allclose(v, [[0, 0, 6], [0, -6, 0], [6, 0, 0], [0, -6, 6]])
True
```

4.19 integrator

4.19.1 AdResS - Object

The AdResS object is an extension to the integrator. It makes sure that the integrator also processes the atomistic particles and not only the CG particles. Hence, this object is of course only used when performing AdResS or H-AdResS simulations.

In detail the AdResS extension makes sure:

- that also the forces on the atomistic particles are initialized and set to by Adress::initForces
- that also the atomistic particles are integrated and propagated by Adress::integrate1 and Adress::integrate2

Example - how to turn on the AdResS integrator extension:

```
>>> adress      = espressopp.integrator.Adress(system)
>>> integrator.addExtension(adress)
```

espressopp.integrator.**Adress**(*_system*, *_verletlist*, *_fixedtuplelist*, *KTI*)

Parameters

- **_system** –
- **_verletlist** –
- **_fixedtuplelist** –
- **KTI** – (default: False)

4.19.2 BerendsenBarostatAnisotropic - Berendsen barostat Object

#TODO fix these comments This is the Berendsen barostat implementation according to the original paper *[Berendsen84]*. If Berendsen barostat is defined (as a property of integrator) then at the each run the system size and the particle coordinates will be scaled by scaling parameter μ according to the formula:

$$\mu = [1 - \Delta t/\tau(P_0 - P)]^{1/3}$$

where Δt - integration timestep, τ - time parameter (coupling parameter), P_0 - external pressure and P - instantaneous pressure.

Example:

```
>>> berendsenP = espressopp.integrator.BerendsenBarostatAnisotropic(system)
>>> berendsenP.tau = 0.1
>>> berendsenP.pressure = 1.0
>>> integrator.addExtension(berendsenP)
```

!IMPORTANT In order to run *npt* simulation one should separately define thermostat as well (e.g. Berendsen-Thermostat).

Definition:

In order to define the Berendsen barostat

```
>>> berendsenP = espressopp.integrator.
↪BerendsenBarostatAnisotropic(system)
```

one should have the System defined.

Properties:

- *berendsenP.tau*

  The property 'tau' defines the time parameter τ.

- *berendsenP.pressure*

  The property 'pressure' defines the external pressure P_0.

Setting the integration property:

```
>>> integrator.addExtension(berendsenP)
```

It will define Berendsen barostat as a property of integrator.

One more example:

```
>>> berendsen_barostat = espressopp.integrator.BerendsenBarostatAnisotropic(system)
>>> berendsen_barostat.tau = 10.0
>>> berendsen_barostat.pressure = 3.5
>>> integrator.addExtension(berendsen_barostat)
```

Canceling the barostat:

If one do not need the pressure regulation in system anymore or need to switch the ensamble or whatever :)

```
>>> # define barostat with parameters
>>> berendsen = espressopp.integrator.
↪BerendsenBarostatAnisotropic(system)
>>> berendsen.tau = 0.8
>>> berendsen.pressure = 15.0
>>> integrator.addExtension(berendsen)
>>> ...
>>> # some runs
>>> ...
>>> # disconnect Berendsen barostat
>>> berendsen.disconnect()
>>> # the next runs will not include the system size and particle␣
↪coordinates scaling
```

Connecting the barostat back after the disconnection

```
>>> berendsen.connect()
```

espressopp.integrator.**BerendsenBarostatAnisotropic**(*system*)

Parameters **system** –

4.19.3 CapForce - Integrator Extension

This class can be used to forcecap all particles or a group of particles. Force capping means that the force vector of a particle is rescaled so that the length of the force vector is <= capforce

Example Usage:

```
>>> capforce     = espressopp.integrator.CapForce(system, 1000.0)
>>> integrator.addExtension(capForce)
```

CapForce can also be used to forcecap only a group of particles:

```
>>> particle_group = [45, 67, 89, 103]
>>> capforce       = espressopp.integrator.CapForce(system, 1000.0, particle_group)
>>> integrator.addExtension(capForce)
```

espressopp.integrator.**CapForce**(*system*, *capForce*, *particleGroup*)

Parameters

- **system** –
- **capForce** –
- **particleGroup** – (default: None)

4.19.4 espressopp.integrator.DPDThermostat

espressopp.integrator.**DPDThermostat**(*system*, *vl*)

Parameters

- **system** –
- **vl** –

4.19.5 ExtAnalyze - Integrator Extension

This class can be used to execute nearly all analysis objects within the main integration loop which allows to automatically accumulate time averages (with standard deviation error bars).

Example Usage:

```
>>> pt           = espressopp.analysis.PressureTensor(system)
>>> extension_pt = espressopp.integrator.ExtAnalyze(pt , interval=100)
>>> integrator.addExtension(extension_pt)
>>> integrator.run(10000)
>>>
>>> pt_ave = pt.getAverageValue()
>>> print "average Pressure Tensor = ", pt_ave[:6]
>>> print "          std deviation = ", pt_ave[6:]
>>> print "number of measurements  = ", pt.getNumberOfMeasurements()
```

espressopp.integrator.**ExtAnalyze**(*action_obj*, *interval*)

Parameters

- **action_obj** –
- **interval** (*int*) – (default: 1)

4.19.6 espressopp.integrator.ExtForce

espressopp.integrator.**ExtForce**(*system*, *extForce*, *particleGroup*)

Parameters

- **system** –
- **extForce** –
- **particleGroup** – (default: None)

4.19.7 espressopp.integrator.Extension

espressopp.integrator.Extension.**connect**()

Return type

espressopp.integrator.Extension.**disconnect**()

Return type

4.19.8 espressopp.integrator.FixPositions

espressopp.integrator.**FixPositions**(*system*, *particleGroup*, *fixMask*)

Parameters

- **system** –
- **particleGroup** –
- **fixMask** –

4.19.9 espressopp.integrator.FreeEnergyCompensation

espressopp.integrator.**FreeEnergyCompensation**(*system*, *center*)

Parameters

- **system** –
- **center** – (default: [])

espressopp.integrator.FreeEnergyCompensation.**addForce**(*itype*, *filename*, *type*)

Parameters

- **itype** –
- **filename** –
- **type** –

Return type

espressopp.integrator.FreeEnergyCompensation.**computeCompEnergy**()

Return type

4.19.10 espressopp.integrator.Isokinetic

espressopp.integrator.**Isokinetic**(*system*)

Parameters **system** –

4.19.11 LatticeBoltzmann - class for lattice Boltzmann methods

The LatticeBoltzmann (LB) class is an extension to the integrator class of ESPResSo++. The main purpose of the LB-fluid in our simulation package is NOT in fluid dynamics applications or investigation of fluid-solid interfacial phenomena. We aim at complex soft matter systems, where the LB-fluid is a bulk solvent and therefore one has rather use some MD particles as solutes. Examples of such systems range from colloids (point-like MD-particles) to polymer chains (point-like MD-particles connected into chains) dissolved in some solvent (LB-fluid) with specific static and dynamic properties.

It is therefore done ON PURPOSE that the user specifies parameters for LB-fluid in Lennard-Jones (LJ) units. In the kernel of the C++ code we transform these into LB-units, if neccessary. Such strategy helps users coming from MD-background to think of the LB-fluid as if it has particle-based structure: to mimic the solvent one only has to specify such parameters as liquid density, rho, temperature, T, and viscosity, η. For a standard LJ-fluid one has: $rho \sim 1[\sigma^{-3}]$, $T \sim 1[\epsilon]$, and $\eta \sim 5[units]$.

Note: Experienced LB-users may find our approach unusual. However, we kindly ask them for a feedback, as for us it is also quite novel. Particularly, we are interested in suggestions on expansion of the LB-possibilities and would like at first get an overview of "what do the people need?". Being it either BGK-scheme, implementation of boundary conditions or something else.

It creates a simulation box with specified dimensions and allocates necessary memory for a lattice Boltzmann simulation. By default we use D3Q19 lattice model (in three dimensions and with 19-velocities on the node model).

LatticeBoltzmann constructor expects 5 parameters (and a system pointer). These are: lattice size in 3D Ni, lattice spacing a, lattice timestep tau, number of dimensions and number of velocity vectors on a lattice node. The lattice size, Ni, is an obligatory parameter and must be set at the beginning of the simulation.

The default lattice model is D3Q19 (numDims = 3, numVels = 19) and both lattice spacing and timestep are set to 1.

Note that at the present stage of development we aim at D3Q19 model. If you want to use something else, please, feel free to modify the code.

Originally, we had planned this module to operate in 3D only, so if you need a 2D version, there is a bit more tuning involved. On the other hand, adding different 3D lattice models (such as D3Q15 or D3Q27) is rather straightforward.

Example

```
>>> lb = espressopp.integrator.LatticeBoltzmann(system, Ni=Int3D(20, 20, 20))
>>> # creates a cubic box of 20^3 nodes with default spacing parameters in D3Q19␣
↪model.
```

Example

```
>>> lb = espressopp.integrator.LatticeBoltzmann(system, Ni=Int3D(30, 20, 20), a =␣
↪0.5, tau = 0.5)
>>> # creates a box of 30*20*20 nodes with lattice spacing of 0.5 and timestep of␣
↪0.5.
>>> # The model of the lattice is D3Q19.
```

After initialization of the Lattice Boltzmann module, one has a possibility to set several properties of the system:

gamma_b and gamma_s are bulk and shear gammas (default values are 0.);

gamma_odd and gamma_even are (hey-hey, surprise!) odd and even gammas (defaults 0.);

(if you are unsure what these gammas are, please refer to any lattice Boltzmann review. In short, they control correspondent viscosities of the liquid.)

lbTemp is the temperature in lb units for setting up fluctuations (default is 0.);

Example

```
>>> lb = espressopp.integrator.LatticeBoltzmann(system, Ni=Int3D(20, 20, 20))
>>> lb.lbTemp = 0.0000005
>>> # creates a box of 20^3 nodes with lattice spacing of 1. and timestep of 1.␣
↪D3Q19 model.
>>> # then the fluctuations with the temperature of 0.0000005 are initialized.
```

Example

```
>>> lb = espressopp.integrator.LatticeBoltzmann(system, Ni=Int3D(20, 20, 20))
>>> lb.gamma_b = 0.5
>>> lb.gamma_s = 0.5
>>> # creates a box of 20^3 nodes with lattice spacing of 1. and timestep of 1.␣
↪D3Q19 model.
>>> # then the bulk and shear gammas are set to 0.5
```

espressopp.integrator.**LatticeBoltzmann**(*system*, *nodeGrid*, *Ni*, *a*, *tau*, *numDims*, *numVels*)

Parameters

- **system** –
- **nodeGrid** –
- **Ni** –
- **a** – (default: 1.)
- **tau** – (default: 1.)
- **numDims** (*int*) – (default: 3)
- **numVels** (*int*) – (default: 19)

4.19.12 LBInit - abstract class for LatticeBoltzmann initialization and external force management

This abstract class provides the interface to (re-)initialize populations and handle external forces.

espressopp.integrator.LBInit.**createDenVel**(*rho0*, *u0*)
to set initial density and velocity of the LB-fluid.

Parameters

- **rho0** – density
- **u0** – velocity

At the moment we support the following options for LB-fluid initialization:

- *espressopp.integrator.LBInitPopUniform* for uniformly distributed density and velocity, i.e. on every lattice site the density is rho0 and velocity is u0;
- *espressopp.integrator.LBInitPopWave* for uniform density at every lattice site, but harmonic velocity $v_z(x)$ with the period of lattice sites in x-direction;

espressopp.integrator.LBInit.**setForce**(*value*)
to set an external force onto LB-fluid.

Parameters **value** (Real3D) – value of the force

espressopp.integrator.LBInit.**addForce**(*value*)
to add a new external force to the existing one.

Parameters **value** (Real3D) – value of the force

Two main external force types are implemented:

- *espressopp.integrator.LBInitConstForce* to manage constant (gravity-like) force acting on every lattice site and
- *espressopp.integrator.LBInitPeriodicForce* to manage harmonic (position-dependent) force

espressopp.integrator.LBInit.**addForce**(*force*)

Parameters **force** –

Return type

espressopp.integrator.LBInit.**createDenVel**(*rho0*, *u0*)

Parameters

- **rho0** –
- **u0** –

Return type

espressopp.integrator.LBInit.**setForce**(*force*)

Parameters **force** –

4.19.13 LBInitConstForce - handles constant (gravity-like) external force

This class sets or adds a constant (gravity-like) external force to the LB-fluid. At first, one has to create an instance. Only after it one may set or add this force to the system.

Example to set the extenal force to $(0., 0., 0.0005)$:

```
>>> lbforce1 = espressopp.integrator.LBInitConstForce(system,lb)
>>> lbforce1.setForce(Real3D(0.,0.,0.0005))
>>> # a vector sets the external body force directly in lb-units
```

Example to add an extenal force of $(0.0001, 0., 0.)$ to the existing forces:

```
>>> lbforce2 = espressopp.integrator.LBInitConstForce(system,lb)
>>> lbforce2.addForce(Real3D(0.0001,0.,0.))
>>> # a vector sets the external body force directly in lb-units
```

espressopp.integrator.**LBInitConstForce**(*system*, *latticeboltzmann*)

Parameters

- **system** –
- **latticeboltzmann** –

4.19.14 LBInitPeriodicForce - handles external periodic forces

This class sets or adds an external periodic forces to the LB-fluid. At first, one has to create an instance. Only after it one may set or add this force to the system.

Note: Please note, that you have to specify the amplitude of the force. Its particular values at every lattice site will be calculated automatically.

Example to set an external force:

```
>>> lbforce1 = espressopp.integrator.LBInitPeriodicForce(system,lb)
>>> lbforce1.setForce(Real3D(0.,0.,0.0005))
>>> # a vector sets the external body force amplitude
```

Example to add an external force with the amplitude $(0.0001, 0., 0.)$:

```
>>> lbforce2 = espressopp.integrator.LBInitPeriodicForce(system,lb)
>>> lbforce2.addForce(Real3D(0.0001,0.,0.))
>>> # a vector adds the external body force with a Real3D amplitude
```

espressopp.integrator.**LBInitPeriodicForce**(*system*, *latticeboltzmann*)

Parameters

- **system** –
- **latticeboltzmann** –

4.19.15 LBInitPopUniform - creates initial populations with uniform density and velocity

This class creates LB-fluid with uniform density rho0 and velocity u0. You have only to specify the corresponding parameters.

Example:

```
>>> initPop = espressopp.integrator.LBInitPopUniform(system,lb)
>>> initPop.createDenVel(1.0, Real3D(0.,0.,0.0))
>>> # first number is the density, second number is a vector of velocity
```

espressopp.integrator.**LBInitPopUniform**(*system*, *latticeboltzmann*)

Parameters

- **system** –
- **latticeboltzmann** –

4.19.16 LBInitPopWave - creates initial populations with uniform density and harmonic velocity

This class creates LB-fluid with uniform density and harmonic velocity: $v_x = 0$, $v_y = 0$, $v_z(i) = A * sin(2 * \pi * i/N_x)$,

where A is the amplitude of the velocity wave, N_x is the number of lattice nodes in x-direction and i is the node index that the velocity is calculated for.

This may be used to test the system: total moment is zero and the liquid tends to equilibrium, i.e. relaxes to a uniform zero velocity.

Example:

```
>>> initPop = espressopp.integrator.LBInitPopWave(system,lb)
>>> initPop.createDenVel(1.0, Real3D(0.,0.,0.0005))
>>> # the Real3D vector in this case includes amplitudes of the velocities
```

espressopp.integrator.**LBInitPopWave**(*system*, *latticeboltzmann*)

Parameters

- **system** –
- **latticeboltzmann** –

4.19.17 espressopp.integrator.LangevinThermostat

espressopp.integrator.**LangevinThermostat**(*system*)

Parameters **system** –

4.19.18 espressopp.integrator.LangevinThermostat1D

espressopp.integrator.**LangevinThermostat1D**(*system*)

Parameters **system** –

4.19.19 espressopp.integrator.MDIntegrator

espressopp.integrator.MDIntegrator.**addExtension**(*extension*)

Parameters **extension** –

Return type

espressopp.integrator.MDIntegrator.**getExtension**(*k*)

Parameters **k** –

Return type

espressopp.integrator.MDIntegrator.**getNumberOfExtensions**()

Return type

espressopp.integrator.MDIntegrator.**run**(*niter*)

Parameters **niter** –

Return type

4.19.20 espressopp.integrator.Settle

espressopp.integrator.**Settle**(*system*, *fixedtuplelist*, *mO*, *mH*, *distHH*, *distOH*)

Parameters

- **system** –
- **fixedtuplelist** –
- **mO** (*real*) – (default: 16.0)
- **mH** (*real*) – (default: 1.0)
- **distHH** (*real*) – (default: 1.58)
- **distOH** (*real*) – (default: 1.0)

espressopp.integrator.Settle.**addMolecules**(*moleculelist*)

Parameters **moleculelist** –

Return type

4.19.21 espressopp.integrator.StochasticVelocityRescaling

espressopp.integrator.**StochasticVelocityRescaling**(*system*)

Parameters **system** –

4.19.22 espressopp.integrator.TDforce

Example - how to turn on thermodynamic force

```
>>> fthd="tabletf.xvg"
>>> thdforce = espressopp.integrator.TDforce(system,verletlist) #info about centre␣
↪and shape of adress region come from the verletlist. info about size of adress␣
↪region not needed, tabulated file tabletf.xvg should be appropriate for the␣
↪region size
>>> thdforce.addForce(itype=3,filename="tabletf.xvg",type=typeCG)
>>> integrator.addExtension(thdforce)
```

espressopp.integrator.**TDforce**(*system*, *verletlist*)

Parameters

- **system** –
- **verletlist** –

4.19.23 espressopp.integrator.VelocityVerlet

espressopp.integrator.**VelocityVerlet**(*system*)

Parameters **system** –

4.19.24 espressopp.integrator.VelocityVerletOnGroup

espressopp.integrator.**VelocityVerletOnGroup**(*system*, *group*)

Parameters

- **system** –
- **group** –

4.19.25 espressopp.integrator.VelocityVerletOnRadius

espressopp.integrator.**VelocityVerletOnRadius**(*system*, *dampingmass*)

Parameters

- **system** –
- **dampingmass** –

4.19.26 espressopp.integrator.MinimizeEnergy

This is a very simple approach to perform energy minimization of the system. The module uses a steepest descent method. The position of particles is updated following the equation:

$$p_{i+1} = p_i + min(\gamma F_i, d_{max})$$

where p_{i+} is a new position, p_i is a position at current step with corresponding force F_i. The parameters γ and d_{max} are set by user and control the relaxation of the energy and the maximum update of the coordinates per step.

Additionaly, a variable γ step is also implemented. In this case, the position of particles is updated following the equation:

$$p_{i+1} = p_i + d_{max}/f_{max}F_i$$

where f_{max} is a maximum force in a single step of steepest descent method. $\gamma = d_{max}/f_{max}$ is automatically adjusted to a force magnitude.

In both cases, the routine runs until the maximum force is bigger than f_{max} or for at most *n* steps.

Please note This module does not support any integrator extensions.

Example1

```
>>> em = espressopp.integrator.MinimizeEnergy(system, gamma=0.001, ftol=0.01, max_
↪displacement=0.0001)
>>> em.run(10000)
```

Example2

```
>>> em = espressopp.integrator.MinimizeEnergy(system, gamma=0.01, ftol=0.01, max_
↪displacement=0.01, variable_step_flag=True)
>>> em.run(10000)
```

API

espressopp.integrator.**MinimizeEnergy**(*system*, *gamma*, *ftol*, *max_displacement*, *variable_step_flag*)

Parameters

- **system** (espressopp.System) – The espressopp system object.
- **gamma** (*float*) – The gamma value.
- **ftol** (*float*) – The force tolerance
- **max_displacement** (*float*) – The maximum displacement.
- **variable_step_flag** (*bool*) – The flag of adjusting gamma to the force strength.

espressopp.integrator.MinimizeEnergy.**run**(*max_steps*, *verbose*)

Parameters

- **max_steps** (*int*) – The maximum number of steps to run.
- **verbose** (*bool*) – If set to True then display information about maximum force during the iterations.

Returns The true if the maximum force in the system is lower than ftol otherwise false.

Return type bool

espressopp.integrator.MinimizeEnergy.**f_max**
The maximum force in the system.

espressopp.integrator.MinimizeEnergy.**displacement**
The maximum displacement used during the run of MinimizeEnergy

espressopp.integrator.MinimizeEnergy.**step**
The current iteration step.

4.20 interaction

4.20.1 espressopp.interaction.AngularCosineSquared

Calculates the Angular Cosine Squared interaction

$$U = K(cos(\theta) - cos(\theta_0))^2$$

espressopp.interaction.**AngularCosineSquared**(*K*, *theta0*)

Parameters

- **K** (*real*) – (default: 1.0)
- **theta0** (*real*) – (default: 0.0)

espressopp.interaction.**FixedTripleListAngularCosineSquared**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedTripleListAngularCosineSquared.**getFixedTripleList**()

Return type A Python list of lists.

espressopp.interaction.FixedTripleListAngularCosineSquared.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

class espressopp.interaction.AngularCosineSquared.**AngularCosineSquared**
The AngularCosineSquared potential.

4.20.2 espressopp.interaction.AngularHarmonic

Calculates the Angular Harmonic interaction

$$U = K(\theta - \theta_0)^2$$

espressopp.interaction.**AngularHarmonic**(*K*, *theta0*)

Parameters

- **K** (*real*) – (default: 1.0)
- **theta0** (*real*) – (default: 0.0)

espressopp.interaction.**FixedTripleListAngularHarmonic**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedTripleListAngularHarmonic.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

class espressopp.interaction.AngularHarmonic.**AngularHarmonic**
The AngularHarmonic potential.

4.20.3 espressopp.interaction.AngularPotential

This is an abstract class, only needed to be inherited from.

espressopp.interaction.AngularPotential.**computeEnergy**(**args*)

Parameters ***args** –

Return type

espressopp.interaction.AngularPotential.**computeForce**(**args*)

Parameters ***args** –

Return type

4.20.4 espressopp.interaction.AngularUniqueCosineSquared

Calculates the angular unique cosine squared interaction.

$$U = K(cos(\theta) - cos(\theta_0))^2$$

espressopp.interaction.**AngularUniqueCosineSquared**(*K*)

Parameters **K** (*real*) – (default: 1.0)

espressopp.interaction.**FixedTripleAngleListAngularUniqueCosineSquared**(*system*, *ftcl*, *potential*)

Parameters

- **system** –
- **ftcl** –
- **potential** –

espressopp.interaction.FixedTripleAngleListAngularUniqueCosineSquared.**getFixedTripleList**

Return type A Python list of lists.

espressopp.interaction.FixedTripleAngleListAngularUniqueCosineSquared.**setPotential**(*potenti*

Parameters **potential** –

class espressopp.interaction.AngularUniqueCosineSquared.**AngularUniqueCosineSquared**
The AngularUniqueCosineSquared potential.

4.20.5 espressopp.interaction.AngularUniqueHarmonic

Calculates the Angular Unique Harmonic interaction

$$U = K(\theta - \theta_0)^2$$

espressopp.interaction.**AngularUniqueHarmonic**(*K*)

Parameters **K** (*real*) – (default: 1.0)

espressopp.interaction.**FixedTripleAngleListAngularUniqueHarmonic**(*system*, *ftal*, *potential*)

Parameters

- **system** –
- **ftal** –
- **potential** –

espressopp.interaction.FixedTripleAngleListAngularUniqueHarmonic.**setPotential**(*potential*)

Parameters **potential** –

4.20.6 espressopp.interaction.AngularUniquePotential

This is an abstract class, only needed to be inherited from.

espressopp.interaction.AngularUniquePotential.**computeEnergy**(**args*)

Parameters ***args** –

Return type

espressopp.interaction.AngularUniquePotential.**computeForce**(**args*)

Parameters ***args** –

Return type

4.20.7 espressopp.interaction.Cosine

Calculates the Cosine Interaction

$$U = K(1 + cos(\theta - \theta_0))$$

espressopp.interaction.**Cosine**(*K*, *theta0*)

Parameters

- **K** (*real*) – (default: 1.0)
- **theta0** (*real*) – (default: 0.0)

espressopp.interaction.**FixedTripleListCosine**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedTripleListCosine.**getFixedTripleList**()

Return type A Python list of lists.

espressopp.interaction.FixedTripleListCosine.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.Cosine.**Cosine**
The Cosine potential.

4.20.8 CoulombKSpaceP3M - Coulomb potential and interaction Objects (*K* space part)

This is the *K* space part of potential of Coulomb long range interaction according to the P3M summation technique. Good explanation of P3M summation could be found here *[Allen89]*, *[Deserno98]*.

Example:

```
>>> ewaldK_pot = espressopp.interaction.CoulombKSpaceP3M(system, coulomb_
↪prefactor, alpha, kspacecutoff)
>>> ewaldK_int = espressopp.interaction.CellListCoulombKSpaceP3M(system.storage,␣
↪ewaldK_pot)
>>> system.addInteraction(ewaldK_int)
```

!IMPORTANT Coulomb interaction needs *R* space part as well CoulombRSpace.

Definition:

It provides potential object *CoulombKSpaceP3M* and interaction object *CellListCoulombKSpaceP3M* based on all particles list.

The *potential* is based on the system information (System) and parameters: Coulomb prefactor (coulomb_prefactor), P3M parameter (alpha), and the cutoff in K space (kspacecutoff).

```
>>> ewaldK_pot = espressopp.interaction.CoulombKSpaceP3M(system, coulomb_
↪prefactor, alpha, kspacecutoff)
```

Potential Properties:

- *ewaldK_pot.prefactor*

  The property 'prefactor' defines the Coulomb prefactor.

- *ewaldK_pot.alpha*

  The property 'alpha' defines the P3M parameter *alpha*.

- *ewaldK_pot.kmax*

  The property 'kmax' defines the cutoff in *K* space.

The *interaction* is based on the all particles list. It needs the information from Storage and *K* space part of potential.

```
>>> ewaldK_int = espressopp.interaction.CellListCoulombKSpaceP3M(system.
↪storage, ewaldK_pot)
```

Interaction Methods:

- *getPotential()*

  Access to the local potential.

Adding the interaction to the system:

```
>>> system.addInteraction(ewaldK_int)
```

espressopp.interaction.**CoulombKSpaceP3M**(*system*, *C_pref*, *alpha*, *M*, *P*, *rcut*, *interpolation*)

Parameters

- **system** –
- **C_pref** –
- **alpha** –
- **M** –
- **P** –
- **rcut** –
- **interpolation** (*int*) – (default: 200192)

espressopp.interaction.**CellListCoulombKSpaceP3M**(*storage*, *potential*)

Parameters

- **storage** –
- **potential** –

espressopp.interaction.CellListCoulombKSpaceP3M.**getPotential**()

Return type

4.20.9 espressopp.interaction.CoulombTruncated

$$U = k\frac{q_i q_j}{d_{ij}}$$

where k is the user-supplied prefactor, q_i is the charge of particle i, and d_{ij} is interparticle distance

In this interaction potential, a different charge can be associated with each particle. For a truncated Coulomb interaction potential where only one $q_i q_j$ value is specified for all interactions, see CoulombTruncatedUniqueCharge.

espressoppp.interaction.**CoulombTruncated**(*prefactor*, *cutoff*)

Parameters

- **prefactor** (*real*) – (default: 1.0) user-supplied prefactor *k*
- **cutoff** (*real*) – (default: infinity) user-supplied interaction cutoff

espressoppp.interaction.**VerletListCoulombTruncated**(*vl*)

Parameters **vl** (VerletList) – verlet list object defined earlier in python script

espressoppp.interaction.VerletListCoulombTruncated.**getPotential**(*type1*, *type2*)

Parameters

- **type1** (*integer*) – type of first atom in pair
- **type2** (*integer*) – type of second atom in pair

espressopppp.interaction.VerletListCoulombTruncated.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** (*integer*) – type of first atom in pair
- **type2** (*integer*) – type of second atom in pair
- **potential** (*CoulombTruncated potential*) – potential object defined earlier in python script

espressopppp.interaction.**FixedPairListTypesCoulombTruncated**(*system*, *vl*)

Parameters

- **system** (System) – system object defined earlier in the python script
- **vl** (FixedPairList) – fixedpairlist object defined earlier in the python script

espressopppp.interaction.FixedPairListTypesCoulombTruncated.**setPotential**(*potential*)

Parameters

- **type1** (*integer*) – type of first atom in pair
- **type2** (*integer*) – type of second atom in pair
- **potential** (*CoulombTruncated potential*) – potential object defined earlier in python script

#Example:

```
>>> pref = 138.935485
>>> rc = 1.2
>>> fixedpairlist = espresso.FixedPairList(system.storage)
>>> fixedpairlist.addBonds([(1,2),(2,3)])
>>> pot = espressopp.interaction.CoulombTruncated(prefactor=pref, cutoff=rc)
>>> interaction=espressopp.interaction.
↪FixedPairListTypesCoulombTruncated(system,fixedpairlist)
>>> interaction.setPotential(type1=0, type2=1, potential=pot)
>>> system.addInteraction(interaction)
```

class espressopp.interaction.CoulombTruncated.**CoulombTruncated**
The CoulombTruncated potential.

4.20.10 espressopp.interaction.CoulombTruncatedUniqueCharge

$$U = \frac{Q}{d}$$

where Q is the product of the charges of the two particles and d is their distance from each other.

In this interaction potential, a unique $Q = q_i q_j$ value is specified per potential. For a more flexible truncated Coulomb interaction potential where each individual particle has its own charge q_i, see CoulombTruncated.

espressopp.interaction.**CoulombTruncatedUniqueCharge**(*qq*, *cutoff*, *shift*)

Parameters

- **qq** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)
- **shift** – (default: “auto”)

espressopp.interaction.**VerletListCoulombTruncatedUniqueCharge**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListCoulombTruncatedUniqueCharge.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListCoulombTruncatedUniqueCharge.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListCoulombTruncatedUniqueCharge**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListCoulombTruncatedUniqueCharge.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListCoulombTruncatedUniqueCharge**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListCoulombTruncatedUniqueCharge.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.CoulombTruncatedUniqueCharge.**CoulombTruncatedUniqueCharge**
The CoulombTruncatedUniqueCharge potential.

4.20.11 espressopp.interaction.DihedralHarmonicCos

$$U = K(cos(\phi) - cos(\phi_0))^2$$

espressopp.interaction.**DihedralHarmonicCos**(*K*, *phi0*)

Parameters

- **K** (*real*) – (default: 0.0)
- **phi0** (*real*) – (default: 0.0)

espressopp.interaction.**FixedQuadrupleListDihedralHarmonicCos**(*system*, *fql*, *potential*)

Parameters

- **system** –
- **fql** –
- **potential** –

espressopp.interaction.FixedQuadrupleListDihedralHarmonicCos.**getFixedQuadrupleList**()

Return type A Python list of lists.

espressopp.interaction.FixedQuadrupleListDihedralHarmonicCos.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.DihedralHarmonicCos.**DihedralHarmonicCos**
The DihedralHarmonicCos potential.

4.20.12 espressopp.interaction.DihedralHarmonicNCos

The dihedral harmonic potential

$$U(\phi_{ijkl}) = K[1 + cos(N \cdot \phi_{ijkl} - \phi_0)]$$

where the *K* is a constant, the angles should be provided in radians. The *N* is a multiplicity.

Reference: http://www.uark.edu/ua/fengwang/DLPOLY2/node49.html

espressopp.interaction.**DihedralHarmonicNCos**(*K*, *phi0*, *multiplicity*)

Parameters

- **K** (*real*) – (default: 0.0)
- **phi0** (*real*) – (default: 0.0)
- **multiplicity** (*int*) – (default: 1)

espressopp.interaction.**FixedQuadrupleListDihedralHarmonicNCos**(*system*, *fql*, *potential*)

Parameters

- **system** –
- **fql** –
- **potential** –

espressopp.interaction.FixedQuadrupleListDihedralHarmonicNCos.**getFixedQuadrupleList**()

Return type A Python list of lists.

espressopp.interaction.FixedQuadrupleListDihedralHarmonicNCos.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.DihedralHarmonicNCos.**DihedralHarmonicNCos**
The DihedralHarmonicNCos potential.

class espressopp.interaction.DihedralHarmonicNCos.**FixedQuadrupleListDihedralHarmonicNCosLo**

The (local) DihedralHarmonicNCos interaction using FixedQuadruple lists.

4.20.13 espressopp.interaction.DihedralHarmonicUniqueCos

$$U = K(cos(\phi) - cos(\phi_0))^2$$

espressopp.interaction.**DihedralHarmonicUniqueCos**(*K*)

Parameters **K** (*real*) – (default: 0.0)

espressopp.interaction.**FixedQuadrupleAngleListDihedralHarmonicUniqueCos**(*system*, *fqal*, *potential*)

Parameters

- **system** –
- **fqal** –
- **potential** –

espressopp.interaction.FixedQuadrupleAngleListDihedralHarmonicUniqueCos.**getFixedQuadrupl**

Return type A Python list of lists.

espressopp.interaction.FixedQuadrupleAngleListDihedralHarmonicUniqueCos.**setPotential**(*pote*

Parameters **potential** –

class espressopp.interaction.DihedralHarmonicUniqueCos.**DihedralHarmonicUniqueCos**

The DihedralHarmonicUniqueCos potential.

4.20.14 espressopp.interaction.DihedralPotential

This is an abstract class, only needed to be inherited from.

espressopp.interaction.DihedralPotential.**computeEnergy**(**args*)

Parameters ***args** –

Return type

espressopp.interaction.DihedralPotential.**computeForce**(**args*)

Parameters ***args** –

Return type

4.20.15 espressopp.interaction.DihedralUniquePotential

This is an abstract class, only needed to be inherited from.

espressopp.interaction.DihedralUniquePotential.**computeEnergy**(**args*)

Parameters ***args** –

Return type

espressopp.interaction.DihedralUniquePotential.**computeForce**(**args*)

Parameters ***args** –

Return type

4.20.16 espressopp.interaction.DihedralRB

The proper dihedral with Ryckaert-Bellemans form.

$$U_{rb}(\phi_{ijkl}) = \sum_{n=0}^{5} K_n (cos(\theta))^n$$

where the $\theta = \phi - 180^\circ$ and $K_{0...5}$ are the coefficients.

By default the IUPAC convention is used, where ϕ is the angle between planes ijk and jkl. The 0° corresponds to the *cis* configuration.

Reference: http://www.gromacs.org/Documentation/Manual

espressopp.interaction.**DihedralRB**(*K0*, *K1*, *K2*, *K3*, *K4*, *K5*, *iupac*)

Parameters

- **K0** (*real*) – (default: 0.0)
- **K1** (*real*) – (default: 0.0)
- **K2** (*real*) – (default: 0.0)
- **K3** (*real*) – (default: 0.0)
- **K4** (*real*) – (default: 0.0)
- **K5** (*real*) – (default: 0.0)
- **iupac** – (default: True)

espressopp.interaction.**FixedQuadrupleListDihedralRB**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedQuadrupleListDihedralRB.**getFixedQuadrupleList**()

Return type A Python list of lists.

espressopp.interaction.FixedQuadrupleListDihedralRB.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

4.20.17 FENE interaction

Implementation of the Finitely Extensible Non-linear Elastic potential:

$$U(r) = -\frac{1}{2} r_{\max}^2 K \log \left[1 - \left(\frac{r - r_0}{r_{\max}} \right)^2 \right]$$

espressopp.interaction.**FENE**(*K*, *r0*, *rMax*, *cutoff*, *shift*)

Parameters

- **K** (*real*) – (default: 1.0)
- **r0** (*real*) – (default: 0.0)
- **rMax** (*real*) – (default: 1.0)
- **cutoff** (*real*) – (default: infinity)
- **shift** (*real*) – (default: 0.0)

espressopp.interaction.**FixedPairListFENE**(*system*, *pair_list*, *potential*)

Parameters

- **system** (*object*) – your system *espressopp.System()*
- **pair_list** (*object*) – list of bonds *espressopp.FixedPairList()*
- **potential** (*object*) – *espressopp.interaction.FENE()*

espressopp.interaction.FixedPairListFENE.**getFixedPairList**()

Return type A Python list of lists.

espressopp.interaction.FixedPairListFENE.**getPotential**()

Return type object

espressopp.interaction.FixedPairListFENE.**setFixedPairList**(*pair_list*)

Parameters **pair_list** (*fixedpairlist*) –

espressopp.interaction.FixedPairListFENE.**setPotential**(*potential*)

Parameters **potential** –

Example of usage

```
>>> # The following example shows how to bond particle 1 to particles 0 and 2 by a␣
↪FENE potential.
>>> # We assume the particles are already in the storage of the system
>>> # Initialize list of pairs that will be bonded by FENE
>>> pair_list = espressopp.FixedPairList(system.storage)
>>> # Set which pairs belong to the pair_list i.e. particle 0 is bonded to␣
↪particles 1 and 2.
>>> pair_list.addBonds([(0,1),(1,2)])
>>> # Initialize the potential and set up the parameters.
>>> potFENE    = espressopp.interaction.FENE(K=30.0, r0=0.0, rMax=1.5)
>>> # Set which system, pair list and potential is the interaction associated with.
>>> interFENE = espressopp.interaction.FixedPairListFENE(system, pair_list,␣
↪potFENE)
>>> # Add the interaction to the system.
>>> system.addInteraction(interFENE)
```

4.20.18 espressopp.interaction.FENECapped

$$U = -\frac{1}{2} r_{max}^2 K \cdot log \left(1 - \frac{D - {r_0}^2}{r_{max}}\right)$$

where $D = dist$ if

${cap_{rad}}^2 > dist$

and $D = cap_{rad}$ else.

espressopp.interaction.**FENECapped**(*K*, *r0*, *rMax*, *cutoff*, *caprad*, *shift*)

Parameters

- **K** (*real*) – (default: 1.0)
- **r0** (*real*) – (default: 0.0)
- **rMax** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)
- **caprad** (*real*) – (default: 1.0)
- **shift** (*real*) – (default: 0.0)

espressopp.interaction.**FixedPairListFENECapped**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListFENECapped.**getFixedPairList**()

Return type A Python list of lists.

espressopp.interaction.FixedPairListFENECapped.**getPotential**()

Return type

espressopp.interaction.FixedPairListFENECapped.**setFixedPairList**(*fixedpairlist*)

Parameters **fixedpairlist** –

espressopp.interaction.FixedPairListFENECapped.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.FENECapped.**FENECapped**
The FENECapped potential.

4.20.19 GravityTruncated

This is an implementation of a truncated (cutoff) Gravity Potential

$$U = P \cdot \frac{m_1 \cdot m_2}{|p_1 - p_2|}$$

where m_i is the mass of the *i* th particle, p_i its position and *P* a prefactor.

espressopp.interaction.**GravityTruncated**(*prefactor*, *cutoff*)

Parameters

- **prefactor** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)

espressopp.interaction.**VerletListGravityTruncated**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListGravityTruncated.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListGravityTruncated.**getVerletList**()

Return type A Python list of lists.

espressopp.interaction.VerletListGravityTruncated.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

4.20.20 espressopp.interaction.Harmonic

$$U = K(d - r_0)^2$$

espressopp.interaction.**Harmonic**(*K*, *r0*, *cutoff*, *shift*)

Parameters

- **K** (*real*) – (default: 1.0)
- **r0** (*real*) – (default: 0.0)
- **cutoff** – (default: infinity)
- **shift** (*real*) – (default: 0.0)

espressopp.interaction.**FixedPairListHarmonic**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListHarmonic.**getFixedPairList**()

Return type A Python list of lists.

espressopp.interaction.FixedPairListHarmonic.**setFixedPairList**(*fixedpairlist*)

Parameters **fixedpairlist** –

espressopp.interaction.FixedPairListHarmonic.**setPotential**(*potential*)

Parameters **potential** –

espressopp.interaction.**FixedPairListTypesHarmonic**(*system*, *vl*)

Parameters

- **system** –
- **vl** –

espressopp.interaction.FixedPairListTypesHarmonic.**getFixedPairList**()

Return type A Python list of lists.

espressopp.interaction.FixedPairListTypesHarmonic.**setFixedPairList**(*fixedpairlist*)

Parameters **fixedpairlist** –

espressopp.interaction.FixedPairListTypesHarmonic.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.FixedPairListTypesHarmonic.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

class espressopp.interaction.Harmonic.**Harmonic**
The Harmonic potential.

4.20.21 espressopp.interaction.HarmonicUnique

$$U = K(d - d_{cur})^2;$$

espressopp.interaction.**HarmonicUnique**(*K*)

Parameters **K** (*real*) – (default: 1.0)

espressopp.interaction.**FixedPairDistListHarmonicUnique**(*system*, *fpl*, *potential*)

Parameters

- **system** –
- **fpl** –
- **potential** –

espressopp.interaction.FixedPairDistListHarmonicUnique.**getFixedPairList**()

Return type A Python list of lists.

espressopp.interaction.FixedPairDistListHarmonicUnique.**setFixedPairList**(*fixedpairlist*)

Parameters **fixedpairlist** –

espressopp.interaction.FixedPairDistListHarmonicUnique.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.HarmonicUnique.**HarmonicUnique**
The HarmonicUnique potential.

4.20.22 espressopp.interaction.Interaction

This is an abstract class, only needed to be inherited from.

espressopp.interaction.Interaction.**bondType**()

Return type int

espressopp.interaction.Interaction.**computeEnergy**()

Return type real

espressopp.interaction.Interaction.**computeEnergyAA**()

Return type real

espressopp.interaction.Interaction.**computeEnergyDeriv**()

Return type real

espressopp.interaction.Interaction.**computeEnergyCG**()

Return type real

espressopp.interaction.Interaction.**computeVirial**()

Return type real

4.20.23 espressopp.interaction.LJcos

if $r^2 \leq border_{pot}$, then:

$$U = 4(\frac{1}{r^{12}} - \frac{1}{r^6}) + 1 - \phi$$

else:

$$U = \frac{1}{2}\phi(cos(\alpha r^2 + \beta) - 1)$$

espressopp.interaction.**LJcos**(*phi*)

Parameters **phi** (*real*) – (default: 1.0)

espressopp.interaction.**VerletListLJcos**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListLJcos.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListLJcos.**getVerletList**()

Return type A Python list of lists.

espressopp.interaction.VerletListLJcos.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListAdressLJcos**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListAdressLJcos.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListAdressLJcos.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressLJcos**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressLJcos.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressLJcos.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListLJcos**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListLJcos.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListLJcos**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListLJcos.**getFixedPairList**()

Return type A Python list of lists.

espressopp.interaction.FixedPairListLJcos.**setFixedPairList**(*fixedpairlist*)

Parameters **fixedpairlist** –

espressopp.interaction.FixedPairListLJcos.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.LJcos.**LJcos**
The Lennard-Jones potential.

4.20.24 espressopp.interaction.LennardJones

$$V(r) = 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6} \right]$$

espressopp.interaction.**LennardJones**(*epsilon*, *sigma*, *cutoff*, *shift*)

Parameters

- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)
- **shift** – (default: “auto”)

espressopp.interaction.**VerletListLennardJones**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListLennardJones.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListLennardJones.**getVerletList**()

Return type A Python list of lists.

espressopp.interaction.VerletListLennardJones.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListAdressLennardJones**(*vl*, *fixedtupleList*)

Parameters

- **vl** –

- **fixedtupleList** –

espressopp.interaction.VerletListAdressLennardJones.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListAdressLennardJones.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListAdressLennardJones2**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListAdressLennardJones2.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListAdressLennardJones2.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressLennardJones**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressLennardJones.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressLennardJones.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressLennardJones2**(*vl*, *fixedtupleList*, *KTI*)

Parameters

- **vl** –
- **fixedtupleList** –
- **KTI** – (default: False)

espressopp.interaction.VerletListHadressLennardJones2.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressLennardJones2.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListLennardJones**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListLennardJones.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListLennardJones**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListLennardJones.**getFixedPairList**()

Return type A Python list of lists.

espressopp.interaction.FixedPairListLennardJones.**getPotential**()

Return type

espressopp.interaction.FixedPairListLennardJones.**setFixedPairList**(*fixedpairlist*)

Parameters **fixedpairlist** –

espressopp.interaction.FixedPairListLennardJones.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.LennardJones.**LennardJones**
The Lennard-Jones potential.

4.20.25 espressopp.interaction.LennardJonesAutoBonds

$$V(r) = 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6} \right]$$

espressopp.interaction.**LennardJonesAutoBonds**(*epsilon*, *sigma*, *cutoff*, *bondlist*, *maxcrosslinks*)

Parameters

- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)
- **bondlist** – (default: None)
- **maxcrosslinks** (*int*) – (default: 2)

espressopp.interaction.**VerletListLennardJonesAutoBonds**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListLennardJonesAutoBonds.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListLennardJonesAutoBonds.**getVerletList**()

Return type A Python list of lists.

espressopp.interaction.VerletListLennardJonesAutoBonds.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListAdressLennardJonesAutoBonds**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListAdressLennardJonesAutoBonds.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressLennardJonesAutoBonds**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressLennardJonesAutoBonds.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListLennardJonesAutoBonds**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListLennardJonesAutoBonds.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListLennardJonesAutoBonds**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListLennardJonesAutoBonds.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.LennardJonesAutoBonds.**LennardJonesAutoBonds**
The Lennard-Jones auto bonds potential.

4.20.26 espressopp.interaction.LennardJonesCapped

$$V(r) = 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6} \right]$$

where *r* is either the distance or the capped distance, depending on which is greater.

espressopp.interaction.**LennardJonesCapped**(*epsilon*, *sigma*, *cutoff*, *caprad*, *shift*)

Parameters

- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)
- **caprad** (*real*) – (default: 0.0)
- **shift** – (default: “auto”)

espressopp.interaction.**VerletListLennardJonesCapped**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListLennardJonesCapped.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListLennardJonesCapped.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –

- **potential** –

espressopp.interaction.**VerletListAdressLennardJonesCapped**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListAdressLennardJonesCapped.**getPotentialAT**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListAdressLennardJonesCapped.**getPotentialCG**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListAdressLennardJonesCapped.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListAdressLennardJonesCapped.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressLennardJonesCapped**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressLennardJonesCapped.**getPotentialAT**(*type1*, *type2*)

Parameters

- **type1** –

- **type2** –

Return type

espressopp.interaction.VerletListHadressLennardJonesCapped.**getPotentialCG**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListHadressLennardJonesCapped.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressLennardJonesCapped.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListLennardJonesCapped**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListLennardJonesCapped.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.CellListLennardJonesCapped.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListLennardJonesCapped**(*system*, *vl*, *potential*)

Parameters

- **system** –

- **vl** –
- **potential** –

espressopp.interaction.FixedPairListLennardJonesCapped.**getPotential**()

Return type

espressopp.interaction.FixedPairListLennardJonesCapped.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.LennardJonesCapped.**LennardJonesCapped**
The Lennard-Jones potential.

4.20.27 espressopp.interaction.LennardJonesEnergyCapped

$$V(r) = 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6} \right]$$

where *r* is either the distance or the capped distance, depending on which is greater.

espressopp.interaction.**LennardJonesEnergyCapped**(*epsilon*, *sigma*, *cutoff*, *caprad*, *shift*)

Parameters

- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)
- **caprad** (*real*) – (default: 0.0)
- **shift** – (default: "auto")

espressopp.interaction.**VerletListLennardJonesEnergyCapped**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListLennardJonesEnergyCapped.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListLennardJonesEnergyCapped.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListAdressLennardJonesEnergyCapped**(*vl*, *fixedtupleList*)

Parameters

- **vl** –

- **fixedtupleList** –

espressopp.interaction.VerletListAdressLennardJonesEnergyCapped.**getPotentialAT**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListAdressLennardJonesEnergyCapped.**getPotentialCG**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListAdressLennardJonesEnergyCapped.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListAdressLennardJonesEnergyCapped.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressLennardJonesEnergyCapped**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressLennardJonesEnergyCapped.**getPotentialAT**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListHadressLennardJonesEnergyCapped.**getPotentialCG**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListHadressLennardJonesEnergyCapped.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressLennardJonesEnergyCapped.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListLennardJonesEnergyCapped**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListLennardJonesEnergyCapped.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.CellListLennardJonesEnergyCapped.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListLennardJonesEnergyCapped**(*system*, *vl*, *potential*)

Parameters

- **system** –

- **vl** –
- **potential** –

espressopp.interaction.FixedPairListLennardJonesEnergyCapped.**getPotential**()

Return type

espressopp.interaction.FixedPairListLennardJonesEnergyCapped.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.LennardJonesEnergyCapped.**LennardJonesEnergyCapped**
The Lennard-Jones potential.

4.20.28 espressopp.interaction.LennardJonesExpand

$$V(r) = 4\varepsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6} \right]$$

espressopp.interaction.**LennardJonesExpand**(*epsilon*, *sigma*, *delta*, *cutoff*, *shift*)

Parameters

- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **delta** (*real*) – (default: 0.0)
- **cutoff** – (default: infinity)
- **shift** – (default: “auto”)

espressopp.interaction.**VerletListLennardJonesExpand**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListLennardJonesExpand.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListLennardJonesExpand.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListLennardJonesExpand**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListLennardJonesExpand.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListLennardJonesExpand**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListLennardJonesExpand.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.LennardJonesExpand.**LennardJonesExpand**
The LennardJonesExpand potential.

4.20.29 espressopp.interaction.LennardJonesGromacs

if $d^2 > r_1^2$

$$U = 4\varepsilon(\frac{sigma^{12}}{d^{12}} - \frac{sigma^6}{d^6}) + (d - r_1)^3(ljsw3 + ljsw4(d - r_1) + ljsw5)$$

else

$$U = 4\varepsilon(\frac{\sigma^{12}}{d^{12}} - \frac{\sigma^6}{d^6})$$

espressopp.interaction.**LennardJonesGromacs**(*epsilon*, *sigma*, *r1*, *cutoff*, *shift*)

Parameters

- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **r1** (*real*) – (default: 0.0)
- **cutoff** – (default: infinity)
- **shift** – (default: “auto”)

espressopp.interaction.**VerletListLennardJonesGromacs**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListLennardJonesGromacs.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListLennardJonesGromacs.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListLennardJonesGromacs**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListLennardJonesGromacs.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListLennardJonesGromacs**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListLennardJonesGromacs.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.LennardJonesGromacs.**LennardJonesGromacs**
The LennardJonesGromacs potential.

4.20.30 espressopp.interaction.Morse

This class provides methods to compute forces and energies of the Morse potential.

$$U = \varepsilon \left(e^{-2\alpha(r-r_{min})} - 2e^{-\alpha(r-r_{min})} \right)$$

espressopp.interaction.**Morse**(*epsilon*, *alpha*, *rMin*, *cutoff*, *shift*)

Parameters

- **epsilon** (*real*) – (default: 1.0)
- **alpha** (*real*) – (default: 1.0)
- **rMin** (*real*) – (default: 0.0)
- **cutoff** – (default: infinity)
- **shift** – (default: “auto”)

espressopp.interaction.**VerletListMorse**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListMorse.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListMorse.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListAdressMorse**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListAdressMorse.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListAdressMorse.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressMorse**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressMorse.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressMorse.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListMorse**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListMorse.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListMorse**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListMorse.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.Morse.**Morse**
The Morse potential.

4.20.31 espressopp.interaction.OPLS

This class provides methods to compute forces and energies of the OPLS dihedral potential. To create a new dihedral potential.

$$U = \sum_{j=1}^{4} K_j(1 + cos(j\phi))$$

espressopp.interaction.**OPLS**(*K1*, *K2*, *K3*, *K4*)

Parameters

- **K1** (*real*) – (default: 1.0)
- **K2** (*real*) – (default: 0.0)
- **K3** (*real*) – (default: 0.0)
- **K4** (*real*) – (default: 0.0)

espressopp.interaction.**FixedQuadrupleListOPLS**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedQuadrupleListOPLS.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

class espressopp.interaction.OPLS.**OPLS**
The OPLS potential.

4.20.32 espressopp.interaction.Potential

This is an abstract class, only needed to be inherited from.

espressopp.interaction.Potential.**computeEnergy**(**args*)

Parameters ***args** –

Return type

espressopp.interaction.Potential.**computeForce**(**args*)

Parameters ***args** –

Return type

4.20.33 espressopp.interaction.PotentialUniqueDist

This is an abstract class, only needed to be inherited from.

espressopp.interaction.PotentialUniqueDist.**computeEnergy**(**args*)

Parameters ***args** –

Return type

espressopp.interaction.PotentialUniqueDist.**computeForce**(**args*)

Parameters ***args** –

Return type

4.20.34 espressopp.interaction.PotentialVSpherePair

This is an abstract class, only needed to be inherited from.

espressopp.interaction.PotentialVSpherePair.**computeEnergy**(**args*)

Parameters ***args** –

Return type

espressopp.interaction.PotentialVSpherePair.**computeForce**(**args*)

Parameters ***args** –

Return type

4.20.35 espressopp.interaction.Quartic

This class provides methods to compute forces and energies of the Quartic potential.

$$U = \frac{K}{4}\left(d^2 - r_0^2\right)^2$$

espressopp.interaction.**Quartic**(*K*, *r0*, *cutoff*, *shift*)

Parameters

- **K** (*real*) – (default: 1.0)
- **r0** (*real*) – (default: 0.0)
- **cutoff** – (default: infinity)
- **shift** (*real*) – (default: 0.0)

espressopp.interaction.**FixedPairListQuartic**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListQuartic.**getFixedPairList**()

Return type A Python list of lists.

espressopp.interaction.FixedPairListQuartic.**setFixedPairList**(*fixedpairlist*)

Parameters **fixedpairlist** –

espressopp.interaction.FixedPairListQuartic.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

class espressopp.interaction.Quartic.**Quartic**
The Quartic potential.

4.20.36 espressopp.interaction.ReactionFieldGeneralized

This class provides methods to compute forces and energies of the generalized reaction field.

$$U = PQ\left(\frac{1}{d} - \frac{\left(1+\frac{(\varepsilon_1-4\varepsilon_2)(1+\kappa r_c)-2\varepsilon_2\kappa {r_c}^2}{(\varepsilon_1+2\varepsilon_2)(1+\kappa r_c)+\varepsilon_2\kappa {r_c}^2}\right)}{r_c^3 2}\cdot d^2 - \frac{3\varepsilon_2}{r_c(2\varepsilon_2+1)}\right)$$

where P is a prefactor, Q is the product of the charges of the two particles, d is their distance from each other, and r_c the cutoff-radius.

espressopp.interaction.**ReactionFieldGeneralized**(*prefactor*, *kappa*, *epsilon1*, *epsilon2*, *cutoff*, *shift*)

Parameters

- **prefactor** (*real*) – (default: 1.0)
- **kappa** (*real*) – (default: 0.0)
- **epsilon1** (*real*) – (default: 1.0)
- **epsilon2** (*real*) – (default: 80.0)
- **cutoff** – (default: infinity)
- **shift** – (default: “auto”)

espressopp.interaction.**VerletListReactionFieldGeneralized**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListReactionFieldGeneralized.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListReactionFieldGeneralized.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListAdressReactionFieldGeneralized**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListAdressReactionFieldGeneralized.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListAdressReactionFieldGeneralized.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressReactionFieldGeneralized**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressReactionFieldGeneralized.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –

- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressReactionFieldGeneralized.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListReactionFieldGeneralized**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListReactionFieldGeneralized.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

class espressopp.interaction.ReactionFieldGeneralized.**ReactionFieldGeneralized**
The ReactionFieldGeneralized potential.

4.20.37 espressopp.interaction.SoftCosine

This class provides methods to compute forces and energies ofthe SoftCosine potential.

$$V(r) = A\left[1.0 + cos\left(\frac{\pi r}{r_c}\right)\right]$$

espressopp.interaction.**SoftCosine**(*A*, *cutoff*, *shift*)

Parameters

- **A** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)
- **shift** – (default: "auto")

espressopp.interaction.**VerletListSoftCosine**(*stor*)

Parameters **stor** –

espressopp.interaction.VerletListSoftCosine.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListSoftCosine**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListSoftCosine.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListSoftCosine**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListSoftCosine.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.SoftCosine.**SoftCosine**
The SoftCosine potential.

4.20.38 espressopp.interaction.StillingerWeberPairTerm

This class provides methods to compute forces and energies of 2 body term of Stillinger-Weber potential.

$$U = \varepsilon A \left[\frac{d}{\sigma}^{-p} (B-1) \right] exp\left(\frac{1}{\frac{d}{\sigma} - r_c} \right)$$

where r_c is the cutoff-radius.

espressopp.interaction.**StillingerWeberPairTerm**(*A*, *B*, *p*, *q*, *epsilon*, *sigma*, *cutoff*)

Parameters

- **A** –
- **B** –
- **p** –
- **q** –
- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)

espressopp.interaction.**VerletListStillingerWeberPairTerm**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListStillingerWeberPairTerm.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListStillingerWeberPairTerm.**getVerletList**()

Return type A Python list of lists.

espressopp.interaction.VerletListStillingerWeberPairTerm.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListAdressStillingerWeberPairTerm**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListAdressStillingerWeberPairTerm.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListAdressStillingerWeberPairTerm.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressStillingerWeberPairTerm**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressStillingerWeberPairTerm.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –

- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressStillingerWeberPairTerm.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListStillingerWeberPairTerm**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListStillingerWeberPairTerm.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListStillingerWeberPairTerm**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListStillingerWeberPairTerm.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.StillingerWeberPairTerm.**StillingerWeberPairTerm**
The Lennard-Jones potential.

4.20.39 espressopp.interaction.StillingerWeberPairTermCapped

This class provides methods to compute forces and energies of 2 body term of Stillinger-Weber potential.

If the distance is smaller than the cap-radius:

$$U = A[d_{12}^{-p}(B-1)]e^{\frac{1}{d_{12}-r_c}}$$

where r_c is the cutoff-radius.

espressopp.interaction.**StillingerWeberPairTermCapped**(*A*, *B*, *p*, *q*, *epsilon*, *sigma*, *cutoff*, *caprad*)

Parameters

- **A** –

- **B** –
- **p** –
- **q** –
- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)
- **caprad** (*real*) – (default: 0.0)

espressopp.interaction.**VerletListStillingerWeberPairTermCapped**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListStillingerWeberPairTermCapped.**getCaprad**()

Return type

espressopp.interaction.VerletListStillingerWeberPairTermCapped.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListStillingerWeberPairTermCapped.**getVerletList**()

Return type A Python list of lists.

espressopp.interaction.VerletListStillingerWeberPairTermCapped.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListAdressStillingerWeberPairTermCapped**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListAdressStillingerWeberPairTermCapped.**setPotentialAT**(*type1 type2 potential*)

Parameters

- **type1** –
- **type2** –

- **potential** –

espressopp.interaction.VerletListAdressStillingerWeberPairTermCapped.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressStillingerWeberPairTermCapped**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressStillingerWeberPairTermCapped.**setPotentialAT**(*type*, *type*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressStillingerWeberPairTermCapped.**setPotentialCG**(*type*, *type*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListStillingerWeberPairTermCapped**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListStillingerWeberPairTermCapped.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListStillingerWeberPairTermCapped**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListStillingerWeberPairTermCapped.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.StillingerWeberPairTermCapped.**StillingerWeberPairTermCapped**
The Lennard-Jones potential.

4.20.40 espressopp.interaction.StillingerWeberTripleTerm

This class provides methods to compute forces and energies of the Stillinger Weber Triple Term potential.

if $d_{12} >= r_{c_1}$ or $d_{32} >= r_{c_2}$

$$U = 0.0$$

else

$$U = \varepsilon\lambda e^{\frac{\sigma\gamma_1}{|r_{12}|-\sigma r_{c_1}}} + \frac{\sigma\gamma_2}{|r_{32}|-\sigma r_{c_2}}\left(\frac{r_{12}r_{32}}{|r_{12}|\cdot|r_{32}|} - cos(\theta_0)\right)^2$$

espressopp.interaction.**StillingerWeberTripleTerm**(*gamma*, *theta0*, *lmbd*, *epsilon*, *sigma*, *cutoff*)

Parameters

- **gamma** (*real*) – (default: 0.0)
- **theta0** (*real*) – (default: 0.0)
- **lmbd** (*real*) – (default: 0.0)
- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)

espressopp.interaction.**VerletListStillingerWeberTripleTerm**(*system*, *vl3*)

Parameters

- **system** –
- **vl3** –

espressopp.interaction.VerletListStillingerWeberTripleTerm.**getPotential**(*type1*, *type2*, *type3*)

Parameters

- **type1** –
- **type2** –
- **type3** –

Return type

espressopp.interaction.VerletListStillingerWeberTripleTerm.**getVerletListTriple**()

Return type A Python list of lists.

espressopp.interaction.VerletListStillingerWeberTripleTerm.**setPotential**(*type1*, *type2*, *type3*, *potential*)

Parameters

- **type1** –
- **type2** –
- **type3** –
- **potential** –

espressopp.interaction.**FixedTripleListStillingerWeberTripleTerm**(*system*, *ftl*, *potential*)

Parameters

- **system** –
- **ftl** –
- **potential** –

espressopp.interaction.FixedTripleListStillingerWeberTripleTerm.**getFixedTripleList**()

Return type A Python list of lists.

espressopp.interaction.FixedTripleListStillingerWeberTripleTerm.**setPotential**(*type1*, *type2*, *type3*, *potential*)

Parameters

- **type1** –
- **type2** –
- **type3** –
- **potential** –

class espressopp.interaction.StillingerWeberTripleTerm.**StillingerWeberTripleTerm**
The StillingerWeberTripleTerm potential.

4.20.41 espressopp.interaction.Tabulated

espressopp.interaction.**Tabulated**(*itype*, *filename*, *cutoff*)

Parameters

- **itype** –
- **filename** –
- **cutoff** – (default: infinity)

espressopp.interaction.**VerletListAdressTabulated**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListAdressTabulated.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListAdressTabulated.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressTabulated**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressTabulated.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressTabulated.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListTabulated**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListTabulated.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListTabulated.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListTabulated**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListTabulated.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListTabulated**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListTabulated.**setPotential**(*potential*)

Parameters **potential** –

espressopp.interaction.**FixedPairListTypesTabulated**(*system*, *ftl*)

Parameters

- **system** (espressopp.System) – The Espresso++ system object.
- **ftl** (espressopp.FixedPairList) – The FixedPair list.

espressopp.interaction.FixedPairListTypesTabulated.**setPotential**(*type1*, *type2*, *potential*)

Defines bond potential for interaction between particles of types type1-type2-type3.

Parameters

- **type1** (*int*) – Type of particle 1.
- **type2** (*int*) – Type of particle 2.
- **potential** (espressopp.interaction.Potential) – The potential to set up.

class espressopp.interaction.Tabulated.**Tabulated**

The Tabulated potential.

4.20.42 espressopp.interaction.TabulatedAngular

espressopp.interaction.**TabulatedAngular**(*itype*, *filename*)

Parameters

- **itype** (*int*) – The interpolation type: 1 - linear, 2 - akima spline, 3 - cubic spline
- **filename** (*str*) – The tabulated potential filename.

espressopp.interaction.**FixedTripleListTabulatedAngular**(*system*, *ftl*, *potential*)

Parameters

- **system** (espressopp.System) – The Espresso++ system object.
- **ftl** (espressopp.FixedTripleList) – The FixedTripleList.
- **potential** (espressopp.interaction.Potential) – The potential.

espressopp.interaction.FixedTripleListTabulatedAngular.**setPotential**(*potential*)

Parameters **potential** (espressopp.interaction.Potential) – The potential object.

espressopp.interaction.**FixedTripleListTypesTabulatedAngular**(*system*, *ftl*)

Parameters

- **system** (espressopp.System) – The Espresso++ system object.
- **ftl** (espressopp.FixedTripleList) – The FixedTriple list.

espressopp.interaction.FixedTripleListTypesTabulatedAngular.**setPotential**(*type1*, *type2*, *type3*, *potential*)

Defines angular potential for interaction between particles of types type1-type2-type3.

Parameters

- **type1** (*int*) – Type of particle 1.
- **type2** (*int*) – Type of particle 2.
- **type3** (*int*) – Type of particle 3.
- **potential** (espressopp.interaction.AngularPotential) – The potential to set up.

class espressopp.interaction.TabulatedAngular.**TabulatedAngular**

The TabulatedAngular potential.

4.20.43 espressopp.interaction.TabulatedDihedral

espressopp.interaction.**TabulatedDihedral**(*itype*, *filename*)

Parameters **itype** – The interpolation type: 1 - linear, 2 - akima spline, 3 - cubic spline :param filename: The tabulated potential filename. :type itype: int :type filename: str

espressopp.interaction.**FixedQuadrupleListTabulatedDihedral**(*system*, *fql*, *potential*)

Parameters

- **system** (espressopp.System) – The Espresso++ system object.
- **fql** (espressopp.FixedQuadrupleList) – The FixedQuadrupleList.
- **potential** (espressopp.interaction.Potential) – The potential.

espressopp.interaction.FixedQuadrupleListTabulatedDihedral.**setPotential**(*potential*)

Parameters **potential** (espressopp.interaction.Potential) – The potential object.

espressopp.interaction.**FixedQuadrupleListTypesTabulatedDihedral**(*system*, *fql*)

Parameters

- **system** (espressopp.System) – The Espresso++ system object.
- **ftl** (espressopp.FixedQuadrupleList) – The FixedQuadrupleList list.

espressopp.interaction.**FixedQuadrupleListTypesTabulatedDihedral**(*system*, *ftl*)

Parameters

- **system** (espressopp.System) – The Espresso++ system object.
- **ftl** (espressopp.FixedQuadrupleList) – The FixedQuadruple list.

espressopp.interaction.FixedQuadrupleListTypesTabulatedDihedral.**setPotential**(*type1*, *type2*, *type3*, *type4*, *potential*)

Defines dihedral potential for interaction between particles of types type1-type2-type3-type4.

Parameters

- **type1** (*int*) – Type of particle 1.
- **type2** (*int*) – Type of particle 2.
- **type3** (*int*) – Type of particle 3.
- **type4** (*int*) – Type of particle 4.
- **potential** (espressopp.interaction.DihedralPotential) – The potential to set up.

class espressopp.interaction.TabulatedDihedral.**TabulatedDihedral**

The TabulatedDihedral potential.

4.20.44 espressopp.interaction.TersoffPairTerm

This class provides methods to compute forces and energies of 2 body term of Tersoff potential.

if $d_{12} > R + D$

$$U = 0$$

if $d_{12} < R - D$

$$U = Ae^{-\lambda 1 d_{12}}$$

else

$$U = \frac{1}{2}\left(1 - sin\left(\frac{\pi}{4D}\left(d_{12} - R\right)\right)\right) Ae^{-\lambda_1 d_{12}}$$

espressopp.interaction.**TersoffPairTerm**(*A*, *lambda1*, *R*, *D*, *cutoff*)

Parameters

- **A** –
- **lambda1** –
- **R** –
- **D** –

- **cutoff** – (default: infinity)

espressopp.interaction.**VerletListTersoffPairTerm**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListTersoffPairTerm.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListTersoffPairTerm.**getVerletList**()

Return type A Python list of lists.

espressopp.interaction.VerletListTersoffPairTerm.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListTersoffPairTerm**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListTersoffPairTerm.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListTersoffPairTerm**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListTersoffPairTerm.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.TersoffPairTerm.**TersoffPairTerm**
The Lennard-Jones potential.

4.20.45 espressopp.interaction.TersoffTripleTerm

This class provides methods to compute forces and energies of the Tersoff Triple Term potential.

$$U = f_{C_j} f_A \left(1 + \left(\beta f_{C_k} \gamma \left(1 + \frac{c_2}{d_2} - \frac{c_2}{d_2 + \left(\frac{r_{12} r_{32}}{|r_{12}||r_{32}|} - cos(\theta_0) \right)^2} \right) \left(e^{\lambda_3 (|r_{12}| - |r_{32}|)} \right)^m \right)^n \right)^{-\frac{1}{2n}}$$

espressopp.interaction.**VerletListTersoffTripleTerm**(*system*, *vl3*)

Parameters

- **system** –
- **vl3** –

espressopp.interaction.VerletListTersoffTripleTerm.**getPotential**(*type1*, *type2*, *type3*)

Parameters

- **type1** –
- **type2** –
- **type3** –

Return type

espressopp.interaction.VerletListTersoffTripleTerm.**getVerletListTriple**()

Return type A Python list of lists.

espressopp.interaction.VerletListTersoffTripleTerm.**setPotential**(*type1*, *type2*, *type3*, *potential*)

Parameters

- **type1** –
- **type2** –
- **type3** –
- **potential** –

espressopp.interaction.**FixedTripleListTersoffTripleTerm**(*system*, *ftl*, *potential*)

Parameters

- **system** –
- **ftl** –
- **potential** –

espressopp.interaction.FixedTripleListTersoffTripleTerm.**getFixedTripleList**()

Return type A Python list of lists.

espressopp.interaction.FixedTripleListTersoffTripleTerm.**setPotential**(*type1*, *type2*, *type3*, *potential*)

Parameters

- **type1** –
- **type2** –
- **type3** –
- **potential** –

4.20.46 espressopp.interaction.VSpherePair

This class provides methods to compute forces and energies of the VSpherePair potential.

$$V(r_ij, \sigma_ij) = \frac{\varepsilon}{\beta}\left(\frac{2\pi}{3}\right)\sigma_ij^{-\frac{3}{2}}e^{-\frac{3}{2}\frac{r_ij}{\sigma_ij}}, r_ij = |\vec{r_i} - \vec{r_j}|, \sigma_ij = \sigma_i^2 + \sigma_j^2$$

espressopp.interaction.**VSpherePair**(*epsilon*, *cutoff*, *shift*)

Parameters

- **epsilon** (*real*) – (default: 1.0)
- **cutoff** – (default: infinity)
- **shift** – (default: "auto")

espressopp.interaction.**VerletListVSpherePair**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListVSpherePair.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListVSpherePair.**getVerletList**()

Return type A Python list of lists.

espressopp.interaction.VerletListVSpherePair.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

class espressopp.interaction.VSpherePair.**VSpherePair**
The Lennard-Jones potential.

4.20.47 espressopp.interaction.VSphereSelf

This class provides methods to compute forces and energies of the VSphereSelf potential.

$$U = e_1\left(\frac{4}{3}\pi\sigma_2\right)^{\frac{3}{2}} + \frac{a_1{N_b}^3}{{\sigma_2}^3} + \frac{2a_2}{N_b}\sigma_2$$

espressopp.interaction.**VSphereSelf**(*e1*, *a1*, *a2*, *Nb*, *cutoff*, *shift*)

Parameters

- **e1** (*real*) – (default: 0.0)
- **a1** (*real*) – (default: 1.0)
- **a2** (*real*) – (default: 0.0)
- **Nb** (*int*) – (default: 1)
- **cutoff** – (default: infinity)

- **shift** (*real*) – (default: 0.0)

espressopp.interaction.**SelfVSphere**(*system*, *potential*)

Parameters

- **system** –
- **potential** –

espressopp.interaction.SelfVSphere.**getPotential**()

Return type

espressopp.interaction.SelfVSphere.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.VSphereSelf.**VSphereSelf**
The VSphereSelf potential.

4.20.48 espressopp.interaction.Zero

This class provides methods for a zero potential no interactions between particles, mainly used for debugging and testing

espressopp.interaction.**Zero**()

espressopp.interaction.**VerletListZero**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListZero.**getPotential**(*type1*, *type2*)

Parameters

- **type1** –
- **type2** –

Return type

espressopp.interaction.VerletListZero.**setFixedTupleList**(*ftpl*)

Parameters **ftpl** –

espressopp.interaction.VerletListZero.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListAdressZero**(*vl*)

Parameters **vl** –

espressopp.interaction.VerletListAdressZero.**setFixedTupleList**(*ftpl*)

Parameters **ftpl** –

espressopp.interaction.VerletListAdressZero.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListAdressZero.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**VerletListHadressZero**(*vl*, *fixedtupleList*)

Parameters

- **vl** –
- **fixedtupleList** –

espressopp.interaction.VerletListHadressZero.**setFixedTupleList**(*ftpl*)

Parameters **ftpl** –

espressopp.interaction.VerletListHadressZero.**setPotentialAT**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.VerletListHadressZero.**setPotentialCG**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**CellListZero**(*stor*)

Parameters **stor** –

espressopp.interaction.CellListZero.**setPotential**(*type1*, *type2*, *potential*)

Parameters

- **type1** –
- **type2** –
- **potential** –

espressopp.interaction.**FixedPairListZero**(*system*, *vl*, *potential*)

Parameters

- **system** –
- **vl** –
- **potential** –

espressopp.interaction.FixedPairListZero.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.Zero.**Zero**
The Zero potential.

4.20.49 espressopp.interaction.LennardJones93Wall

This class defines a Lennard-Jones 9-3 SingleParticlePotential in the direction x.

$$V(r) = \epsilon \left(\left(\frac{\sigma}{r}\right)^9 - \left(\frac{\sigma}{r}\right)^3 \right)$$

where r is the distance from the lower or upper wall in the x direction. $V(r) = 0$ after a distance *sigmaCutoff*.

The parameters have to be defined for every species present in the system with *setParams* and can be retrieved with *getParams*.

Example:

```
>>> LJ93 = espressopp.interaction.LennardJones93Wall()
>>> LJ93.setParams(0, 6., 1., wall_cutoff)
>>> SPLJ93 = espressopp.interaction.SingleParticleLennardJones93Wall(system, LJ93)
>>> system.addInteraction(SPLJ93)
```

espressopp.interaction.**LennardJones93Wall**()

espressopp.interaction.LennardJones93Wall.**getParams**(*type_var*)

Parameters **type_var** –

Return type

espressopp.interaction.LennardJones93Wall.**setParams**(*type_var*, *epsilon*, *sigma*, *sigmaCutoff*, *r0*)

Parameters

- **type_var** –
- **epsilon** –
- **sigma** –
- **sigmaCutoff** –
- **r0** –

espressopp.interaction.**SingleParticleLennardJones93Wall**(*system*, *potential*)

Parameters

- **system** –
- **potential** –

espressopp.interaction.SingleParticleLennardJones93Wall.**setPotential**(*potential*)

Parameters **potential** –

class espressopp.interaction.LennardJones93Wall.**LennardJones93Wall**
The LennardJones93Wall potential.

4.21 io

4.21.1 DumpGRO - IO Object

- *dump()* write configuration to trajectory GRO file. By default filename is "out.gro", coordinates are folded.

  Properties
- *filename* Name of trajectory file. By default trajectory file name is "out.gro"
- *unfolded* False if coordinates are folded, True if unfolded. By default - False

- *append* True if new trajectory data is appended to existing trajectory file. By default - True
- *length_factor* If length dimension in current system is nm, and unit is 0.23 nm, for example, then length_factor should be 0.23
- *length_unit* It is length unit. Can be LJ, nm or A. By default - LJ

usage:

writing down trajectory

```
>>> dump_conf_gro = espressopp.io.DumpGRO(system, integrator, filename='trajectory.
↪gro')
>>> for i in range (200):
>>>   integrator.run(10)
>>>   dump_conf_gro.dump()
```

writing down trajectory using ExtAnalyze extension

```
>>> dump_conf_gro = espressopp.io.DumpGRO(system, integrator, filename='trajectory.
↪gro')
>>> ext_analyze = espressopp.integrator.ExtAnalyze(dump_conf_gro, 10)
>>> integrator.addExtension(ext_analyze)
>>> integrator.run(2000)
```

Both exapmles will give the same result: 200 configurations in trajectory .gro file.

setting up length scale

For example, the Lennard-Jones model for liquid argon with $\sigma = 0.34[nm]$

```
>>> dump_conf_gro = espressopp.io.DumpGRO(system, integrator, filename='trj.gro',␣
↪unfolded=False, length_factor=0.34, length_unit='nm', append=True)
```

will produce trj.gro with in nanometers

espressopp.io.**DumpGRO**(*system*, *integrator*, *filename*, *unfolded*, *length_factor*, *length_unit*, *append*)

Parameters

- **system** –
- **integrator** –
- **filename** – (default: 'out.gro')
- **unfolded** – (default: False)
- **length_factor** (*real*) – (default: 1.0)
- **length_unit** – (default: 'LJ')
- **append** – (default: True)

espressopp.io.DumpGRO.**dump**()

Return type

4.21.2 DumpXYZ - IO Object

- *dump()* write configuration to trajectory XYZ file. By default filename is "out.xyz", coordinates are folded.

  Properties
- *filename* Name of trajectory file. By default trajectory file name is "out.xyz"
- *unfolded* False if coordinates are folded, True if unfolded. By default - False

- *append* True if new trajectory data is appended to existing trajectory file. By default - True
- *length_factor* If length dimension in current system is nm, and unit is 0.23 nm, for example, then length_factor should be 0.23
- *length_unit* It is length unit. Can be LJ, nm or A. By default - LJ

usage:

writing down trajectory

```
>>> dump_conf_xyz = espressopp.io.DumpXYZ(system, integrator, filename='trajectory.
↪xyz')
>>> for i in range (200):
>>>   integrator.run(10)
>>>   xyz.dump()
```

writing down trajectory using ExtAnalyze extension

```
>>> dump_conf_xyz = espressopp.io.DumpXYZ(system, integrator, filename='trajectory.
↪xyz')
>>> ext_analyze = espressopp.integrator.ExtAnalyze(dump_conf_xyz, 10)
>>> integrator.addExtension(ext_analyze)
>>> integrator.run(2000)
```

Both exapmles will give the same result: 200 configurations in trajectory .xyz file.

setting up length scale

For example, the Lennard-Jones model for liquid argon with $\sigma = 0.34[nm]$

```
>>> dump_conf_xyz = espressopp.io.DumpXYZ(system, integrator, filename='trj.xyz',␣
↪unfolded=False, length_factor=0.34, length_unit='nm', append=True)
```

will produce trj.xyz with in nanometers

espressopp.io.**DumpXYZ**(*system*, *integrator*, *filename*, *unfolded*, *length_factor*, *length_unit*, *append*)

Parameters

- **system** –
- **integrator** –
- **filename** – (default: 'out.xyz')
- **unfolded** – (default: False)
- **length_factor** (*real*) – (default: 1.0)
- **length_unit** – (default: 'LJ')
- **append** – (default: True)

espressopp.io.DumpXYZ.**dump**()

Return type

4.22 standard_system

4.22.1 espressopp.standard_system.Default

espressopp.standard_system.**Default**(*box*, *rc*, *skin*, *dt*, *temperature*)

Parameters

- **box** –
- **rc** (*real*) – (default: 1.12246)
- **skin** (*real*) – (default: 0.3)
- **dt** (*real*) – (default: 0.005)
- **temperature** – (default: None)

Return default system and integrator, no interactions, no particles are set if tempearture is != None then Langevin thermostat is set to temperature (gamma is 1.0)

4.22.2 espressopp.standard_system.KGMelt

espressopp.standard_system.**KGMelt**(*num_chains*, *chain_len*)

Parameters

- **num_chains** –
- **chain_len** –

4.22.3 espressopp.standard_system.LennardJones

espressopp.standard_system.**LennardJones**(*num_particles*, *box*, *rc*, *skin*, *dt*, *epsilon*, *sigma*, *shift*, *temperature*, *xyzfilename*, *xyzrfilename*)

Parameters

- **num_particles** –
- **box** – (default: (000))
- **rc** (*real*) – (default: 1.12246)
- **skin** (*real*) – (default: 0.3)
- **dt** (*real*) – (default: 0.005)
- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **shift** – (default: 'auto')
- **temperature** – (default: None)
- **xyzfilename** – (default: None)
- **xyzrfilename** – (default: None)

return random Lennard Jones system and integrator: if tempearture is != None then Langevin thermostat is set to temperature (gamma is 1.0)

4.22.4 espressopp.standard_system.Minimal

espressopp.standard_system.**Minimal**(*num_particles*, *box*, *rc*, *skin*, *dt*, *temperature*)

Parameters

- **num_particles** –
- **box** –
- **rc** (*real*) – (default: 1.12246)
- **skin** (*real*) – (default: 0.3)

- **dt** (*real*) – (default: 0.005)
- **temperature** – (default: None)

Return minimal system and integrator whithout any interactions defined: particles have random positions in box if tempearture is != None then Langevin thermostat is set to temperature (gamma is 1.0)

4.22.5 espressopp.standard_system.PolymerMelt

espressopp.standard_system.**PolymerMelt**(*num_chains*, *monomers_per_chain*, *box*, *bondlen*, *rc*, *skin*, *dt*, *epsilon*, *sigma*, *shift*, *temperature*, *xyzfilename*, *xyzrfilename*)

Parameters

- **num_chains** –
- **monomers_per_chain** –
- **box** – (default: (000))
- **bondlen** (*real*) – (default: 0.97)
- **rc** (*real*) – (default: 1.12246)
- **skin** (*real*) – (default: 0.3)
- **dt** (*real*) – (default: 0.005)
- **epsilon** (*real*) – (default: 1.0)
- **sigma** (*real*) – (default: 1.0)
- **shift** – (default: 'auto')
- **temperature** – (default: None)
- **xyzfilename** – (default: None)
- **xyzrfilename** – (default: None)

returns random walk polymer melt system and integrator: if tempearture is != None then Langevin thermostat is set to temperature (gamma is 1.0)

4.23 storage

4.23.1 espressopp.storage.DomainDecomposition

espressopp.storage.**DomainDecomposition**(*system*, *nodeGrid*, *cellGrid*)

Parameters

- **system** –
- **nodeGrid** –
- **cellGrid** –

espressopp.storage.DomainDecomposition.**getCellGrid**()

Return type

espressopp.storage.DomainDecomposition.**getNodeGrid**()

Return type

4.23.2 DomainDecompositionAdress - Object

The DomainDecompositionAdress is the Domain Decomposition for AdResS and H- AdResS simulations. It makes sure that tuples (i.e. a coarse-grained particle and its corresponding atomistic particles) are always stored together on one CPU. When setting DomainDecompositionAdress you have to provide the system as well as the nodegrid and the cellgrid.

Example - setting DomainDecompositionAdress:

```
>>> system.storage = espressopp.storage.DomainDecompositionAdress(system,␣
↪nodeGrid, cellGrid)
```

espressopp.storage.**DomainDecompositionAdress**(*system*, *nodeGrid*, *cellGrid*)

Parameters

- **system** –
- **nodeGrid** –
- **cellGrid** –

4.23.3 espressopp.storage.DomainDecompositionNonBlocking

espressopp.storage.**DomainDecompositionNonBlocking**(*system*, *nodeGrid*, *cellGrid*)

Parameters

- **system** –
- **nodeGrid** –
- **cellGrid** –

4.23.4 Storage - Storage Object

This is the base class for all storage objects. All derived classes implement at least the following methods:

- *decompose()*

  Send all particles to their corresponding cell/cpu

- *addParticle(pid, pos)*:

  Add a particle to the storage

- *removeParticle(pid)*:

  Remove a particle with id number *pid* from the storage.

  ```
  >>> system.storage.removeParticle(4)
  ```

  There is an example in *examples* folder

- *getParticle(pid)*:

  Get a particle object. This can be used to get specific particle information:

  ```
  >>> particle = system.storage.getParticle(15)
  >>> print "Particle ID is       : ", particle.id
  >>> print "Particle position is : ", particle.pos
  ```

  you cannot use this particle object to modify particle data. You have to use the modifyParticle command for that (see below).

- *addAdrParticle(pid, pos, last_pos)*:

Add an AdResS Particle to the storage

- *setFixedTuplesAdress(fixed_tuple_list)*:
- *addParticles(particle_list, *properties)*:

  This routine adds particles with certain properties to the storage.

  param particleList list of particles (and properties) to be added

  param properties property strings

  Each particle in the list must be itself a list where each entry corresponds to the property specified in properties.

  Example:

```
>>> addParticles([[id, pos, type, ... ], ...], 'id', 'pos', 'type', ...
↪)
```

- *modifyParticle(pid, property, value, decompose='yes')*

  This routine allows to modify any properties of an already existing particle.

  Example:

```
>>> modifyParticle(pid, 'pos', Real3D(new_x, new_y, new_z))
```

- *removeAllParticles()*:

  This routine removes all particles from the storage.

- 'system':

  The property 'system' returns the System object of the storage.

Examples:

```
>>> s.storage.addParticles([[1, espressopp.Real3D(3,3,3)], [2, espressopp.
↪Real3D(4,4,4)]],'id','pos')
>>> s.storage.decompose()
>>> s.storage.modifyParticle(15, 'pos', Real3D(new_x, new_y, new_z))
```

espressopp.storage.Storage.**addAdrATParticle**(*pid*, **args*)

Parameters

- **pid** –
- ***args** –

Return type

espressopp.storage.Storage.**addParticle**(*pid*, *pos*)

Parameters

- **pid** –
- **pos** –

Return type

espressopp.storage.Storage.**addParticles**(*particleList*, **properties*)

Parameters

- **particleList** –
- ***properties** –

Return type

espressopp.storage.Storage.**clearSavedPositions**()

Return type

espressopp.storage.Storage.**getParticle**(*pid*)

Parameters **pid** –

Return type

espressopp.storage.Storage.**getRealParticleIDs**()

Return type

espressopp.storage.Storage.**modifyParticle**(*pid*, *property*, *value*)

Parameters

- **pid** –
- **property** –
- **value** –

Return type

espressopp.storage.Storage.**particleExists**(*pid*)

Parameters **pid** –

Return type

espressopp.storage.Storage.**printRealParticles**()

Return type

espressopp.storage.Storage.**removeAllParticles**()

Return type

espressopp.storage.Storage.**removeParticle**(*pid*)

Parameters **pid** –

Return type

espressopp.storage.Storage.**restorePositions**()

Return type

espressopp.storage.Storage.**savePositions**(*idList*)

Parameters **idList** –

Return type

espressopp.storage.Storage.**setFixedTuplesAdress**(*fixedtuples*)

Parameters **fixedtuples** –

4.24 Logging mechanism

ESPResSo++ uses Loggers

Logging can be switched on in your python script with the following command:

```
>>> logging.getLogger("*name of the logger*").setLevel(logging.*Level*)
```

Level is one of the following:

ERROR	for errors that might still allow the application to continue
WARN	for potentially harmful situations
INFO	informational messages highlighting progress
DEBUG	designates fine-grained informational events

Example:

```
>>> import espressopp
>>> import logging
>>> logging.getLogger("Storage").setLevel(logging.ERROR)
```

To log everything (WARNING: this will produce **lots** of output):

```
>>> logging.getLogger("").setLevel(logging.DEBUG)
```

The following loggers are currently available:

- Configurations
- Observable
- Velocities
- BC
- Logger
- FixedListComm
- FixedPairList
- FixedQuadrupleList
- FixedTripleList
- FixedTupleList
- Langevin
- MDIntegrator
- AngularPotential
- DihedralPotential
- Interaction
- InterpolationAkima
- InterpolationCubic
- InterpolationLinear
- InterpolationTable
- Potential
- CellListAllPairsIterator
- DomainDecomposition.CellGrid
- DomainDecomposition
- DomainDecomposition.NodeGrid
- Storage
- DomainDecompositionAdress
- StorageAdress
- VerletList

- VerletList

CHAPTER

FIVE

FREQUENTLY ASKED QUESTIONS

Do I need to learn Python when using ESPResSo++?

The short answer is “no”. Most of the example scripts are self-explanatory and can be adapted for your purposes by simple changes. You can also use ESPResSo++ like other MD simulation software, that is driven by some kind of configuration file.

The long answer is “yes”. If you want to take advantage of all features of ESPResSo++ you need some knowledge of how the Python interpreter works.

But don’t be afraid of learning Python:

- Python is easy to learn
- The ESPResSo++ example simulation scripts gives you a very fast insight of how Python works.
- Writing programs in Python is much easier than writing programs in C++
- Python programs are easier to read than Tcl or Perl programs.

And here are some arguments why it is worth while:

- There are many Python programs you can use in your applications
- Python gives you a flexible way of running MD simulations with ESPResSo++

Do you support other script languages, e.g. Tcl/Tk?

No. We choose the support only Python as ESPResSo++ scripting language. This enables ESPResSo++ users to read and adapt scripts written by other ESPResSo++ users.

Can Tcl scripts converted to Python automatically?

The recommendation is - don’t do it! Instead, a Tcl interpreter can be loaded via Python and given the job to do. That is similar to what Tkinter does; Tkinter is a wrapper to use the Tk toolkit from Python.

Why should I use Python if C++ programs are much faster?

Python is the driver of your simulation which will still run in the ESPResSo++ C++ engine.

Python programs are about 30 to 50 times slower than the same programs written in C++.

That is why we use Python to set up and control simulations while the simulation system itself is written in efficient C++ code.

Can I run ESPResSo++ on parallel machines?

Yes. The parallel version uses MPI and is therefore as portable as MPI is. Typical MD simulations scale rather well.

Do I need to write parallel scripts for parallel machines?

No. The Python scripts are executed only by the first processor which will broadcast the ESPResSo++ commands to the other processors automatically using the PMI interface (Parallel Method Invocation). For you, it will look like a serial script. But the particles of the simulation are distributed among the available processors and the commands issued for ESPResSo++ will be executed by each processor.

How efficient is ESPResSo++?

Efficiency is a high priority though less than the extendability of the system. You should expect a good performance but might be that ESPResSo++ is less efficient than other simulation programs that are around.

If you experience that ESPResSo++ is more than 2 times slower than other simulation systems you have found a performance bug.

Do I need the source code distribution or can I use binary version?

Currently, we only provide a source code distribution. This might change in the future. Our major problem to provide binary versions is that there are many different Python versions and the binary versions of the ESPResSo++ and python libraries must not be of mixed versions.

Which build systems are used for ESPResSo++?

Compilation and installation of ESPResSo++ is due to the many shared libraries and loadable modules rather complex and so we use a build system to make our job and maintainability easier.

Currently we support building the system with cmake.

What means extendability?

Each software is in a certain sense extendable by adding some functionality somewhere in the code. But we understand extendability in the following sense:

- You can add functionality without changing existent interfaces. For the object-oriented approach this means in practice: take an available base class and define a new derived class with your needed functionality.

CHAPTER

SIX

GETTING HELP

We currently have two mailing lists that provide help for users and developers of ESPResSo++

If you are a user please subscribe to ESPResSo++ Users List

If you are a developer please subscribe to ESPResSo++ Developers List

CHAPTER

SEVEN

DEVELOPER TEAM

Current developers:

- Torsten Stuehn (Max Planck Institute for Polymer Research, Germany)
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CHAPTER

EIGHT

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