# LUMA

1.2.0-alpha

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# Contents

# Chapter 1

# Main Page

----— Lattice Boltzmann @ The University of Manchester ---—

------------------------— L-U-M-A -------------------------—

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# Chapter 2

# Hierarchical Index

## 2.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

# Chapter 3

# Class Index

## 3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

# Chapter 4

# File Index

## 4.1 File List

Here is a list of all files with brief descriptions:

# Chapter 5

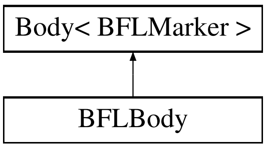
# Class Documentation

## 5.1 BFLBody Class Reference

BFL body.

`#include <BFLBody.h>`

Inheritance diagram for BFLBody:




### Public Member Functions

- BFLBody (void)

  *Default constructor.*
- ∼BFLBody (void)

  *Default destructor.*
- BFLBody (PCpts ∗_PCpts, GridObj ∗g_hierarchy, size_t id)

  *Custom constructor to populate body from array of points.*

### Protected Member Functions

- void computeQ (int i, int j, int k, GridObj ∗g)

  *Routine to compute wall distance Q.*
- void computeQ (int i, int j, GridObj ∗g)

  *Routine to compute wall distance Q.*

### Protected Attributes

- std::vector< std::vector< double > > Q

  *Distance between adjacent lattice site and the surface of the body.*

## Friends

- class GridObj

### 5.1.1 Detailed Description

BFL body.

A BFL body is made up of a collection of BFLMarkers.

### 5.1.2 Constructor & Destructor Documentation

#### 5.1.2.1 BFLBody::BFLBody ( void )

Default constructor.

#### 5.1.2.2 BFLBody::∼BFLBody ( void )

Default destructor.

#### 5.1.2.3 BFLBody::BFLBody ( PCpts ∗ *_PCpts*, GridObj ∗ *g_hierarchy*, size_t *id* )

Custom constructor to populate body from array of points.

**Parameters**

| | |
|---|---|
| *_PCpts* | pointer to point cloud data |
| *g_hierarchy* | pointer to grid hierarchy |
| *id* | ID of body in array of bodies. |

### 5.1.3 Member Function Documentation

#### 5.1.3.1 void BFLBody::computeQ ( int *i*, int *j*, int *k*, GridObj ∗ *g* ) [protected]

Routine to compute wall distance Q.

Computes Q values in 3D at a given local voxel for each application of the BFL BC. Performs a line-plane intersection algorithm for every possible triangular plane constructed out of the marker in the voxel and its nearest neighbours.

**Parameters**

| | |
|---|---|
| *i* | local i-index of BFL voxel |
| *j* | local j-index of BFL voxel |
| *k* | local k-index of BFL voxel |
| *g* | pointer to owner grid |

#### 5.1.3.2 void BFLBody::computeQ ( int *i*, int *j*, GridObj $*$ *g* ) [protected]

Routine to compute wall distance Q.

Computes Q values in 2D at a given local voxel for each application of the BFL BC. Performs a line-line intersection algorithm for each line segment either side of the voxel marker.

**Parameters**

| | |
|---|---|
| *i* | local i-index of BFL voxel |
| *j* | local j-index of BFL voxel |
| *g* | pointer to owner grid |

### 5.1.4 Friends And Related Function Documentation

#### 5.1.4.1 friend class GridObj [friend]

### 5.1.5 Member Data Documentation

#### 5.1.5.1 std::vector< std::vector<double> > BFLBody::Q [protected]

Distance between adjacent lattice site and the surface of the body.

There are two stores of values. Store 1 is the distance on one side of the wall and store 2 the distance on the other side. One store is appended to the other in this structure.

The documentation for this class was generated from the following files:

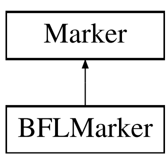
- BFLBody.h
- BFLBody.cpp

## 5.2 BFLMarker Class Reference

BFL marker.

```
#include <BFLMarker.h>
```

Inheritance diagram for BFLMarker:



## Public Member Functions

- BFLMarker (void)

    *Default constructor.*
- ∼BFLMarker (void)

    *Default destructor.*
- BFLMarker (double x, double y, double z)

    *Custom constructor with position.*

## Friends

- class BFLBody

## Additional Inherited Members

### 5.2.1 Detailed Description

BFL marker.

This class declaration is for a BFL Lagrange point. A collection of these points form BFL body.

### 5.2.2 Constructor & Destructor Documentation

#### 5.2.2.1 BFLMarker::BFLMarker ( void )

Default constructor.

#### 5.2.2.2 BFLMarker::∼BFLMarker ( void )

Default destructor.

#### 5.2.2.3 BFLMarker::BFLMarker ( double *x*, double *y*, double *z* )

Custom constructor with position.

**Parameters**

| | |
|---|---|
| *x* | x-position of marker |
| *y* | y-position of marker |
| *z* | z-position of marker |

### 5.2.3 Friends And Related Function Documentation

#### 5.2.3.1 friend class BFLBody [friend]

The documentation for this class was generated from the following files:

- BFLMarker.h
- BFLMarker.cpp

## 5.3 Body< MarkerType > Class Template Reference

Generic body class.

`#include <Body.h>`

### Public Member Functions

- Body (void)

  *Default Constructor.*
- ∼Body (void)

  *Default destructor.*
- Body (GridObj ∗g, size_t id)

  *Custom constructor setting owning grid.*

### Protected Member Functions

- void addMarker (double x, double y, double z)

  *Add marker to the body.*
- MarkerData ∗ getMarkerData (double x, double y, double z)

  *Retrieve marker data.*
- virtual void markerAdder (double x, double y, double z, int &curr_mark, std::vector< int > &counter, bool flag)

  *Downsampling marker adding method.*
- bool isInVoxel (double x, double y, double z, int curr_mark)

  *Determines whether a point is inside another marker's support voxel.*
- bool isVoxelMarkerVoxel (double x, double y, double z)

  *Determines whether a point is inside an existing marker's support voxel.*

### Protected Attributes

- double spacing

  *Spacing of the markers in physical units.*
- std::vector< MarkerType > markers

  *Array of markers which make up the body.*
- bool closed_surface

  *Flag to specify whether or not it is a closed surface (for output)*
- GridObj ∗ _Owner

  *Pointer to owning grid.*
- size_t id

  *ID of body in array of bodies.*

### 5.3.1 Detailed Description

**template<typename MarkerType>**
**class Body< MarkerType >**

Generic body class.

Can consist of any type of Marker so templated.

### 5.3.2 Constructor & Destructor Documentation

#### 5.3.2.1 template<typename MarkerType > Body< MarkerType >::Body ( void )

Default Constructor.

#### 5.3.2.2 template<typename MarkerType > Body< MarkerType >::~Body ( void )

Default destructor.

#### 5.3.2.3 template<typename MarkerType > Body< MarkerType >::Body ( GridObj * *g*, size_t *id* )

Custom constructor setting owning grid.

**Parameters**

| | |
|---|---|
| *g* | pointer to grid which owns this body. |
| *id* | indicates position of body in array of bodies. |

### 5.3.3 Member Function Documentation

#### 5.3.3.1 template<typename MarkerType > void Body< MarkerType >::addMarker ( double *x*, double *y*, double *z* ) [protected]

Add marker to the body.

**Parameters**

| | |
|---|---|
| *x* | global X-position of marker. |
| *y* | global Y-position of marker. |
| *z* | global Z-position of marker. |

#### 5.3.3.2 template<typename MarkerType > MarkerData * Body< MarkerType >::getMarkerData ( double *x*, double *y*, double *z* ) [protected]

Retrieve marker data.

Return marker and voxel/primary support data associated with supplied global position.

**Parameters**

| | |
|---|---|
| *x* | global X-position nearest to marker to be retrieved. |
| *y* | global Y-position nearest to marker to be retrieved. |
| *z* | global Z-position nearest to marker to be retrieved. |

**Returns**

MarkerData marker data structure returned. If no marker found, structure is marked as invalid.

#### 5.3.3.3 template<typename MarkerType > bool Body< MarkerType >::isInVoxel ( double *x*, double *y*, double *z*, int *curr_mark* ) [protected]

Determines whether a point is inside another marker's support voxel.

**Parameters**

| | |
|---|---|
| *x* | X-position of point. |
| *y* | Y-position of point. |
| *z* | Z-position of point. |
| *curr_mark* | ID of the marker. |

**Returns**

true of false

#### 5.3.3.4 template<typename MarkerType > bool Body< MarkerType >::isVoxelMarkerVoxel ( double *x*, double *y*, double *z* ) [protected]

Determines whether a point is inside an existing marker's support voxel.

**Parameters**

| | |
|---|---|
| *x* | global X-position of point. |
| *y* | global Y-position of point. |
| *z* | global Z-position of point. |

**Returns**

true of false

#### 5.3.3.5 template< typename MarkerType > void Body< MarkerType >::markerAdder ( double *x*, double *y*, double *z*, int & *curr_mark*, std::vector< int > & *counter*, bool *flag* ) [protected], [virtual]

Downsampling marker adding method.

This method tries to add a marker to body at the global location given but obeys the rules of a voxel-grid filter to ensure markers are distributed such that their spacing roughly matches the background lattice. Making it virtual allows different attirbutes to be passed to the addMarker() methods to allow for different marker types.

**Parameters**

| | |
|---|---|
| *x* | desired global X-position of new marker. |
| *y* | desired globalY-position of new marker. |
| *z* | desired globalZ-position of new marker. |
| *curr_mark* | is a reference to the ID of last marker. |
| *counter* | is a reference to the total number of markers in the body. |
| *flag* | is an optional flag argument this is used in overrides of this method. |

Reimplemented in IBBody.

### 5.3.4 Member Data Documentation

#### 5.3.4.1 template<typename MarkerType> GridObj* Body< MarkerType >::_Owner [protected]

Pointer to owning grid.

#### 5.3.4.2 template<typename MarkerType> bool Body< MarkerType >::closed_surface [protected]

Flag to specify whether or not it is a closed surface (for output)

#### 5.3.4.3 template<typename MarkerType> size_t Body< MarkerType >::id [protected]

ID of body in array of bodies.

#### 5.3.4.4 template<typename MarkerType> std::vector<MarkerType> Body< MarkerType >::markers [protected]

Array of markers which make up the body.

#### 5.3.4.5 template<typename MarkerType> double Body< MarkerType >::spacing [protected]

Spacing of the markers in physical units.

The documentation for this class was generated from the following file:

- Body.h

## 5.4 MpiManager::buffer_struct Struct Reference

Structure storing buffers sizes in each direction for particular grid.

`#include <MpiManager.h>`

### Public Attributes

- int size [L_MPI_dir]
  *Buffer sizes for each direction.*
- int level
  *Grid level.*
- int region
  *Region number.*

### 5.4.1 Detailed Description

Structure storing buffers sizes in each direction for particular grid.

### 5.4.2 Member Data Documentation

#### 5.4.2.1 int MpiManager::buffer_struct::level

Grid level.

#### 5.4.2.2 int MpiManager::buffer_struct::region

Region number.

#### 5.4.2.3 int MpiManager::buffer_struct::size[L_MPI_dir]

Buffer sizes for each direction.

The documentation for this struct was generated from the following file:

- MpiManager.h

## 5.5 GridObj Class Reference

Grid class.

`#include <GridObj.h>`

### Public Member Functions

- GridObj ()
  *Default Constructor.*
- GridObj (int level)
  *Constructor for top level grid.*
- GridObj (int RegionNumber, GridObj &pGrid)
  *Constructor for a sub-grid.*
- GridObj (int level, std::vector< int > local_size, std::vector< std::vector< int > > GlobalLimsInd, std::vector< std::vector< double > > GlobalLimsPos)
  *MPI constructor for top level grid.*
- ∼GridObj ()
  *Default Destructor.*
- void LBM_initVelocity ()
  *Method to initialise the lattice velocity.*
- void LBM_initRho ()
  *Method to initialise the lattice density.*
- void LBM_initGrid ()
  *Wrapper to initialise all L0 lattice quantities.*
- void LBM_initGrid (std::vector< int > local_size, std::vector< std::vector< int > > GlobalLimsInd, std::vector< std::vector< double > > GlobalLimsPos)
  *Method to initialise all L0 lattice quantities.*
- void LBM_initSubGrid (GridObj &pGrid)
  *Method to initialise all sub-grid quantities.*
- void LBM_initBoundLab ()
  *Method to initialise wall and object labels on L0.*
- void LBM_initSolidLab ()
  *Method to initialise label-based solids.*
- void LBM_initRefinedLab (GridObj &pGrid)
  *Method to initialise all labels on sub-grids.*
- void LBM_init_getInletProfile ()
  *Method to import an input profile from a file.*
- void LBM_multi (bool ibmFlag)
  *LBM multi-grid kernel.*
- void LBM_collide ()
  *Apply collision operator.*
- double LBM_collide (int i, int j, int k, int v)
  *Equilibrium calculation.*
- void LBM_kbcCollide (int i, int j, int k, IVector< double > &f_new)
  *KBC collision operator.*
- void LBM_stream ()
  *Streaming operator.*
- void LBM_macro ()
  *Macroscopic update.*

- void LBM_macro (int i, int j, int k)

  *Site-specific macroscopic update.*
- void LBM_boundary (int bc_type_flag)

  *Method to apply boundary conditions on lattice.*
- void LBM_forceGrid ()

  *Method to compute body forces.*
- void LBM_resetForces ()

  *Method to reset body forces.*
- void bc_applyBounceBack (int label, int i, int j, int k)

  *Method to apply half-way bounce-back.*
- void bc_applySpecReflect (int label, int i, int j, int k)

  *Method to apply half-way specular reflection.*
- void bc_applyRegularised (int label, int i, int j, int k)

  *Method to apply regularised velocity inlet.*
- void bc_applyExtrapolation (int label, int i, int j, int k)

  *Method to apply extrapolation outlet.*
- void bc_applyBfl (int i, int j, int k)

  *Method to apply BFL bounce-back.*
- void bc_applyNrbc (int i, int j, int k)

  *Method to apply NRBC.*
- void bc_solidSiteReset ()

  *Helper method to set macroscopic quantities of solid sites.*
- void LBM_explode (int RegionNumber)

  *Explosion operation for pushing information to finer grids.*
- void LBM_coalesce (int RegionNumber)

  *Coalesce operation for pulling information from finer grids.*
- void LBM_addSubGrid (int RegionNumber)

  *Wrapper method to add sub-grid to this grid.*
- void io_textout (std::string output_tag)

  *Verbose ASCII writer.*
- void io_restart (bool IO_flag)

  *Restart file read-writer.*
- void io_probeOutput ()

  *Probe writer.*
- void io_lite (double tval, std::string Tag)

  *ASCII dump of grid data.*
- int io_hdf5 (double tval)

  *HDF5 writer.*

## Public Attributes

- std::vector< int > XInd

  *Vector of global X indices of each site.*
- std::vector< int > YInd

  *Vector of global Y indices of each site.*
- std::vector< int > ZInd

  *Vector of global Z indices of each site.*
- std::vector< double > XPos

  *Vector of global X positions of each site.*
- std::vector< double > YPos

*Vector of global Y positions of each site.*
- std::vector< double > ZPos

  *Vector of global Z positions of each site.*
- IVector< eType > LatTyp

  *Flattened 3D array of site labels.*
- double dx

  *Physical lattice X spacing.*
- double dy

  *Physical lattice Y spacing.*
- double dz

  *Physical lattice Z spacing.*
- int region_number

  *Region number.*
- int level

  *Level in embedded grid hierarchy.*
- double dt

  *Physical time step size.*
- int t

  *Number of completed iterations on this level.*
- double nu

  *Kinematic viscosity (in lattice units)*
- double omega

  *Relaxation frequency.*
- double timeav_mpi_overhead

  *Time-averaged time of MPI communication.*
- double timeav_timestep

  *Time-averaged time of a timestep.*
- int N_lim

  *Local size of grid in X-direction.*
- int M_lim

  *Local size of grid in Y-direction.*
- int K_lim

  *Local size of grid in Z-direction.*
- double XOrigin

  *Global position of grid left edge.*
- double YOrigin

  *Global position of grid bottom edge.*
- double ZOrigin

  *Global position of grid front edge.*

## Friends

- class MpiManager
- class ObjectManager
- class GridUtils

### 5.5.1 Detailed Description

Grid class.

This class represents a grid (lattice) and is capable of owning a nested hierarchy of child grids.

### 5.5.2 Constructor & Destructor Documentation

#### 5.5.2.1 GridObj::GridObj ( void )

Default Constructor.

#### 5.5.2.2 GridObj::GridObj ( int *level* )

Constructor for top level grid.

Coarse limits are set to zero and then L0-specific initialiser called.

**Parameters**

| | |
|---|---|
| *level* | always should be zero astop level grid. |

#### 5.5.2.3 GridObj::GridObj ( int *RegionNumber,* GridObj & *pGrid* )

Constructor for a sub-grid.

**Parameters**

| | |
|---|---|
| *RegionNumber* | ID indicating the region of nested refinement to which this sub-grid belongs. |
| *pGrid* | pointer to parent grid. |

#### 5.5.2.4 GridObj::GridObj ( int *level,* std::vector< int > *local_size,* std::vector< std::vector< int > > *GlobalLimsInd,* std::vector< std::vector< double > > *GlobalLimsPos* )

MPI constructor for top level grid.

When using MPI, this constructors a local grid which represents an appropriate portion of the top-level grid as dictated by the extent of this rank.

**Parameters**

| | |
|---|---|
| *level* | always should be zero astop level grid. |
| *local_size* | vector indicating dimensions of local grid including halo. |
| *GlobalLimsInd* | vector indicating the global indices of the edges of this local grid. |
| *GlobalLimsPos* | vector indicating the global positions of the edges of this local grid. |

#### 5.5.2.5 GridObj::∼GridObj ( void )

Default Destructor.

### 5.5.3 Member Function Documentation

#### 5.5.3.1 void GridObj::bc_applyBfl ( int *i*, int *j*, int *k* )

Method to apply BFL bounce-back.

Currently, assumes only 1 BFL body present on the grid.

**Parameters**

| | |
|---|---|
| *i* | current site i-index. |
| *j* | current site j-index. |
| *k* | current site k-index. |

#### 5.5.3.2 void GridObj::bc_applyBounceBack ( int *label*, int *i*, int *j*, int *k* )

Method to apply half-way bounce-back.

**Parameters**

| | |
|---|---|
| *label* | current site label. |
| *i* | current site i-index. |
| *j* | current site j-index. |
| *k* | current site k-index. |

#### 5.5.3.3 void GridObj::bc_applyExtrapolation ( int *label*, int *i*, int *j*, int *k* )

Method to apply extrapolation outlet.

Can only be applied on right-hand wall.

**Parameters**

| | |
|---|---|
| *label* | current site label. |
| *i* | current site i-index. |
| *j* | current site j-index. |
| *k* | current site k-index. |

#### 5.5.3.4 void GridObj::bc_applyNrbc ( int *i*, int *j*, int *k* )

Method to apply NRBC.

Not implemented in this version.

**Parameters**

| | |
|---|---|
| *i* | current site i-index. |
| *j* | current site j-index. |
| *k* | current site k-index. |

#### 5.5.3.5 void GridObj::bc_applyRegularised ( int *label*, int *i*, int *j*, int *k* )

Method to apply regularised velocity inlet.

Can be applied on any wall.

**Parameters**

| | |
|---|---|
| *label* | current site label. |
| *i* | current site i-index. |
| *j* | current site j-index. |
| *k* | current site k-index. |

#### 5.5.3.6 void GridObj::bc_applySpecReflect ( int *label*, int *i*, int *j*, int *k* )

Method to apply half-way specular reflection.

Symmetry boundary condition for free-slip walls.

**Parameters**

| | |
|---|---|
| *label* | current site label. |
| *i* | current site i-index. |
| *j* | current site j-index. |
| *k* | current site k-index. |

#### 5.5.3.7 void GridObj::bc_solidSiteReset ( )

Helper method to set macroscopic quantities of solid sites.

Velocity is set to zero and density is set to initial density. Applies to eSolid and eRefinedSolid sites only.

#### 5.5.3.8 int GridObj::io_hdf5 ( double *tval* )

HDF5 writer.

Useful grid quantities written out as scalar arrays. One ∗.h5 file per grid and data is grouped into timesteps within each file.

**Parameters**

| | |
|---|---|
| *tval* | time value being written out. |

#### 5.5.3.9 void GridObj::io_lite ( double *tval*, std::string *TAG* )

ASCII dump of grid data.

Generic ASCII writer for each rank to write out all grid data in rows into a single, unsorted file.

**Parameters**

| | |
|---|---|
| *tval* | time value being written out. |
| *TAG* | text identifier for the data. |

#### 5.5.3.10 void GridObj::io_probeOutput ( )

Probe writer.

This routine writes the quantities at hte probe locations to a single file.

#### 5.5.3.11 void GridObj::io_restart ( bool *IO_flag* )

Restart file read-writer.

This routine writes/reads the current rank's data in the custom restart file format. If the file already exists, data is appended. IB body data are also written out but no other body information at present.

**Parameters**

| | |
|---|---|
| *IO_flag* | flag to indicate whether a write (true) or read (false) is required. |

#### 5.5.3.12 void GridObj::io_textout ( std::string *output_tag* )

Verbose ASCII writer.

Writes all the contents of the grid class at time t and call recursviely for any sub-grids. Writes to text file "Grids.out" by default.

**Parameters**

| | |
|---|---|
| *output_tag* | text string added to top of output for identification. |

#### 5.5.3.13 void GridObj::LBM_addSubGrid ( int *RegionNumber* )

Wrapper method to add sub-grid to this grid.

**Parameters**

| | |
|---|---|
| *RegionNumber* | ID indicating the region of nested refinement to which this sub-grid belongs. |

#### 5.5.3.14 void GridObj::LBM_boundary ( int *bc_type_flag* )

Method to apply boundary conditions on lattice.

This method will exmaine the entire lattice for sites which require a boundary condition but only apply the boundary condition requested in the bc_type_flag argument.

**Parameters**

| | |
|---|---|
| *bc_type_flag* | Flag indicating which set of BCs to apply. |

#### 5.5.3.15 void GridObj::LBM_coalesce ( int *RegionNumber* )

Coalesce operation for pulling information from finer grids.

Uses the algorithm of Rohde et al. 2006 to pull information from a fine grid TL to a coarse grid TL.

**Parameters**

| | |
|---|---|
| *RegionNumber* | region number of the sub-grid. |

#### 5.5.3.16 void GridObj::LBM_collide ( )

Apply collision operator.

#### 5.5.3.17 double GridObj::LBM_collide ( int *i*, int *j*, int *k*, int *v* )

Equilibrium calculation.

Computes the equilibrium distribution in direction supplied at the given lattice site and returns the value.

**Parameters**

| | |
|---|---|
| *i* | i-index of lattice site. |
| *j* | j-index of lattice site. |
| *k* | k-index of lattice site. |
| *v* | lattice direction. |

**Returns**

equilibrium function.

#### 5.5.3.18 void GridObj::LBM_explode ( int *RegionNumber* )

Explosion operation for pushing information to finer grids.

Uses the algorithm of Rohde et al. 2006 to pass information from a coarse grid TL to a fine grid TL.

**Parameters**

| | |
|---|---|
| *RegionNumber* | region number of the sub-grid. |

#### 5.5.3.19 void GridObj::LBM_forceGrid ( )

Method to compute body forces.

Takes Cartesian force vector and populates forces for each lattice direction. If reset_flag is true, then resets the force vectors to zero.

#### 5.5.3.20 void GridObj::LBM_init_getInletProfile ( )

Method to import an input profile from a file.

Input data may be over- or under-sampled but it must span the physical dimensions of the inlet otherwise the software does not known how to scale the data to fit. Inlet profile is always assumed to be oriented vertically (y-direction).

#### 5.5.3.21 void GridObj::LBM_initBoundLab ( )

Method to initialise wall and object labels on L0.

The virtual wind tunnel definitions are implemented by this method.

#### 5.5.3.22 void GridObj::LBM_initGrid ( )

Wrapper to initialise all L0 lattice quantities.

This method wraps the MPI-specific version. It is called by the serial build and sets the MPI-specific arguments to default values before calling the full initialiser.

#### 5.5.3.23 void GridObj::LBM_initGrid ( std::vector< int > *local_size,* std::vector< std::vector< int > > *global_edge_ind,* std::vector< std::vector< double > > *global_edge_pos* )

Method to initialise all L0 lattice quantities.

**Parameters**

| | |
|---|---|
| *local_size* | local grid size on this rank including halo. |
| *global_edge_ind* | global indices of the rank edges. |
| *global_edge_pos* | global positions of the rank edges. |

#### 5.5.3.24 void GridObj::LBM_initRefinedLab ( GridObj & *pGrid* )

Method to initialise all labels on sub-grids.

Boundary labels are set by considering parent labels on overlapping sites and then assigning child labels appropriately.

**Parameters**

| | |
|---|---|
| *pGrid* | reference to parent grid. |

#### 5.5.3.25 void GridObj::LBM_initRho ( )

Method to initialise the lattice density.

#### 5.5.3.26 void GridObj::LBM_initSolidLab ( )

Method to initialise label-based solids.

#### 5.5.3.27 void GridObj::LBM_initSubGrid ( GridObj & *pGrid* )

Method to initialise all sub-grid quantities.

**Parameters**

| | |
|---|---|
| *pGrid* | reference to parent grid. |

#### 5.5.3.28 void GridObj::LBM_initVelocity ( )

Method to initialise the lattice velocity.

Unless the L_NO_FLOW macro is defined, the initial velocity everywhere will be set to the values specified in the definitions file.

#### 5.5.3.29 void GridObj::LBM_kbcCollide ( int *i*, int *j*, int *k*, IVector< double > & *f_new* )

KBC collision operator.

Applies KBC collision operator using the KBC-N4 and KBC-D models in 3D and 2D, respectively.

**Parameters**

| | |
|---|---|
| *i* | i-index of lattice site. |
| *j* | j-index of lattice site. |
| *k* | k-index of lattice site. |
| *f_new* | reference to the temporary, post-collision grid. |

#### 5.5.3.30 void GridObj::LBM_macro ( )

Macroscopic update.

Updates macroscopic quantities over the lattice. Also updates time-averaged quantities.

#### 5.5.3.31 void GridObj::LBM_macro ( int *i*, int *j*, int *k* )

Site-specific macroscopic update.

Overload of macroscopic quantity calculation to allow it to be applied to a single site as used by the MPI unpacking routine to update the values for the next collision step. This routine does not update the time-averaged quantities.

**Parameters**

| | |
|---|---|
| *i* | i-index of lattice site. |
| *j* | j-index of lattice site. |
| *k* | k-index of lattice site. |

#### 5.5.3.32 void GridObj::LBM_multi ( bool *ibmFlag* )

LBM multi-grid kernel.

The LBM kernel manages the calling of all IBM and LBM methods on a given grid. In addition, this method also manages the recursive calling of the method on sub-grids and manages the framework for grid-grid interaction.

**Parameters**

| | |
|---|---|
| *ibmFlag* | flag to indicate whether this kernel is a predictor (true) or corrector (false) step when using IBM. |

#### 5.5.3.33 void GridObj::LBM_resetForces ( )

Method to reset body forces.

Resets both Cartesian and Lattice force vectors to zero.

#### 5.5.3.34 void GridObj::LBM_stream ( )

Streaming operator.

Currently, periodic BCs are only applied on L0. Considers site typing as well as grid location when determining viable streaming.

### 5.5.4 Friends And Related Function Documentation

#### 5.5.4.1 friend class GridUtils [friend]

#### 5.5.4.2 friend class MpiManager [friend]

#### 5.5.4.3 friend class ObjectManager [friend]

### 5.5.5 Member Data Documentation

#### 5.5.5.1 double GridObj::dt

Physical time step size.

#### 5.5.5.2 double GridObj::dx

Physical lattice X spacing.

#### 5.5.5.3 double GridObj::dy

Physical lattice Y spacing.

#### 5.5.5.4 double GridObj::dz

Physical lattice Z spacing.

#### 5.5.5.5 int GridObj::K_lim

Local size of grid in Z-direction.

#### 5.5.5.6 IVector<eType> GridObj::LatTyp

Flattened 3D array of site labels.

#### 5.5.5.7 int GridObj::level

Level in embedded grid hierarchy.

#### 5.5.5.8 int GridObj::M_lim

Local size of grid in Y-direction.

#### 5.5.5.9 int GridObj::N_lim

Local size of grid in X-direction.

#### 5.5.5.10 double GridObj::nu

Kinematic viscosity (in lattice units)

#### 5.5.5.11 double GridObj::omega

Relaxation frequency.

#### 5.5.5.12 int GridObj::region_number

Region number.

#### 5.5.5.13 int GridObj::t

Number of completed iterations on this level.

#### 5.5.5.14 double GridObj::timeav_mpi_overhead

Time-averaged time of MPI communication.

#### 5.5.5.15 double GridObj::timeav_timestep

Time-averaged time of a timestep.

#### 5.5.5.16 std::vector<int> GridObj::XInd

Vector of global X indices of each site.

#### 5.5.5.17 double GridObj::XOrigin

Global position of grid left edge.

#### 5.5.5.18 std::vector<double> GridObj::XPos

Vector of global X positions of each site.

#### 5.5.5.19 std::vector<int> GridObj::YInd

Vector of global Y indices of each site.

#### 5.5.5.20 double GridObj::YOrigin

Global position of grid bottom edge.

#### 5.5.5.21 std::vector<double> GridObj::YPos

Vector of global Y positions of each site.

#### 5.5.5.22 std::vector<int> GridObj::ZInd

Vector of global Z indices of each site.

#### 5.5.5.23 double GridObj::ZOrigin

Global position of grid front edge.

#### 5.5.5.24 std::vector<double> GridObj::ZPos

Vector of global Z positions of each site.

The documentation for this class was generated from the following files:

- GridObj.h
- GridObj.cpp
- GridObj_init_grids.cpp
- GridObj_ops_boundary.cpp
- GridObj_ops_io.cpp
- GridObj_ops_lbm.cpp

## 5.6 GridUtils Class Reference

Grid utility class.

```
#include <GridUtils.h>
```

### Static Public Member Functions

- static int createOutputDirectory (std::string path_str)

  *Create output directory.*
- static std::vector< int > onespace (int min, int max)

  *Creates a linearly-spaced vector of integers.*
- static std::vector< double > linspace (double min, double max, int n)

  *Creates a linearly-spaced vector of values.*
- static double vecnorm (double vec[L_dims])

  *Computes the L2 norm using the vector supplied.*
- static double vecnorm (double val1, double val2)

  *Computes the L2 norm using the vector components supplied.*
- static double vecnorm (double val1, double val2, double val3)

  *Computes the L2 norm using the vector components supplied.*
- static double vecnorm (std::vector< double > vec)

  *Computes the L2 norm using the vector supplied.*
- static std::vector< int > getFineIndices (int coarse_i, int x_start, int coarse_j, int y_start, int coarse_k, int z_start)

  *Gets the indices of the fine site given the coarse site.*
- static std::vector< int > getCoarseIndices (int fine_i, int x_start, int fine_j, int y_start, int fine_k, int z_start)

  *Gets the indices of the coarse site given the fine site.*
- static double dotprod (std::vector< double > vec1, std::vector< double > vec2)

  *Computes the scalar product of two vectors.*
- static std::vector< double > subtract (std::vector< double > a, std::vector< double > b)

  *Subtracts two vectors.*
- static std::vector< double > add (std::vector< double > a, std::vector< double > b)

  *Adds two vectors.*
- static std::vector< double > vecmultiply (double scalar, std::vector< double > vec)

  *Multiplies a scalar by a vector.*
- static std::vector< double > crossprod (std::vector< double > vec1, std::vector< double > vec2)

  *Computes vector product.*
- static std::vector< double > matrix_multiply (const std::vector< std::vector< double > > &A, const std↩ ::vector< double > &x)

  *Multiplies matrix A by vector x.*
- static int getOpposite (int direction)

  *Gets the opposite lattice direction to the one supplied.*
- static void getGrid (GridObj *&Grids, int level, int region, GridObj *&ptr)

  *Get a pointer to a given grid in the hierarchy.*
- static std::vector< int > getVoxInd (double x, double y, double z, GridObj *g)

  *Get local voxel indices.*
- static bool isOverlapPeriodic (int i, int j, int k, const GridObj &pGrid)

  *Finds out whether halo containng i,j,k links to neighbour rank periodically.*
- static bool isOnThisRank (int gi, int gj, int gk, const GridObj &pGrid)

  *Finds out whether site with supplied index in on the current rank.*
- static bool isOnThisRank (int gl, enum eCartesianDirection xyz, const GridObj &pGrid)

  *Finds out whether global index can be found on the current rank.*
- static bool hasThisSubGrid (const GridObj &pGrid, int RegNum)

  *Finds out whether specified refined region is on the grid provided.*
- static bool isOnSenderLayer (double pos_x, double pos_y, double pos_z)

  *Check whether site is on an inner (sender) halo.*
- static bool isOnRecvLayer (double pos_x, double pos_y, double pos_z)

*Check whether site is on an outer (receiver) halo.*
- static bool isOnSenderLayer (double site_position, enum eCartesianDirection xyz, enum eMinMax minmax)
  *Check whether site is on an inner (sender) halo.*
- static bool isOnRecvLayer (double site_position, enum eCartesianDirection xyz, enum eMinMax minmax)
  *Check whether site is on an outer (receiver) halo.*
- static bool isOffGrid (int i, int j, int k, GridObj &g)
  *Tests whether a site is on a given grid.*
- template<typename NumType >
  static NumType vecnorm (NumType a1, NumType a2, NumType a3)
  *Computes the L2-norm.*
- template<typename NumType >
  static NumType vecnorm (NumType a1, NumType a2)
  *Computes the L2-norm.*
- template<typename NumType >
  static NumType upToZero (NumType x)
  *Rounds a negative value up to zero.*
- template<typename NumType >
  static NumType downToLimit (NumType x, NumType limit)
  *Rounds a value greater than a limit down to this value.*
- template<typename NumType >
  static NumType factorial (NumType n)
  *Computes the factorial of the supplied value.*
- template<typename NumType >
  static void stridedCopy (NumType *dest, NumType *src, size_t block, size_t offset, size_t stride, size_t count, size_t buf_offset=0)
  *Performs a strided memcpy.*
- template<typename NumType >
  static void global_to_local (int i, int j, int k, GridObj *g, std::vector< NumType > &locals)
  *Maps global indices to local indices.*
- template<typename NumType >
  static void local_to_global (int i, int j, int k, GridObj *g, std::vector< NumType > &globals)
  *Maps local indices to global indices.*

## Static Public Attributes

- static std::ofstream * logfile
  *Handle to output file.*
- static std::string path_str
  *Static string representing output path.*
- static const int dir_reflect [L_dims *2][L_nVels]
  *Array with hardcoded direction numbering for specular reflection.*

### 5.6.1 Detailed Description

Grid utility class.

Class provides grid utilities including commonly used logical tests. This is a static class and so there is no need to instantiate it.

### 5.6.2 Member Function Documentation

#### 5.6.2.1 std::vector< double > GridUtils::add ( std::vector< double > *a*, std::vector< double > *b* ) [static]

Adds two vectors.

**Parameters**

| | |
|---|---|
| *a* | a vector. |
| *b* | a second vector. |

**Returns**

vector which is a + b.

#### 5.6.2.2 int GridUtils::createOutputDirectory ( std::string *path_str* ) [static]

Create output directory.

Compatible with both Windows and Linux. Filename and path passed as a single string. Returns 9 if the directory creation was not attempted due to not being rank 0. Returns platform specific codes for everything else.

**Parameters**

| | |
|---|---|
| *path_str* | full path and filename as string. |

**Returns**

indicator of status of action.

#### 5.6.2.3 std::vector< double > GridUtils::crossprod ( std::vector< double > *a*, std::vector< double > *b* ) [static]

Computes vector product.

**Parameters**

| | |
|---|---|
| *a* | a vector. |
| *b* | a second vector. |

**Returns**

a vector which is the cross product of a and b.

#### 5.6.2.4 double GridUtils::dotprod ( std::vector< double > *vec1*, std::vector< double > *vec2* ) [static]

Computes the scalar product of two vectors.

**Parameters**

| | |
|---|---|
| *vec1* | a vector. |
| *vec2* | a second vector. |

**Returns**

the dot product of the two vectors.

#### 5.6.2.5 template<typename NumType > static NumType GridUtils::downToLimit ( NumType *x*, NumType *limit* ) [inline], [static]

Rounds a value greater than a limit down to this value.

If value is less than or equal to the limit, return the value unchanged.

**Parameters**

| | |
|---|---|
| *x* | value to be rounded |
| *limit* | value to be rounded down to |

**Returns**

NumType rounded value

#### 5.6.2.6 template<typename NumType > static NumType GridUtils::factorial ( NumType *n* ) [inline], [static]

Computes the factorial of the supplied value.

If n == 0 then returns 1.

**Parameters**

| | |
|---|---|
| *n* | factorial |

**Returns**

NumType n factorial

#### 5.6.2.7 std::vector< int > GridUtils::getCoarseIndices ( int *fine_i*, int *x_start*, int *fine_j*, int *y_start*, int *fine_k*, int *z_start* ) [static]

Gets the indices of the coarse site given the fine site.

Maps the indices of a fine grid site to a corresponding coarse site on the level above.

**Parameters**

| | |
|---|---|
| *fine_i* | local i-index of fine site to be mapped. |
| *x_start* | local x-index of start of refined region on the grid above. |
| *fine_j* | local j-index of fine site to be mapped. |

**Parameters**

| | |
|---|---|
| *y_start* | local y-index of start of refined region on the grid above. |
| *fine↩_k* | local k-index of fine site to be mapped. |
| *z_start* | local z-index of start of refined region on the grid above. |

**Returns**

local indices of the coarse grid site.

#### 5.6.2.8 std::vector< int > GridUtils::getFineIndices ( int *coarse_i,* int *x_start,* int *coarse_j,* int *y_start,* int *coarse_k,* int *z_start* ) [static]

Gets the indices of the fine site given the coarse site.

Maps the indices of a coarse grid site to a corresponding fine site on the level below.

**Parameters**

| | |
|---|---|
| *coarse↩_i* | local i-index of coarse site to be mapped. |
| *x_start* | local x-index of start of refined region. |
| *coarse↩_j* | local j-index of coarse site to be mapped. |
| *y_start* | local y-index of start of refined region. |
| *coarse↩_k* | local k-index of coarse site to be mapped. |
| *z_start* | local z-index of start of refined region. |

**Returns**

local indices of the fine grid site.

#### 5.6.2.9 void GridUtils::getGrid ( GridObj *& *Grids,* int *level,* int *region,* GridObj *& *ptr* ) [static]

Get a pointer to a given grid in the hierarchy.

Takes a NULL pointer by reference and updates it when matching grid is found in hierarchy on this rank. If grid not found, pointer is returned without change and stays NULL. Can be used to test for the existence of a grid on a rank by passing in a NULL pointer and checking if a NULL pointer is returned.

**Parameters**

| | | |
|---|---|---|
| | *Grids* | x-position of site. |
| | *level* | y-position of site. |
| | *region* | z-position of site. |
| out | *ptr* | pointer containing address of grid in hierarchy. |

#### 5.6.2.10 int GridUtils::getOpposite ( int *direction* ) [static]

Gets the opposite lattice direction to the one supplied.

This is model independent as long as the model directions are specified such that the oppoiste direction is either one vector on or one vector back in the listing depending on whether the direction supplied is even or odd.

**Parameters**

| | |
|---|---|
| *direction* | direction to be reversed. |

**Returns**

opposite direction in lattice model.

#### 5.6.2.11 std::vector< int > GridUtils::getVoxInd ( double *x*, double *y*, double *z*, GridObj * *g* ) [static]

Get local voxel indices.

Will return the voxel indices of the nearest voxel on the lattice provided for a given point described as a position in global space. Can return global values that are not on this MPI rank. Use the GridUtils::isOnThisRank() method to check the result. This method is used as a position -> voxel converter.

**Parameters**

| | |
|---|---|
| *x* | global x-position. |
| *y* | global y-position. |
| *z* | global z-position. |
| *g* | lattice on which to look for nearest voxel. |

**Returns**

vector of indices of the nearest voxel on supplied lattice level.

#### 5.6.2.12 template<typename NumType > static void GridUtils::global_to_local ( int *i*, int *j*, int *k*, GridObj * *g*, std::vector< NumType > & *locals* ) [inline], [static]

Maps global indices to local indices.

Takes a vector container and populates it with the local indices where the supplied global site can be found on the grid supplied. If global indicies are not found on the supplied grid then local index of -1 is returned.

**Parameters**

| | | |
|---|---|---|
| | *i* | global index |
| | *j* | global index |
| | *k* | global index |
| | *g* | grid on which local indices are required |
| out | *locals* | vector container for local indices |

#### 5.6.2.13 bool GridUtils::hasThisSubGrid ( const GridObj & *pGrid,* int *RegNum* ) [static]

Finds out whether specified refined region is on the grid provided.

**Parameters**

| | |
|---|---|
| *pGrid* | parent grid at appropriate level. |
| *RegNum* | region number desired. |

**Returns**

boolean answer.

#### 5.6.2.14 bool GridUtils::isOffGrid ( int *i,* int *j,* int *k,* GridObj & *g* ) [static]

Tests whether a site is on a given grid.

**Parameters**

| | |
|---|---|
| *i* | local i-index. |
| *j* | local j-index. |
| *k* | local k-index. |
| *g* | grid on which to check. |

**Returns**

boolean answer.

#### 5.6.2.15 bool GridUtils::isOnRecvLayer ( double *pos_x,* double *pos_y,* double *pos_z* ) [static]

Check whether site is on an outer (receiver) halo.

Wrapper which checks every halo region of the rank for intersection with supplied site position.

**Parameters**

| | |
|---|---|
| *pos_x* | x-position of site. |
| *pos_y* | y-position of site. |
| *pos_z* | z-position of site. |

**Returns**

boolean answer.

#### 5.6.2.16 bool GridUtils::isOnRecvLayer ( double *site_position*, enum **eCartesianDirection** *dir*, enum **eMinMax** *maxmin* ) [static]

Check whether site is on an outer (receiver) halo.

Wrapper available which checks every halo. This method only checks the halo specified by the Cartesian direction and whether it is the left/bottom/front (minimum) or right/top/back (maximum) edge of the block.

**Parameters**

| | |
|---|---|
| *site_position* | position of site. |
| *dir* | cartesian direction. |
| *maxmin* | choice of edge in given direction. |

**Returns**

boolean answer.

#### 5.6.2.17 bool GridUtils::isOnSenderLayer ( double *pos_x*, double *pos_y*, double *pos_z* ) [static]

Check whether site is on an inner (sender) halo.

Wrapper which checks every halo region of the rank for intersection with supplied site position.

**Parameters**

| | |
|---|---|
| *pos_x* | x-position of site. |
| *pos_y* | y-position of site. |
| *pos_z* | z-position of site. |

**Returns**

boolean answer.

#### 5.6.2.18 bool GridUtils::isOnSenderLayer ( double *site_position*, enum **eCartesianDirection** *dir*, enum **eMinMax** *maxmin* ) [static]

Check whether site is on an inner (sender) halo.

Wrapper available which checks every halo. This method only checks the halo specified by the Cartesian direction and whether it is the left/bottom/front (minimum) or right/top/back (maximum) edge of the block.

**Parameters**

| | |
|---|---|
| *site_position* | position of site. |
| *dir* | cartesian direction. |
| *maxmin* | choice of edge in given direction. |

**Returns**

boolean answer.

#### 5.6.2.19 bool GridUtils::isOnThisRank ( int *gi*, int *gj*, int *gk*, const GridObj & *grid* ) [static]

Finds out whether site with supplied index in on the current rank.

**Parameters**

| | |
|---|---|
| *gi* | global i-index of site. |
| *gj* | global j-index of site. |
| *gk* | global k-index of site. |
| *grid* | grid being queried. |

**Returns**

boolean answer.

#### 5.6.2.20 bool GridUtils::isOnThisRank ( int *gl*, enum eCartesianDirection *xyz*, const GridObj & *grid* ) [static]

Finds out whether global index can be found on the current rank.

**Parameters**

| | |
|---|---|
| *gl* | global index (i,j or k). |
| *xyz* | cartesian direction of interest. |
| *grid* | grid being queried. |

**Returns**

boolean answer.

#### 5.6.2.21 bool GridUtils::isOverlapPeriodic ( int *i*, int *j*, int *k*, const GridObj & *g* ) [static]

Finds out whether halo containng i,j,k links to neighbour rank periodically.

Checks the receiver layer containing local site i,j,k and determines from the MPI topology information whether this layer couples to an adjacent or periodic neighbour rank. I.e. if the neighbour is physically next to the rank or whether it is actaully at the other side of the domain.

**Parameters**

| | |
|---|---|
| *i* | local i-index of recv layer site being queried. |
| *j* | local j-index of recv layer site being queried. |
| *k* | local k-index of recv layer site being queried. |
| *g* | grid on which point being queried resides. |

**Returns**

boolean answer.

#### 5.6.2.22 std::vector< double > GridUtils::linspace ( double *min*, double *max*, int *n* ) [static]

Creates a linearly-spaced vector of values.

**Parameters**

| | |
|---|---|
| *min* | starting value of output vector. |
| *max* | ending point of output vector. |
| *n* | number of values in output vector. |

**Returns**

a vector with n uniformly spaced values between min and max.

#### 5.6.2.23 template<typename NumType > static void GridUtils::local_to_global ( int *i*, int *j*, int *k*, GridObj ∗ *g*, std::vector< NumType > & *globals* ) [inline], [static]

Maps local indices to global indices.

Takes a vector container and populates it with the global indices of the supplied local site

**Parameters**

| | | |
|---|---|---|
| | *i* | local index |
| | *j* | local index |
| | *k* | local index |
| | *g* | grid on which global indices are required |
| out | *globals* | vector container for global indices |

#### 5.6.2.24 std::vector< double > GridUtils::matrix_multiply ( const std::vector< std::vector< double > > & *A*, const std::vector< double > & *x* ) [static]

Multiplies matrix A by vector x.

**Parameters**

| | |
|---|---|
| *A* | a matrix represented as a vector or vectors. |
| *x* | a vector. |

**Returns**

a vector which is A ∗ x.

#### 5.6.2.25 std::vector< int > GridUtils::onespace ( int *min*, int *max* ) [static]

Creates a linearly-spaced vector of integers.

**Parameters**

| | |
|---|---|
| *min* | starting value of output vector. |
| *max* | ending point of output vector. |

**Returns**

a vector with uniformly spaced integer values between min and max.

#### 5.6.2.26 template<typename NumType > static void GridUtils::stridedCopy ( NumType * *dest*, NumType * *src*, size_t *block*, size_t *offset*, size_t *stride*, size_t *count*, size_t *buf_offset* = 0 ) [inline], [static]

Performs a strided memcpy.

Memcpy() is designed to copy blocks of contiguous memory. Strided copy copies a pattern of contiguous blocks.

**Parameters**

| | |
|---|---|
| *dest* | pointer to start of destination memory |
| *src* | pointer to start of source memory |
| *block* | size of contiguous block |
| *offset* | offset from the start of the soruce array |
| *stride* | number of elements between start of first block and start of second |
| *count* | number of blocks in pattern |
| *buf_offset* | offset from start of destination buffer to start writing. Default is zero if not supplied. |

#### 5.6.2.27 std::vector< double > GridUtils::subtract ( std::vector< double > *a*, std::vector< double > *b* ) [static]

Subtracts two vectors.

**Parameters**

| | |
|---|---|
| *a* | a vector. |
| *b* | a second vector. |

**Returns**

a vector which is a - b.

#### 5.6.2.28 template<typename NumType > static NumType GridUtils::upToZero ( NumType *x* ) [inline], [static]

Rounds a negative value up to zero.

If value is positive, return the value unchanged.

**Parameters**

| | |
|---|---|
| *x* | value to be rounded |

**Returns**

NumType rounded value

#### 5.6.2.29 std::vector< double > GridUtils::vecmultiply ( double *scalar,* std::vector< double > *vec* ) [static]

Multiplies a scalar by a vector.

**Parameters**

| | |
|---|---|
| *scalar* | a scalar double. |
| *vec* | a vector double. |

**Returns**

a vector which is a scalar multiplied by a vector.

#### 5.6.2.30 double GridUtils::vecnorm ( double *vec[L_dims]* ) [static]

Computes the L2 norm using the vector supplied.

**Parameters**

| | |
|---|---|
| *vec* | old-style C array representing a vector with the same number of number of components as the problem dimension. |

**Returns**

the L2 norm.

#### 5.6.2.31 double GridUtils::vecnorm ( double *val1,* double *val2* ) [static]

Computes the L2 norm using the vector components supplied.

**Parameters**

| | |
|---|---|
| *val1* | first vector component. |
| *val2* | second vector component. |

**Returns**

the L2 norm.

#### 5.6.2.32 double GridUtils::vecnorm ( double *val1*, double *val2*, double *val3* ) [static]

Computes the L2 norm using the vector components supplied.

**Parameters**

| | |
|---|---|
| *val1* | first vector component. |
| *val2* | second vector component. |
| *val3* | third vector component. |

**Returns**

the L2 norm.

#### 5.6.2.33 double GridUtils::vecnorm ( std::vector< double > *vec* ) [static]

Computes the L2 norm using the vector supplied.

**Parameters**

| | |
|---|---|
| *vec* | C++ std::vector. |

**Returns**

the L2 norm.

#### 5.6.2.34 template<typename NumType > static NumType GridUtils::vecnorm ( NumType *a1*, NumType *a2*, NumType *a3* ) [inline], [static]

Computes the L2-norm.

**Parameters**

| | |
|---|---|
| *a1* | first component of the vector |
| *a2* | second component of the vector |
| *a3* | third component of the vector |

**Returns**

NumType scalar quantity

#### 5.6.2.35 template< typename NumType > static NumType GridUtils::vecnorm ( NumType *a1*, NumType *a2* ) [inline], [static]

Computes the L2-norm.

**Parameters**

| | |
|---|---|
| *a1* | first component of the vector |
| *a2* | second component of the vector |

**Returns**

NumType scalar quantity

### 5.6.3 Member Data Documentation

#### 5.6.3.1 const int GridUtils::dir_reflect [static]

**Initial value:**

```
=
    {
        {1, 0, 2, 3, 7, 6, 5, 4, 8},
        {1, 0, 2, 3, 4, 6, 5, 4, 8},
        {0, 1, 3, 2, 6, 7, 4, 5, 8},
        {0, 1, 3, 2, 6, 7, 4, 5, 8}
    }
```

Array with hardcoded direction numbering for specular reflection.

#### 5.6.3.2 std::ofstream * GridUtils::logfile [static]

Handle to output file.

#### 5.6.3.3 std::string GridUtils::path_str [static]

Static string representing output path.

The documentation for this class was generated from the following files:

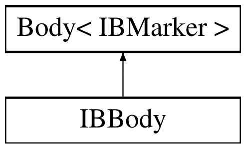
- GridUtils.h
- GridObj.cpp
- GridUtils.cpp
- main_lbm.cpp

## 5.7 IBBody Class Reference

Immersed boundary body.

```
#include <IBBody.h>
```

Inheritance diagram for IBBody:




### Public Member Functions

- IBBody (void)

  *Constructor which sets group ID to zero by default.*
- ∼IBBody (void)

  *Default destructor.*
- IBBody (GridObj ∗g, size_t id)

  *Constructor which assigns the owner grid.*
- void addMarker (double x, double y, double z, bool flex_rigid)

  *Method to add an IB marker to the body.*
- virtual void markerAdder (double x, double y, double z, int &curr_mark, std::vector< int > &counter, bool flex_rigid)

  *Downsampling marker adding method (override)*
- void makeBody (double radius, std::vector< double > centre, bool flex_rigid, bool moving, int group)

  *Method to seed markers for a sphere / circle.*
- void makeBody (std::vector< double > width_length_depth, std::vector< double > angles, std::vector< double > centre, bool flex_rigid, bool deform, int group)

  *Method to seed markers for a cuboid / rectangle.*
- void makeBody (int numbermarkers, std::vector< double > start_point, double fil_length, std::vector< double > angles, std::vector< int > BCs, bool flex_rigid, bool deform, int group)

  *Method to seed markers for a flexible filament.*
- double makeBody (std::vector< double > width_length, double angle, std::vector< double > centre, bool flex_rigid, bool deform, int group, bool plate)

  *Method to seed markers for a 3D plate inclined from the XZ plane.*
- void makeBody (PCpts ∗_PCpts)

  *Method to build a body from a point cloud.*

### Protected Attributes

- bool flex_rigid

  *Flag to indicate flexibility: false == rigid body; true == flexible filament.*
- bool deformable

  *Flag to indicate deformable body: false == rigid; true == deformable.*
- int groupID

  *ID of IBbody group – position updates can be driven from a flexible body in a group.*
- double delta_rho

*Difference in density between fluid and solid in lattice units.*

- double flexural_rigidity

  *Young's modulus E $*$ Second moment of area I.*

- std::vector$<$ double $>$ tension

  *Tension between the current marker and its neighbour.*

- std::vector$<$ int $>$ BCs

  *BCs type flags (flexible bodies)*

## Friends

- class ObjectManager

## Additional Inherited Members

### 5.7.1 Detailed Description

Immersed boundary body.

### 5.7.2 Constructor & Destructor Documentation

#### 5.7.2.1 IBBody::IBBody ( void )

Constructor which sets group ID to zero by default.

#### 5.7.2.2 IBBody::$\sim$IBBody ( void )

Default destructor.

#### 5.7.2.3 IBBody::IBBody ( GridObj $*$ *g*, size_t *id* )

Constructor which assigns the owner grid.

Also sets the group ID to zero.

**Parameters**

| | |
|---|---|
| *g* | pointer to owner grid |
| *id* | ID of body in array of bodies. |

### 5.7.3 Member Function Documentation

#### 5.7.3.1 void IBBody::addMarker ( double *x*, double *y*, double *z*, bool *flex_rigid* )

Method to add an IB marker to the body.

Adds marker at the given position with the given moving/non-moving flag.

**Parameters**

| | |
|---|---|
| *x* | global x-position of marker. |
| *y* | global y-position of marker. |
| *z* | global z-position of marker. |
| *flex_rigid* | flag to indicate whether marker is movable or not. |

#### 5.7.3.2 void IBBody::makeBody ( double *radius,* std::vector< double > *centre,* bool *flex_rigid,* bool *deform,* int *group* )

Method to seed markers for a sphere / circle.

**Parameters**

| | |
|---|---|
| *radius* | radius of circle/sphere. |
| *centre* | position vector of circle/sphere centre. |
| *flex_rigid* | flag to indicate whether body is flexible and requires a structural calculation. |
| *deform* | flag to indicate whether body is movable and requires relocation each time step. |
| *group* | ID indicating which group the body is part of for collective operations. |

#### 5.7.3.3 void IBBody::makeBody ( std::vector< double > *width_length_depth,* std::vector< double > *angles,* std::vector< double > *centre,* bool *flex_rigid,* bool *deform,* int *group* )

Method to seed markers for a cuboid / rectangle.

**Parameters**

| | |
|---|---|
| *width_length_depth* | principal dimensions of cuboid / rectangle. |
| *angles* | principal orientation of cuboid / rectangle w.r.t. domain axes. |
| *centre* | position vector of cuboid / rectangle centre. |
| *flex_rigid* | flag to indicate whether body is flexible and requires a structural calculation. |
| *deform* | flag to indicate whether body is movable and requires relocation each time step. |
| *group* | ID indicating which group the body is part of for collective operations. |

#### 5.7.3.4 void IBBody::makeBody ( int *nummarkers,* std::vector< double > *start_point,* double *fil_length,* std::vector< double > *angles,* std::vector< int > *BCs,* bool *flex_rigid,* bool *deform,* int *group* )

Method to seed markers for a flexible filament.

**Parameters**

| | |
|---|---|
| *nummarkers* | number of markers to use for filament. |
| *start_point* | 3D position vector of the start of the filament. |
| *fil_length* | length of filament in physical units. |
| *angles* | two angles representing filament inclination w.r.t. domain axes (horizontal plane and vertical plane). |

**Parameters**

| | |
|---|---|
| *BCs* | vector containing start and end boundary condition types (see class definition for valid values). |
| *flex_rigid* | flag to indicate whether body is flexible and requires a structural calculation. |
| *deform* | flag to indicate whether body is movable and requires relocation each time step. |
| *group* | ID indicating which group the body is part of for collective operations. |

#### 5.7.3.5 double IBBody::makeBody ( std::vector< double > *width_length*, double *angle*, std::vector< double > *centre*, bool *flex_rigid*, bool *deform*, int *group*, bool *plate* )

Method to seed markers for a 3D plate inclined from the XZ plane.

**Parameters**

| | |
|---|---|
| *width_length* | 2D vector of principal dimensions of thin plate. |
| *angle* | inclination angle from horizontal. |
| *centre* | position vector of the plate centre. |
| *flex_rigid* | flag to indicate whether body is flexible and requires a structural calculation. |
| *deform* | flag to indicate whether body is movable and requires relocation each time step. |
| *group* | ID indicating which group the body is part of for collective operations. |
| *plate* | arbitrary argument to allow overload otherwise would have the same signature as a filament builder. |

#### 5.7.3.6 void IBBody::makeBody ( PCpts * *_PCpts* )

Method to build a body from a point cloud.

Flexibility and deformable properties taken from definitions.

**Parameters**

| | |
|---|---|
| *_PCpts* | pointer to pointer cloud data. |

#### 5.7.3.7 void IBBody::markerAdder ( double *x*, double *y*, double *z*, int & *curr_mark*, std::vector< int > & *counter*, bool *flex_rigid* ) [virtual]

Downsampling marker adding method (override)

This method is an override of the same method in the Body class. This version uses the optional flag argument to pass extra information to IBB marker constructors.

**Parameters**

| | |
|---|---|
| *x* | desired global X-position of new marker. |
| *y* | desired globalY-position of new marker. |
| *z* | desired globalZ-position of new marker. |

**Parameters**

| | |
|---|---|
| *curr_mark* | is a reference to the ID of last marker. |
| *counter* | is a reference to the total number of markers in the body. |
| *flex_rigid* | indicates whether markers added should form part of flexible or rigid body. |

Reimplemented from Body< IBMarker >.

## 5.7.4 Friends And Related Function Documentation

### 5.7.4.1 friend class ObjectManager [friend]

## 5.7.5 Member Data Documentation

### 5.7.5.1 std::vector<int> IBBody::BCs [protected]

BCs type flags (flexible bodies)

### 5.7.5.2 bool IBBody::deformable [protected]

Flag to indicate deformable body: false == rigid; true == deformable.

### 5.7.5.3 double IBBody::delta_rho [protected]

Difference in density between fluid and solid in lattice units.

### 5.7.5.4 bool IBBody::flex_rigid [protected]

Flag to indicate flexibility: false == rigid body; true == flexible filament.

### 5.7.5.5 double IBBody::flexural_rigidity [protected]

Young's modulus E $*$ Second moment of area I.

### 5.7.5.6 int IBBody::groupID [protected]

ID of IBbody group – position updates can be driven from a flexible body in a group.

#### 5.7.5.7 std::vector<double> IBBody::tension [protected]

Tension between the current marker and its neighbour.

The documentation for this class was generated from the following files:

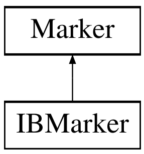
- IBBody.h
- IBBody.cpp

## 5.8 IBMarker Class Reference

Immersed boundary marker.

`#include <IBMarker.h>`

Inheritance diagram for IBMarker:




### Public Member Functions

- IBMarker (void)

  *Default constructor.*
- ∼IBMarker (void)

  *Default destructor.*
- IBMarker (double xPos, double yPos, double zPos, bool flex_rigid=false)

  *Custom constructor with position.*

### Protected Attributes

- std::vector< double > fluid_vel

  *Fluid velocity interpolated from lattice nodes.*
- std::vector< double > desired_vel

  *Desired velocity at marker.*
- std::vector< double > force_xyz

  *Restorative force vector on marker.*
- std::vector< double > position_old

  *Vector containing the physical coordinates (x,y,z) of the marker at t-1. Used for moving bodies.*
- std::vector< double > deltaval

  *Value of delta function for a given support node.*
- bool flex_rigid

  *Indication as to whether marker is part of a moving or flexible body: false == rigid/fixed; true == flexible/moving.*
- double epsilon

  *Scaling parameter.*
- double local_area

  *Area associated with support node in lattice units (same for all points if from same grid and regularly spaced like LBM)*
- double dilation

  *Dilation parameter in lattice units (same in all directions for uniform Eulerian grid)*

## Friends

- class ObjectManager
- class IBBody

## Additional Inherited Members

### 5.8.1 Detailed Description

Immersed boundary marker.

This class declaration is for an immersed boundary Lagrange point. A collection of these points form an immersed boundary body.

### 5.8.2 Constructor & Destructor Documentation

#### 5.8.2.1 IBMarker::IBMarker ( void ) [inline]

Default constructor.

#### 5.8.2.2 IBMarker::~IBMarker ( void ) [inline]

Default destructor.

#### 5.8.2.3 IBMarker::IBMarker ( double *xPos*, double *yPos*, double *zPos*, bool *flex_rigid* = false )

Custom constructor with position.

**Parameters**

| | |
|---|---|
| *xPos* | x-position of marker. |
| *yPos* | y-position of marker. |
| *zPos* | z-position of marker. |
| *flex_rigid* | flag to indicate whether marker is movable or not. |

### 5.8.3 Friends And Related Function Documentation

#### 5.8.3.1 friend class IBBody [friend]

#### 5.8.3.2 friend class ObjectManager [friend]

### 5.8.4 Member Data Documentation

#### 5.8.4.1 std::vector<double> IBMarker::deltaval [protected]

Value of delta function for a given support node.

#### 5.8.4.2 std::vector<double> IBMarker::desired_vel [protected]

Desired velocity at marker.

#### 5.8.4.3 double IBMarker::dilation [protected]

Dilation parameter in lattice units (same in all directions for uniform Eulerian grid)

#### 5.8.4.4 double IBMarker::epsilon [protected]

Scaling parameter.

#### 5.8.4.5 bool IBMarker::flex_rigid [protected]

Indication as to whether marker is part of a moving or flexible body: false == rigid/fixed; true == flexible/moving.

#### 5.8.4.6 std::vector<double> IBMarker::fluid_vel [protected]

Fluid velocity interpolated from lattice nodes.

#### 5.8.4.7 std::vector<double> IBMarker::force_xyz [protected]

Restorative force vector on marker.

#### 5.8.4.8 double IBMarker::local_area [protected]

Area associated with support node in lattice units (same for all points if from same grid and regularly spaced like LBM)

#### 5.8.4.9 std::vector<double> IBMarker::position_old [protected]

Vector containing the physical coordinates (x,y,z) of the marker at t-1. Used for moving bodies.

The documentation for this class was generated from the following files:

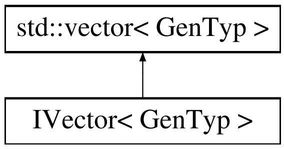
- IBMarker.h
- IBMarker.cpp

## 5.9 IVector< GenTyp > Class Template Reference

Index-collapsing vector class.

`#include <IVector.h>`

Inheritance diagram for IVector< GenTyp >:




### Public Member Functions

- IVector ()
  *Default constructor.*
- ~IVector ()
  *Default destructor.*
- IVector (size_t size, GenTyp val)
  *Custom constructor taking type and value.*
- GenTyp & operator() (size_t i, size_t j, size_t k, size_t v, size_t j_max, size_t k_max, size_t v_max)
  *4D array index flatten.*
- GenTyp & operator() (size_t i, size_t j, size_t k, size_t j_max, size_t k_max)
  *3D array index flatten.*
- GenTyp & operator() (size_t i, size_t j, size_t j_max)
  *2D array index flatten.*

### 5.9.1 Detailed Description

**template<typename GenTyp>**
**class IVector< GenTyp >**

Index-collapsing vector class.

This class has all the behaviour of std::vector but has a overriden operator() to allow automatic flattening of indices before returning a reference of value at indexed location. Needs to be able to accept different datatypes so templated.

### 5.9.2 Constructor & Destructor Documentation

#### 5.9.2.1 template<typename GenTyp> IVector< GenTyp >::IVector ( ) [inline]

Default constructor.

#### 5.9.2.2 template<typename GenTyp> IVector< GenTyp >::~IVector ( ) [inline]

Default destructor.

#### 5.9.2.3 template<typename GenTyp> IVector< GenTyp >::IVector ( size_t *size*, GenTyp *val* ) [inline]

Custom constructor taking type and value.

**Parameters**

| | |
|---|---|
| *size* | the desired size of vector |
| *val* | the value to fill the new vector with |

### 5.9.3 Member Function Documentation

#### 5.9.3.1 template<typename GenTyp> GenTyp& IVector< GenTyp >::operator() ( size_t *i*, size_t *j*, size_t *k*, size_t *v*, size_t *j_max*, size_t *k_max*, size_t *v_max* ) [inline]

4D array index flatten.

Override of parentheses to auto-flatten indices to a single index.

**Parameters**

| | |
|---|---|
| *i* | the i index |
| *j* | the j index |
| *k* | the k index |
| *v* | the index in the fourth dimension |
| *j_max* | the number of j elements |
| *k_max* | the number of k elements |
| *v_max* | the number of elements in the fourth dimension |

**Returns**

GenTyp& a reference to the value at this position in the vector

#### 5.9.3.2 template<typename GenTyp> GenTyp& IVector< GenTyp >::operator() ( size_t *i*, size_t *j*, size_t *k*, size_t *j_max*, size_t *k_max* ) [inline]

3D array index flatten.

Override of parentheses to auto-flatten indices to a single index.

**Parameters**

| | |
|---|---|
| *i* | the i index |
| *j* | the j index |
| *k* | the k index |
| *j_max* | the number of j elements |
| *k_max* | the number of k elements |

**Returns**

GenTyp& a reference to the value at this position in the vector

#### 5.9.3.3 template<typename GenTyp> GenTyp& IVector< GenTyp >::operator() ( size_t *i*, size_t *j*, size_t *j_max* ) [inline]

2D array index flatten.

**Parameters**

| | |
|---|---|
| *i* | the i index |
| *j* | the j index |
| *j_max* | the number of j elements |

**Returns**

GenTyp& a reference to the value at this position in the vector

The documentation for this class was generated from the following file:

- IVector.h

## 5.10 MpiManager::layer_edges Struct Reference

Structure containing global positions of the edges of halos.

```
#include <MpiManager.h>
```

### Public Attributes

- double X [4]
  *X limits.*
- double Y [4]
  *Y limits.*
- double Z [4]
  *Z limits.*

### 5.10.1 Detailed Description

Structure containing global positions of the edges of halos.

Sender (inner) and receiver (outer) parts of halo are located using the convention [left_min left_max right_min right_max] for X,Y and Z.

### 5.10.2 Member Data Documentation

#### 5.10.2.1 double MpiManager::layer_edges::X[4]

X limits.

#### 5.10.2.2 double MpiManager::layer_edges::Y[4]

Y limits.

#### 5.10.2.3 double MpiManager::layer_edges::Z[4]

Z limits.

The documentation for this struct was generated from the following file:

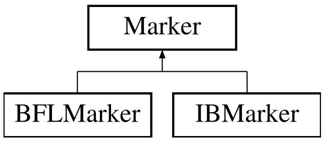
- MpiManager.h

## 5.11 Marker Class Reference

Generic marker class.

`#include <Marker.h>`

Inheritance diagram for Marker:




### Public Member Functions

- Marker (void)

  *Default constructor.*
- ∼Marker (void)

  *Default destructor.*
- Marker (double x, double y, double z)

  *Custom constructor which locates marker.*

### Public Attributes

- std::vector< double > position

  *Position vector of marker location in physical units.*
- std::vector< int > supp_i

  *X-indices of lattice sites in support of this marker.*
- std::vector< int > supp_j

  *Y-indices of lattice sites in support of this marker.*
- std::vector< int > supp_k

  *Z-indices of lattice sites in support of this marker.*
- std::vector< int > support_rank

  *Array of indices indicating on which rank the given support point resides.*

### 5.11.1 Detailed Description

Generic marker class.

### 5.11.2 Constructor & Destructor Documentation

#### 5.11.2.1 Marker::Marker ( void ) [inline]

Default constructor.

#### 5.11.2.2 Marker::~Marker ( void ) [inline]

Default destructor.

#### 5.11.2.3 Marker::Marker ( double *x*, double *y*, double *z* ) [inline]

Custom constructor which locates marker.

**Parameters**

| | |
|---|---|
| *x* | X-position of marker in physical units |
| *y* | Y-position of marker in physical units |
| *z* | Z-position of marker in physical units |

### 5.11.3 Member Data Documentation

#### 5.11.3.1 std::vector<double> Marker::position

Position vector of marker location in physical units.

#### 5.11.3.2 std::vector<int> Marker::supp_i

X-indices of lattice sites in support of this marker.

#### 5.11.3.3 std::vector<int> Marker::supp_j

Y-indices of lattice sites in support of this marker.

#### 5.11.3.4 std::vector<int> Marker::supp_k

Z-indices of lattice sites in support of this marker.

#### 5.11.3.5 std::vector<int> Marker::support_rank

Array of indices indicating on which rank the given support point resides.

The documentation for this class was generated from the following file:

- Marker.h

## 5.12 MarkerData Class Reference

Container class to hold marker information.

`#include <Body.h>`

### Public Member Functions

- MarkerData (int i, int j, int k, double x, double y, double z, int ID)
  *Constructor.*
- MarkerData (void)
  *Default Constructor.*
- ∼MarkerData (void)
  *Default destructor.*

### Public Attributes

- int i
  *i-index of primary support site*
- int j
  *j-index of primary support site*
- int k
  *k-index of primary support site*
- int ID
  *Marker ID (position in array of markers)*
- double x
  *x-position of marker*
- double y
  *y-position of marker*
- double z
  *z-position of marker*

### 5.12.1 Detailed Description

Container class to hold marker information.

### 5.12.2 Constructor & Destructor Documentation

#### 5.12.2.1 MarkerData::MarkerData ( int *i*, int *j*, int *k*, double *x*, double *y*, double *z*, int *ID* ) [inline]

Constructor.

**Parameters**

| | |
|---|---|
| *i* | i-index of primary support site |
| *j* | j-index of primary support site |
| *k* | k-index of primary support site |
| *x* | x-position of marker |
| *y* | y-position of marker |
| *z* | z-position of marker |
| *ID* | marker number in a given body |

#### 5.12.2.2 MarkerData::MarkerData ( void ) [inline]

Default Constructor.

Initialise with invalid marker indicator which is to set the x position to NaN.

#### 5.12.2.3 MarkerData::∼MarkerData ( void ) [inline]

Default destructor.

### 5.12.3 Member Data Documentation

#### 5.12.3.1 int MarkerData::i

i-index of primary support site

#### 5.12.3.2 int MarkerData::ID

Marker ID (position in array of markers)

#### 5.12.3.3 int MarkerData::j

j-index of primary support site

#### 5.12.3.4 int MarkerData::k

k-index of primary support site

#### 5.12.3.5 double MarkerData::x

x-position of marker

#### 5.12.3.6 double MarkerData::y

y-position of marker

#### 5.12.3.7 double MarkerData::z

z-position of marker

The documentation for this class was generated from the following file:

- Body.h

## 5.13 MpiManager Class Reference

MPI Manager class.

`#include <MpiManager.h>`

### Classes

- struct buffer_struct

  *Structure storing buffers sizes in each direction for particular grid.*
- struct layer_edges

  *Structure containing global positions of the edges of halos.*
- struct phdf5_struct

  *Structure for storing halo information for HDF5.*

### Public Member Functions

- void mpi_init ()

  *Initialisation routine.*
- void mpi_gridbuild ()

  *Domain decomposition.*
- int mpi_buildCommunicators ()

  *Define writable sub-grid communicators.*
- void mpi_buffer_pack (int dir, GridObj ∗g)

  *Method to pack the communication buffer.*
- void mpi_buffer_unpack (int dir, GridObj ∗g)

  *Method to unpack the communication buffer.*
- void mpi_buffer_size ()

  *Pre-calcualtion of the buffer sizes.*
- void mpi_buffer_size_send (GridObj ∗&g)

  *Method to pre-compute the size of the sender layer buffer.*
- void mpi_buffer_size_recv (GridObj ∗&g)

  *Method to pre-compute the size of the receiver layer buffer.*
- void mpi_writeout_buf (std::string filename, int dir)

  *Buffer ASCII writer.*
- void mpi_communicate (int level, int regnum)

  *Communication routine.*
- int mpi_getOpposite (int direction)

  *Helper method to find opposite direction in MPI topology.*

### Static Public Member Functions

- static MpiManager * getInstance ()

  *Instance creator.*
- static void destroyInstance ()

  *Instance destroyer.*

### Public Attributes

- MPI_Comm world_comm

  *Global MPI communicator.*
- int MPI_dims [L_dims]

  *Size of MPI Cartesian topology.*
- int neighbour_rank [L_MPI_dir]

  *Neighbour rank number for each direction in Cartesian topology.*
- int neighbour_coords [L_dims][L_MPI_dir]

  *Coordinates in MPI topology of neighbour ranks.*
- MPI_Comm subGrid_comm [1]

  *Communicators for sub-grid / region combinations.*
- std::vector< phdf5_struct > p_data

  *Vector of structures containing halo descriptors for block writing (HDF5)*
- int global_dims [3]

  *Global dimensions of problem coarse lattice.*
- std::vector< int > local_size

  *Dimensions of coarse lattice represented on this rank (includes inner and outer halos).*
- std::vector< std::vector< int > > global_edge_ind

  *Global indices of coarse lattice nodes represented on this rank.*
- std::vector< std::vector< double > > global_edge_pos

  *Global positions of coarse lattice nodes represented on this rank.*
- layer_edges sender_layer_pos

  *Structure containing sender layer edge positions.*
- layer_edges recv_layer_pos

  *Structure containing receiver layer edge positions.*
- std::vector< std::vector< double > > f_buffer_send

  *Array of resizeable outgoing buffers used for data transfer.*
- std::vector< std::vector< double > > f_buffer_recv

  *Array of resizeable incoming buffers used for data transfer.*
- MPI_Status recv_stat

  *Status structure for Receive return information.*
- MPI_Request send_requests [L_MPI_dir]

  *Array of request structures for handles to posted ISends.*
- MPI_Status send_stat [L_MPI_dir]

  *Array of statuses for each Isend.*
- std::vector< buffer_struct > buffer_send_info

  *Vectors of buffer_info structures holding sender layer size info.*
- std::vector< buffer_struct > buffer_recv_info

  *Vectors of buffer_info structures holding receiver layer size info.*

### Static Public Attributes

- static const int MPI_cartlab [3][26]

  *Cartesian unit vectors pointing to each neighbour in Cartesian topology.*
- static int my_rank

  *Rank number.*
- static int num_ranks

  *Total number of ranks in MPI Cartesian topology.*
- static int MPI_coords [L_dims]

  *Coordinates in MPI Cartesian topolgy.*
- static GridObj ∗ Grids

  *Pointer to grid hierarchy.*
- static std::ofstream ∗ logout

  *Logfile handle.*

## 5.13.1 Detailed Description

MPI Manager class.

Class to manage all MPI apsects of the code.

## 5.13.2 Member Function Documentation

### 5.13.2.1 void MpiManager::destroyInstance ( ) [static]

Instance destroyer.

### 5.13.2.2 MpiManager ∗ MpiManager::getInstance ( ) [static]

Instance creator.

### 5.13.2.3 void MpiManager::mpi_buffer_pack ( int *dir*, GridObj ∗ *g* )

Method to pack the communication buffer.

Communication buffer is packed with distribution values from the supplied grid. Amount of information is dictated by the direction of the communication being prepared.

**Parameters**

| | |
|---|---|
| *dir* | communication direction. |
| *g* | grid doing the communication. |

#### 5.13.2.4 void MpiManager::mpi_buffer_size ( )

Pre-calcualtion of the buffer sizes.

Wrapper method for computing the buffer sizes for every grid on the rank, both sender and receiver. Must be called post-initialisation.

#### 5.13.2.5 void MpiManager::mpi_buffer_size_recv ( GridObj ∗& *g* )

Method to pre-compute the size of the receiver layer buffer.

A halo consists of a receiver (outer) and sender (inner) layer. This method computes the size of the receiver layers in each communication direction (MPI directions).

**Parameters**

| | |
|---|---|
| *g* | grid being inspected. |

#### 5.13.2.6 void MpiManager::mpi_buffer_size_send ( GridObj ∗& *g* )

Method to pre-compute the size of the sender layer buffer.

A halo consists of a receiver (outer) and sender (inner) layer. This method computes the size of the sender layers in each communication direction (MPI directions).

**Parameters**

| | |
|---|---|
| *g* | grid being inspected. |

#### 5.13.2.7 void MpiManager::mpi_buffer_unpack ( int *dir*, GridObj ∗ *g* )

Method to unpack the communication buffer.

Communication buffer is unpacked onto the supplied grid. Amount and region of unpacking is dictated by the direction of the communication taking place.

**Parameters**

| | |
|---|---|
| *dir* | communication direction. |
| *g* | grid doing the communication. |

#### 5.13.2.8 int MpiManager::mpi_buildCommunicators ( )

Define writable sub-grid communicators.

When using HDF5 in parallel, collective IO operations require all processes to write a non-zero amount of data to the same file. This method examines availability of sub-grid and writable data on the grid (if found) and ensures it is added to a new communicator. Must be called AFTER the grids and buffers have been initialised.

#### 5.13.2.9 void MpiManager::mpi_communicate ( int *lev*, int *reg* )

Communication routine.

This method implements the communication between grids of the same level and region across MPI processes. Each call effects communication in all valid directions for the grid of the supplied level and region.

**Parameters**

| | |
|---|---|
| *lev* | level of grid to communicate. |
| *reg* | region number of grid to communicate. |

#### 5.13.2.10 int MpiManager::mpi_getOpposite ( int *direction* )

Helper method to find opposite direction in MPI topology.

The MPI directional vectors do not necessarily correspond to the lattice model direction. The MPI directional vectors are defined separately and hence there is a separate opposite finding method.

**Parameters**

| | |
|---|---|
| *direction* | the outgoing direction whose opposite you wish to find. |

#### 5.13.2.11 void MpiManager::mpi_gridbuild ( )

Domain decomposition.

Method to decompose the domain and identify local grid sizes. Parameters defined here are used in GridObj construction.

#### 5.13.2.12 void MpiManager::mpi_init ( )

Initialisation routine.

Method is responsible for initialising the MPI topolgy and associated data. Must be called immediately after MPI_↩ init().

#### 5.13.2.13 void MpiManager::mpi_writeout_buf ( std::string *filename*, int *dir* )

Buffer ASCII writer.

When verbose MPI logging is turned on this method will write out the communication buffer to an ASCII file.

### 5.13.3 Member Data Documentation

#### 5.13.3.1 std::vector<buffer_struct> MpiManager::buffer_recv_info

Vectors of buffer_info structures holding receiver layer size info.

#### 5.13.3.2 std::vector<buffer_struct> MpiManager::buffer_send_info

Vectors of buffer_info structures holding sender layer size info.

#### 5.13.3.3 std::vector< std::vector<double> > MpiManager::f_buffer_recv

Array of resizeable incoming buffers used for data transfer.

#### 5.13.3.4 std::vector< std::vector<double> > MpiManager::f_buffer_send

Array of resizeable outgoing buffers used for data transfer.

#### 5.13.3.5 int MpiManager::global_dims[3]

Global dimensions of problem coarse lattice.

#### 5.13.3.6 std::vector< std::vector<int> > MpiManager::global_edge_ind

Global indices of coarse lattice nodes represented on this rank.

Excludes outer overlapping layer. Rows are x,y,z start and end pairs and columns are rank number.

#### 5.13.3.7 std::vector< std::vector<double> > MpiManager::global_edge_pos

Global positions of coarse lattice nodes represented on this rank.

Excluding outer overlapping layer. Rows are x,y,z start and end pairs and columns are rank number.

#### 5.13.3.8 GridObj * MpiManager::Grids [static]

Pointer to grid hierarchy.

#### 5.13.3.9 std::vector<int> MpiManager::local_size

Dimensions of coarse lattice represented on this rank (includes inner and outer halos).

#### 5.13.3.10 std::ofstream * MpiManager::logout [static]

Logfile handle.

#### 5.13.3.11 const int MpiManager::MPI_cartlab [static]

**Initial value:**

```
=
    {
        {1, -1,  1, -1,  0,  0, -1,  1,     0,  0,      1, -1,  1, -1,  0,  0, -1,  1, -1,  1, -1,  1,  0,
       0,  1, -1},
        {0,  0,  1, -1,  1, -1,  1, -1,     0,  0,      0,  0,  1, -1,  1, -1,  1, -1,  0,  0, -1,  1, -1,
       1, -1,  1},
        {0,  0,  0,  0,  0,  0,  0,  0,     1, -1,      1, -1,  1, -1,  1, -1,  1, -1,  1, -1,  1, -1,  1,
      -1,  1, -1}
    }
```

Cartesian unit vectors pointing to each neighbour in Cartesian topology.

Define 3D such that first 8 mimic the 2D ones. Opposites are simply the next or previous column in the array.

#### 5.13.3.12 int MpiManager::MPI_coords [static]

Coordinates in MPI Cartesian topolgy.

#### 5.13.3.13 int MpiManager::MPI_dims[L_dims]

Size of MPI Cartesian topology.

#### 5.13.3.14 int MpiManager::my_rank [static]

Rank number.

#### 5.13.3.15 int MpiManager::neighbour_coords[L_dims][L_MPI_dir]

Coordinates in MPI topology of neighbour ranks.

#### 5.13.3.16 int MpiManager::neighbour_rank[L_MPI_dir]

Neighbour rank number for each direction in Cartesian topology.

#### 5.13.3.17 int MpiManager::num_ranks [static]

Total number of ranks in MPI Cartesian topology.

#### 5.13.3.18 std::vector< phdf5_struct > MpiManager::p_data

Vector of structures containing halo descriptors for block writing (HDF5)

#### 5.13.3.19 layer_edges MpiManager::recv_layer_pos

Structure containing receiver layer edge positions.

#### 5.13.3.20 MPI_Status MpiManager::recv_stat

Status structure for Receive return information.

#### 5.13.3.21 MPI_Request MpiManager::send_requests[L_MPI_dir]

Array of request structures for handles to posted ISends.

#### 5.13.3.22 MPI_Status MpiManager::send_stat[L_MPI_dir]

Array of statuses for each Isend.

#### 5.13.3.23 layer_edges MpiManager::sender_layer_pos

Structure containing sender layer edge positions.

#### 5.13.3.24 MPI_Comm MpiManager::subGrid_comm[1]

Communicators for sub-grid / region combinations.

#### 5.13.3.25 MPI_Comm MpiManager::world_comm

Global MPI communicator.

The documentation for this class was generated from the following files:

- MpiManager.h
- GridObj.cpp
- main_lbm.cpp
- Mpi_buffer_pack.cpp
- Mpi_buffer_size_recv.cpp
- Mpi_buffer_size_send.cpp
- Mpi_buffer_unpk.cpp
- MpiManager.cpp

## 5.14 ObjectManager Class Reference

Object Manager class.

```
#include <ObjectManager.h>
```

### Public Member Functions

- void ibm_apply ()

  *Perform IBM procedure.*
- void ibm_buildBody (int body_type)

  *Builds a prefab immersed boundary body.*
- void ibm_buildBody (PCpts ∗_PCpts, GridObj ∗owner)

  *Wrapper for building a body from a point cloud.*
- void ibm_initialise ()

  *Initialise the array of iBodies.*
- double ibm_deltaKernel (double rad, double dilation)

  *Method to evaluate delta kernel at supplied location.*
- void ibm_interpol (int ib)

  *Interpolate velocity field onto markers.*
- void ibm_spread (int ib)

  *Spread restorative force back onto marker support.*
- void ibm_findSupport (int ib, int m)

  *Finds support points for iBody.*
- void ibm_computeForce (int ib)

  *Compute restorative force at each marker in a body.*
- double ibm_findEpsilon (int ib)

  *Compute epsilon for a given iBody.*
- void ibm_moveBodies ()

  *Moves iBodies after applying IBM.*
- double ibm_bicgstab (std::vector< std::vector< double > > &Amatrix, std::vector< double > &bVector, std::vector< double > &epsilon, double tolerance, int maxiterations)

  *Biconjugate gradient method.*
- void ibm_jacowire (int ib)

  *Structural calculation of flexible cilia.*
- void ibm_positionUpdate (int ib)

  *Update the position of a deformable iBody.*
- void ibm_positionUpdateGroup (int group)

  *Update the position of a group of deformable iBodies.*
- void ibm_banbks (double ∗∗a, long n, int m1, int m2, double ∗∗al, unsigned long indx[ ], double b[ ])

  *Solution of a banded diagonal linear system.*
- void ibm_bandec (double ∗∗a, long n, int m1, int m2, double ∗∗al, unsigned long indx[ ], double ∗d)

  *LU decomposition of band diagonal matrix.*
- void bfl_buildBody (int body_type)

  *Prefab body building routine.*
- void bfl_buildBody (PCpts ∗_PCpts)

  *Wrapper for building BFL body from point cloud.*
- void computeLiftDrag (int i, int j, int k, GridObj ∗g)

  *Compute forces on a rigid object.*
- void io_vtkIBBWriter (double tval)

*Write IB body data to VTK file.*
- void io_writeBodyPosition (int timestep)

  *Write out position of immersed boundary bodies.*
- void io_writeLiftDrag (int timestep)

  *Write out forces on the markers of immersed boundary bodies.*
- void io_restart (bool IO_flag, int level)

  *Read/write IB body information to restart file.*
- void io_readInCloud (PCpts ∗_PCpts, eObjectType objtype)

  *Read in point cloud data.*
- void io_writeForceOnObject (double tval)

  *Write out the forces on a solid object.*

## Static Public Member Functions

- static ObjectManager ∗ getInstance ()

  *Get instance method.*
- static void destroyInstance ()

  *Destroy instance method.*
- static ObjectManager ∗ getInstance (GridObj ∗g)

  *Overloaded get instance passing in pointer to grid hierarchy.*

## Friends

- class GridObj

### 5.14.1 Detailed Description

Object Manager class.

Class to manage all objects in the domain from creation through manipulation to destruction.

### 5.14.2 Member Function Documentation

#### 5.14.2.1 void ObjectManager::bfl_buildBody ( int *body_type* )

Prefab body building routine.

Not implemented in this version.

**Parameters**

| | |
|---|---|
| *body_type* | type of prefab body to be built. |

#### 5.14.2.2 void ObjectManager::bfl_buildBody ( PCpts ∗ *_PCpts* )

Wrapper for building BFL body from point cloud.

**Parameters**

| | |
|---|---|
| *_PCpts* | pointer to point cloud data. |

#### 5.14.2.3 void ObjectManager::computeLiftDrag ( int *i*, int *j*, int *k*, GridObj ∗ *g* )

Compute forces on a rigid object.

Uses momentum exchange to compute forces on rigid bodies. Currently working with bounce-back objects only. There is no bounding box so if we have walls in the domain they will be counted as well. Also only possible to differentiate between bodies. Lumps all bodies together.identify which body this site relates to so we can differentiate.

**Parameters**

| | |
|---|---|
| *i* | local i-index of solid site. |
| *j* | local j-index of solid site. |
| *k* | local k-index of solid site. |
| *g* | pointer to grid on which object resides. |

#### 5.14.2.4 void ObjectManager::destroyInstance ( ) [static]

Destroy instance method.

Instance destuctor.

#### 5.14.2.5 ObjectManager ∗ ObjectManager::getInstance ( ) [static]

Get instance method.

Instance creator.

#### 5.14.2.6 ObjectManager ∗ ObjectManager::getInstance ( GridObj ∗ *g* ) [static]

Overloaded get instance passing in pointer to grid hierarchy.

Instance creator with grid hierarchy assignment.

**Parameters**

| | |
|---|---|
| *g* | pointer to grid hierarchy. |

#### 5.14.2.7 void ObjectManager::ibm_apply ( )

Perform IBM procedure.

#### 5.14.2.8 void ObjectManager::ibm_banbks ( double $**$ *a,* long *n,* int *m1,* int *m2,* double $**$ *al,* unsigned long *indx[ ],* double *b[ ]* )

Solution of a banded diagonal linear system.

Given the arrays A, AL, and INDX as returned from ibm_bandec(), and given a right-hand side vector B[1..n], solves the band diagonal linear equations AX = B. The solution vector X overwrites B. The other input arrays are not modified, and can be left in place for successive calls with different right-hand sides. (C) Copr. 1986-92 Numerical Recipes Software ?421.1-9.

**Parameters**

| | |
|---|---|
| *a* | array of subdiagonal and superdiagonals rows |
| *n* | size of the square matrix A |
| *m1* | number of subdiagonal rows |
| *m2* | number of superdiagonal rows |
| *al* | lower triangular matrix |
| *indx* | row permutation vector |
| *b* | right hand side vector |

#### 5.14.2.9 void ObjectManager::ibm_bandec ( double $**$ *a,* long *n,* int *m1,* int *m2,* double $**$ *al,* unsigned long *indx[ ],* double $*$ *d* )

LU decomposition of band diagonal matrix.

Given an n by n band diagonal matrix A with m1 subdiagonal rows and m2 superdiagonal rows, compactly stored in the array A[1..n][1..m1+m2+1] , this routine constructs an LU decomposition of a rowwise permutation of A. The upper triangular matrix replaces A, while the lower triangular matrix is returned in AL[1..n][1..m1]. INDX[1..n] is an output vector which records the row permutation effected by the partial pivoting; D is output as +/-1 depending on whether the number of row interchanges was even or odd, respectively. This routine is used in combination with ibm_banbks() to solve band-diagonal sets of equations. Once the matrix A has been decomposed, any number of right-hand sides can be solved in turn by repeated calls to ibm_banbks(). (C) Copr. 1986-92 Numerical Recipes Software ?421.1-9.

**Parameters**

| | |
|---|---|
| *a* | array of subdiagonal and superdiagonals rows |
| *n* | size of the square matrix A |
| *m1* | number of subdiagonal rows |
| *m2* | number of superdiagonal rows |
| *al* | lower triangular matrix |
| *indx* | row permutation vector |
| *d* | odd or even number of row interchanges |

#### 5.14.2.10 double ObjectManager::ibm_bicgstab ( std::vector< std::vector< double > > & *Amatrix,* std::vector< double > & *bVector,* std::vector< double > & *epsilon,* double *tolerance,* int *maxiterations* )

Biconjugate gradient method.

Biconjugate gradient stabilised method of solving a linear system Ax = b. Solution is performed iteratively.

**Parameters**

| | |
|---|---|
| *Amatrix* | the A matrix in the linear system. |
| *bVector* | the b vector in the linear system. |
| *epsilon* | epsilon paramters for each marker. |
| *tolerance* | tolerance of solution. |
| *maxiterations* | maximum number of iterations. |

**Returns**

the minimum residual achieved by the solver.

#### 5.14.2.11 void ObjectManager::ibm_buildBody ( int *body_type* )

Builds a prefab immersed boundary body.

**Parameters**

| | |
|---|---|
| *body_type* | type of body to be built. |

#### 5.14.2.12 void ObjectManager::ibm_buildBody ( PCpts * *_PCpts*, GridObj * *owner* )

Wrapper for building a body from a point cloud.

**Parameters**

| | |
|---|---|
| *_PCpts* | pointer to point cloud data. |
| *owner* | pointer to the grid on which the body is to be placed. |

#### 5.14.2.13 void ObjectManager::ibm_computeForce ( int *ib* )

Compute restorative force at each marker in a body.

**Parameters**

| | |
|---|---|
| *ib* | iBody being operated on. |

#### 5.14.2.14 double ObjectManager::ibm_deltaKernel ( double *radius*, double *dilation* )

Method to evaluate delta kernel at supplied location.

Radius and dilation must be in the same units.

**Parameters**

| | |
|---|---|
| *radius* | location at which kernel should be evaluated. |
| *dilation* | width of kernel function. |

**Returns**

value of kernel function.

#### 5.14.2.15 double ObjectManager::ibm_findEpsilon ( int *ib* )

Compute epsilon for a given iBody.

**Parameters**

| | |
|---|---|
| *ib* | iBody being operated on. |

#### 5.14.2.16 void ObjectManager::ibm_findSupport ( int *ib*, int *m* )

Finds support points for iBody.

Support for given marker in given body is sought on the owning grid.

**Parameters**

| | |
|---|---|
| *ib* | body under consideration. |
| *m* | marker whose support is to be found. |

#### 5.14.2.17 void ObjectManager::ibm_initialise ( )

Initialise the array of iBodies.

Computes support and epsilon values.

#### 5.14.2.18 void ObjectManager::ibm_interpol ( int *ib* )

Interpolate velocity field onto markers.

**Parameters**

| | |
|---|---|
| *ib* | iBody being operated on. |

#### 5.14.2.19 void ObjectManager::ibm_jacowire ( int *ib* )

Structural calculation of flexible cilia.

Models the structural behaviour of a thin wire using Euler-Bernoulli beam elements. Only implemented for one simply supported end and one free end at present.

**Parameters**

| | |
|---|---|
| *ib* | index of body to which calculation is to be applied. |

#### 5.14.2.20 void ObjectManager::ibm_moveBodies ( )

Moves iBodies after applying IBM.

Wrapper for relocating markers of an iBody be calling appropriate positional update routine.

#### 5.14.2.21 void ObjectManager::ibm_positionUpdate ( int *ib* )

Update the position of a deformable iBody.

Wrapper for applying external forcing or structural calculations to iBodies marked as deformable. Updates support on completion.

**Parameters**

| | |
|---|---|
| *ib* | index of body to which calculation is to be applied. |

#### 5.14.2.22 void ObjectManager::ibm_positionUpdateGroup ( int *group* )

Update the position of a group of deformable iBodies.

Updates the position of a group of non-flexible moving (deformable) bodies by using the first flexible body in the group as the driver. Must be called after all previous positional update routines have been called.

**Parameters**

| | |
|---|---|
| *group* | group ID to be updated. |

#### 5.14.2.23 void ObjectManager::ibm_spread ( int *ib* )

Spread restorative force back onto marker support.

**Parameters**

| | |
|---|---|
| *ib* | iBody being operated on. |

#### 5.14.2.24 void ObjectManager::io_readInCloud ( PCpts * _PCpts, eObjectType objtype )

Read in point cloud data.

Input data must be in tab separated, 3-column format in the input directory.

**Parameters**

| | |
|---|---|
| *_PCpts* | pointer to empty point cloud data container. |
| *objtype* | type of object to be read in. |

#### 5.14.2.25 void ObjectManager::io_restart ( bool IO_flag, int level )

Read/write IB body information to restart file.

**Parameters**

| | |
|---|---|
| *IO_flag* | flag indicating write (true) or read (false). |
| *level* | level of the grid begin written/read |

#### 5.14.2.26 void ObjectManager::io_vtkIBBWriter ( double tval )

Write IB body data to VTK file.

Currently can only write out un-closed bodies like filaments.

**Parameters**

| | |
|---|---|
| *tval* | time value at which the write out is being performed. |

#### 5.14.2.27 void ObjectManager::io_writeBodyPosition ( int timestep )

Write out position of immersed boundary bodies.

**Parameters**

| | |
|---|---|
| *timestep* | timestep at which the write out is being performed. |

#### 5.14.2.28 void ObjectManager::io_writeForceOnObject ( double tval )

Write out the forces on a solid object.

Writes out the forces on solid objects in the domain computed using momentum exchange. Each rank writes its own file. Output is a CSV file.

**Parameters**

| | |
|---|---|
| *tval* | time value at which write out is taking place. |

#### 5.14.2.29 void ObjectManager::io_writeLiftDrag ( int *timestep* )

Write out forces on the markers of immersed boundary bodies.

**Parameters**

| | |
|---|---|
| *timestep* | timestep at which the write out is being performed. |

### 5.14.3 Friends And Related Function Documentation

#### 5.14.3.1 friend class GridObj [friend]

The documentation for this class was generated from the following files:

- ObjectManager.h
- ObjectManager.cpp
- ObjectManager_init_bflbody.cpp
- ObjectManager_init_ibmbody.cpp
- ObjectManager_ops_ibm.cpp
- ObjectManager_ops_ibmflex.cpp
- ObjectManager_ops_io.cpp

## 5.15 PCpts Class Reference

Class to hold point cloud data.

`#include <PCpts.h>`

### Public Member Functions

- PCpts (void)

  *Default constructor.*
- ∼PCpts (void)

  *Default destructor.*

### Public Attributes

- std::vector< double > x

  *Vector of X positions.*
- std::vector< double > y

  *Vector of Y positions.*
- std::vector< double > z

  *Vector of Z positions.*

### 5.15.1 Detailed Description

Class to hold point cloud data.

A container class for hold the X, Y and Z positions of points in a point cloud.

### 5.15.2 Constructor & Destructor Documentation

#### 5.15.2.1 PCpts::PCpts ( void ) [inline]

Default constructor.

#### 5.15.2.2 PCpts::∼PCpts ( void ) [inline]

Default destructor.

### 5.15.3 Member Data Documentation

#### 5.15.3.1 std::vector<double> PCpts::x

Vector of X positions.

#### 5.15.3.2 std::vector<double> PCpts::y

Vector of Y positions.

#### 5.15.3.3 std::vector<double> PCpts::z

Vector of Z positions.

The documentation for this class was generated from the following file:

- PCpts.h

## 5.16 MpiManager::phdf5_struct Struct Reference

Structure for storing halo information for HDF5.

`#include <MpiManager.h>`

## Public Attributes

- int i_start

    *Starting i-index for writable region.*
- int i_end

    *Ending i-index for writable region.*
- int j_start

    *Starting j-index for writable region.*
- int j_end

    *Ending j-index for writable region.*
- int k_start

    *Starting k-index for writable region.*
- int k_end

    *Ending k-index for writable region.*
- int halo_min

    *Size of halo on the top end of a 1D block.*
- int halo_max

    *Size of halo on the bottom end of a 1D block.*
- int level

    *Grid level to which these data correspond.*
- int region

    *Region number to which these data correspond.*
- unsigned int writable_data_count = 0

    *Writable data count.*

### 5.16.1 Detailed Description

Structure for storing halo information for HDF5.

Structure also stores the amount of writable data on the grid.

### 5.16.2 Member Data Documentation

#### 5.16.2.1 int MpiManager::phdf5_struct::halo_max

Size of halo on the bottom end of a 1D block.

#### 5.16.2.2 int MpiManager::phdf5_struct::halo_min

Size of halo on the top end of a 1D block.

#### 5.16.2.3 int MpiManager::phdf5_struct::i_end

Ending i-index for writable region.

#### 5.16.2.4 int MpiManager::phdf5_struct::i_start

Starting i-index for writable region.

#### 5.16.2.5 int MpiManager::phdf5_struct::j_end

Ending j-index for writable region.

#### 5.16.2.6 int MpiManager::phdf5_struct::j_start

Starting j-index for writable region.

#### 5.16.2.7 int MpiManager::phdf5_struct::k_end

Ending k-index for writable region.

#### 5.16.2.8 int MpiManager::phdf5_struct::k_start

Starting k-index for writable region.

#### 5.16.2.9 int MpiManager::phdf5_struct::level

Grid level to which these data correspond.

#### 5.16.2.10 int MpiManager::phdf5_struct::region

Region number to which these data correspond.

#### 5.16.2.11 unsigned int MpiManager::phdf5_struct::writable_data_count = 0

Writable data count.

The documentation for this struct was generated from the following file:

- MpiManager.h

# Chapter 6

# File Documentation

## 6.1 BFLBody.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/BFLBody.h"
#include "../inc/MpiManager.h"
#include "../inc/PCpts.h"
#include "../inc/GridObj.h"
#include "../inc/GridUtils.h"
```

## 6.2 BFLBody.h File Reference

```
#include "stdafx.h"
#include "Body.h"
#include "BFLMarker.h"
```

### Classes

- class BFLBody

  *BFL body.*

## 6.3 BFLMarker.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/BFLMarker.h"
#include "../inc/GridUtils.h"
```

## 6.4 BFLMarker.h File Reference

```
#include "stdafx.h"
#include "Marker.h"
```

### Classes

- class BFLMarker

  *BFL marker.*

## 6.5 Body.h File Reference

```
#include "stdafx.h"
#include "GridUtils.h"
```

### Classes

- class MarkerData

  *Container class to hold marker information.*
- class Body< MarkerType >

  *Generic body class.*

## 6.6 definitions.h File Reference

```
#include <time.h>
#include <iostream>
#include <fstream>
#include <vector>
#include <iomanip>
#include <math.h>
#include <string>
#include <mpi.h>
```

### Macros

- #define LUMA_VERSION "1.2.0-alpha"

  *LUMA version.*
- #define L_PI 3.14159265358979323846

  *PI definition.*
- #define L_out_every 100

  *How many timesteps before whole grid output.*
- #define L_out_every_forces 100

  *Specific output frequency of body forces.*

- #define L_output_precision 8

    *Precision of output (for text writers)*
- #define L_IO_LITE

    *ASCII dump on output.*
- #define L_HDF5_OUTPUT

    *HDF5 dump on output.*
- #define L_LD_OUT

    *Write out lift and drag (all bodies)*
- #define L_out_every_probe 250

    *Write out frequency of probe output.*
- #define L_grav_force 0

    *Expression for the gravity force.*
- #define L_grav_direction eXDirection

    *Gravity direction (specify using enumeration)*
- #define L_restart_out_every 100

    *Frequency of write out of restart file.*
- #define L_Timesteps 100

    *Number of time steps to run simulation for.*
- #define L_Xcores 2

    *Number of MPI ranks to divide domain into in X direction.*
- #define L_Ycores 3
- #define L_Zcores 2
- #define L_dims 2

    *Number of dimensions to the problem.*
- #define L_N 100

    *Number of x lattice sites.*
- #define L_M 100

    *Number of y lattice sites.*
- #define L_K 100

    *Number of z lattice sites.*
- #define L_a_x 0

    *Start of domain-x.*
- #define L_b_x 1

    *End of domain-x.*
- #define L_a_y 0

    *Start of domain-y.*
- #define L_b_y 1

    *End of domain-y.*
- #define L_a_z 0

    *Start of domain-z.*
- #define L_b_z 1

    *End of domain-z.*
- #define L_u_ref 0.04

    *Reference velocity for scaling, can be mean inelt velocity.*
- #define L_u_max L_u_ref*1.5

    *Max velocity of inlet profile.*
- #define L_u_0x L_u_ref

    *Initial/inlet x-velocity.*
- #define L_u_0y 0

    *Initial/inlet y-velocity.*
- #define L_u_0z 0

*Initial/inlet z-velocity.*

- #define L_rho_in 1

  *Initial density.*
- #define L_Re 100

  *Desired Reynolds number.*
- #define L_IBM_ON

  *Turn on IBM.*
- #define L_IB_Lev 0

  *Grid level for immersed boundary object (0 if no refined regions, -1 if no IBM)*
- #define L_IB_Reg 0

  *Grid region for immersed boundary object (0 if no refined regions, -1 if no IBM)*
- #define L_VTK_BODY_WRITE

  *Write out the bodies to a VTK file.*
- #define L_IBB_FROM_FILE

  *Build immersed bodies from a point cloud file.*
- #define L_ibb_on_grid_lev L_IB_Lev

  *Provide grid level on which object should be added.*
- #define L_ibb_on_grid_reg L_IB_Reg

  *Provide grid region on which object should be added.*
- #define L_start_ibb_x 0.3

  *Start X of object bounding box.*
- #define L_start_ibb_y 0.2

  *Start Y of object bounding box.*
- #define L_centre_ibb_z 0.5

  *Centre of object bounding box in Z direction.*
- #define L_ibb_length 0.5

  *The object input is scaled based on this dimension.*
- #define L_ibb_scale_direction eXDirection

  *Scale in this direction (specify as enumeration)*
- #define L_ibb_length_ref 0.5

  *Reference length to be used in the definition of Reynolds number.*
- #define L_num_markers 120

  *Number of Lagrange points to use when building a prefab body (approximately)*
- #define L_ibb_deform false

  *Default deformable property of body to be built (whether it moves or not)*
- #define L_ibb_flex_rigid false

  *Whether a structural calculation needs to be performed on the body.*
- #define L_ibb_x 0.2

  *X Position of body centre.*
- #define L_ibb_y 0.5

  *Y Position of body centre.*
- #define L_ibb_z 0.0

  *Z Position of body centre.*
- #define L_ibb_w 0.5

  *Width (x) of IB body.*
- #define L_ibb_l 0.5

  *Length (y) of IB body.*
- #define L_ibb_d 0.5

  *Depth (z) of IB body.*
- #define L_ibb_r 0.25

  *Radius of IB body.*

- #define L_ibb_filament_length 0.5

    *Length of filament.*
- #define L_ibb_filament_start_x 0.2

    *Start X position of the filament.*
- #define L_ibb_filament_start_y 0.5

    *Start Y position of the filament.*
- #define L_ibb_filament_start_z 0.5

    *Start Z position of the filament.*
- #define L_ibb_angle_vert 90

    *Inclination of filament in XY plane.*
- #define L_ibb_angle_horz 0

    *Inclination of filament in XZ plane.*
- #define L_start_BC 2

    *Type of boundary condition at filament start: 0 == free; 1 = simply supported; 2 == clamped.*
- #define L_end_BC 0

    *Type of boundary condition at filament end: 0 == free; 1 = simply supported; 2 == clamped.*
- #define L_ibb_delta_rho 1.0

    *Difference in density (lattice units) between solid and fluid.*
- #define L_ibb_EI 2.0

    *Flexural rigidity (lattice units) of filament.*
- #define L_FREESTREAM_TUNNEL

    *Adds a inlet to all faces.*
- #define L_INLET_ON

    *Turn on inlet boundary (assumed left-hand wall - default Do Nothing)*
- #define L_wall_thickness_bottom 1

    *Thickness of walls in coarsest lattice units.*
- #define L_wall_thickness_top 1

    *Thickness of top walls in coarsest lattice units.*
- #define L_wall_thickness_front 1

    *Thickness of front (3D) walls in coarsest lattice units.*
- #define L_wall_thickness_back 1

    *Thickness of back (3D) walls in coarsest lattice units.*
- #define L_block_on_grid_lev 0

    *Provide grid level on which block should be added.*
- #define L_block_on_grid_reg 0

    *Provide grid region on which block should be added.*
- #define L_block_x_min 32

    *Index of start of object/wall in x-direction.*
- #define L_block_x_max 64

    *Index of end of object/wall in x-direction.*
- #define L_block_y_min 16

    *Index of start of object/wall in y-direction.*
- #define L_block_y_max 48

    *Index of end of object/wall in y-direction.*
- #define L_block_z_min 16

    *Index of start of object/wall in z-direction.*
- #define L_block_z_max 48

    *Index of end of object/wall in z-direction.*
- #define L_object_on_grid_lev 4

    *Provide grid level on which object should be added.*
- #define L_object_on_grid_reg 0

*Provide grid region on which object should be added.*
- #define L_start_object_x 40

  *Index for start of object bounding box in X direction.*
- #define L_start_object_y 16

  *Index for start of object bounding box in Y direction.*
- #define L_centre_object_z 121

  *Index for cetnre of object bounding box in Z direction.*
- #define L_object_length 160

  *The object input is scaled based on this dimension.*
- #define L_object_scale_direction eXDirection

  *Scale in this direction (specify as enumeration)*
- #define L_object_length_ref 160

  *Reference length to be used in the definition of Reynolds number.*
- #define L_bfl_on_grid_lev 1

  *Provide grid level on which BFL body should be added.*
- #define L_bfl_on_grid_reg 0

  *Provide grid region on which BFL body should be added.*
- #define L_start_bfl_x 50

  *Index for start of object bounding box in X direction.*
- #define L_start_bfl_y 100

  *Index for start of object bounding box in Y direction.*
- #define L_centre_bfl_z 20

  *Index for cetnre of object bounding box in Z direction.*
- #define L_bfl_length 50

  *The BFL object input is scaled based on this dimension.*
- #define L_bfl_scale_direction eXDirection

  *Scale in this direction (specify as enumeration)*
- #define L_bfl_length_ref 10

  *Reference length to be used in the definition of Reynolds number.*
- #define L_NumLev 0

  *Levels of refinement (0 = coarse grid only.*
- #define L_NumReg 1

  *Number of refined regions (can be arbitrary if L_NumLev = 0)*
- #define L_IB_Lev 0

  *Grid level for immersed boundary object (0 if no refined regions, -1 if no IBM)*
- #define L_IB_Reg 0

  *Grid region for immersed boundary object (0 if no refined regions, -1 if no IBM)*
- #define L_nVels 9
- #define L_MPI_dir 8
- #define L_a_z 0

  *Start of domain-z.*
- #define L_b_z 2

  *End of domain-z.*
- #define L_K 1

  *Number of z lattice sites.*
- #define L_block_z_min 0

  *Index of start of object/wall in z-direction.*
- #define L_block_z_max 0

  *Index of end of object/wall in z-direction.*
- #define L_ibb_d 0

  *Depth (z) of IB body.*

- #define L_centre_object_z 0

  *Index for cetnre of object bounding box in Z direction.*
- #define L_centre_bfl_z 0

  *Index for cetnre of object bounding box in Z direction.*
- #define L_centre_ibb_z 0

  *Centre of object bounding box in Z direction.*
- #define L_u_0z 0

  *Initial/inlet z-velocity.*
- #define L_NumReg 1

  *Number of refined regions (can be arbitrary if L_NumLev = 0)*

## Variables

- static const int nProbes [3] = {3, 3, 3}

  *Number of probes in each direction (x, y, z)*
- static const int xProbeLims [2] = {90, 270}

  *Limits of X plane for array of probes.*
- static const int yProbeLims [2] = {15, 45}

  *Limits of Y plane for array of probes.*
- static const int zProbeLims [2] = {30, 120}

  *Limits of Z plane for array of probes.*
- static const int RefXstart [1][1] = {0}
- static const int RefXend [1][1] = {0}
- static const int RefYstart [1][1] = {0}
- static const int RefYend [1][1] = {0}
- static int RefZstart [1][1] = {0}
- static int RefZend [1][1] = {0}

### 6.6.1 Macro Definition Documentation

#### 6.6.1.1 #define L_a_x 0

Start of domain-x.

#### 6.6.1.2 #define L_a_y 0

Start of domain-y.

#### 6.6.1.3 #define L_a_z 0

Start of domain-z.

#### 6.6.1.4 #define L_a_z 0

Start of domain-z.

#### 6.6.1.5 #define L_b_x 1

End of domain-x.

#### 6.6.1.6 #define L_b_y 1

End of domain-y.

#### 6.6.1.7 #define L_b_z 1

End of domain-z.

#### 6.6.1.8 #define L_b_z 2

End of domain-z.

#### 6.6.1.9 #define L_bfl_length 50

The BFL object input is scaled based on this dimension.

#### 6.6.1.10 #define L_bfl_length_ref 10

Reference length to be used in the definition of Reynolds number.

#### 6.6.1.11 #define L_bfl_on_grid_lev 1

Provide grid level on which BFL body should be added.

#### 6.6.1.12 #define L_bfl_on_grid_reg 0

Provide grid region on which BFL body should be added.

#### 6.6.1.13 #define L_bfl_scale_direction eXDirection

Scale in this direction (specify as enumeration)

#### 6.6.1.14 #define L_block_on_grid_lev 0

Provide grid level on which block should be added.

#### 6.6.1.15 #define L_block_on_grid_reg 0

Provide grid region on which block should be added.

#### 6.6.1.16 #define L_block_x_max 64

Index of end of object/wall in x-direction.

#### 6.6.1.17 #define L_block_x_min 32

Index of start of object/wall in x-direction.

#### 6.6.1.18 #define L_block_y_max 48

Index of end of object/wall in y-direction.

#### 6.6.1.19 #define L_block_y_min 16

Index of start of object/wall in y-direction.

#### 6.6.1.20 #define L_block_z_max 48

Index of end of object/wall in z-direction.

#### 6.6.1.21 #define L_block_z_max 0

Index of end of object/wall in z-direction.

#### 6.6.1.22 #define L_block_z_min 16

Index of start of object/wall in z-direction.

#### 6.6.1.23 #define L_block_z_min 0

Index of start of object/wall in z-direction.

#### 6.6.1.24 #define L_centre_bfl_z 20

Index for cetnre of object bounding box in Z direction.

#### 6.6.1.25 #define L_centre_bfl_z 0

Index for cetnre of object bounding box in Z direction.

#### 6.6.1.26 #define L_centre_ibb_z 0.5

Centre of object bounding box in Z direction.

#### 6.6.1.27 #define L_centre_ibb_z 0

Centre of object bounding box in Z direction.

#### 6.6.1.28 #define L_centre_object_z 121

Index for cetnre of object bounding box in Z direction.

#### 6.6.1.29 #define L_centre_object_z 0

Index for cetnre of object bounding box in Z direction.

#### 6.6.1.30 #define L_dims 2

Number of dimensions to the problem.

#### 6.6.1.31 #define L_end_BC 0

Type of boundary condition at filament end: 0 == free; 1 = simply supported; 2 == clamped.

#### 6.6.1.32 #define L_FREESTREAM_TUNNEL

Adds a inlet to all faces.

#### 6.6.1.33 #define L_grav_direction eXDirection

Gravity direction (specify using enumeration)

#### 6.6.1.34 #define L_grav_force 0

Expression for the gravity force.

#### 6.6.1.35 #define L_HDF5_OUTPUT

HDF5 dump on output.

#### 6.6.1.36 #define L_IB_Lev 0

Grid level for immersed boundary object (0 if no refined regions, -1 if no IBM)

#### 6.6.1.37 #define L_IB_Lev 0

Grid level for immersed boundary object (0 if no refined regions, -1 if no IBM)

#### 6.6.1.38 #define L_IB_Reg 0

Grid region for immersed boundary object (0 if no refined regions, -1 if no IBM)

#### 6.6.1.39 #define L_IB_Reg 0

Grid region for immersed boundary object (0 if no refined regions, -1 if no IBM)

#### 6.6.1.40 #define L_ibb_angle_horz 0

Inclination of filament in XZ plane.

#### 6.6.1.41 #define L_ibb_angle_vert 90

Inclination of filament in XY plane.

#### 6.6.1.42 #define L_ibb_d 0.5

Depth (z) of IB body.

#### 6.6.1.43 #define L_ibb_d 0

Depth (z) of IB body.

#### 6.6.1.44 #define L_ibb_deform false

Default deformable property of body to be built (whether it moves or not)

#### 6.6.1.45 #define L_ibb_delta_rho 1.0

Difference in density (lattice units) between solid and fluid.

#### 6.6.1.46 #define L_ibb_EI 2.0

Flexural rigidity (lattice units) of filament.

#### 6.6.1.47 #define L_ibb_filament_length 0.5

Length of filament.

#### 6.6.1.48 #define L_ibb_filament_start_x 0.2

Start X position of the filament.

#### 6.6.1.49 #define L_ibb_filament_start_y 0.5

Start Y position of the filament.

#### 6.6.1.50 #define L_ibb_filament_start_z 0.5

Start Z position of the filament.

#### 6.6.1.51 #define L_ibb_flex_rigid false

Whether a structural calculation needs to be performed on the body.

#### 6.6.1.52 #define L_IBB_FROM_FILE

Build immersed bodies from a point cloud file.

#### 6.6.1.53 #define L_ibb_l 0.5

Length (y) of IB body.

#### 6.6.1.54 #define L_ibb_length 0.5

The object input is scaled based on this dimension.

#### 6.6.1.55 #define L_ibb_length_ref 0.5

Reference length to be used in the definition of Reynolds number.

#### 6.6.1.56 #define L_ibb_on_grid_lev L_IB_Lev

Provide grid level on which object should be added.

#### 6.6.1.57 #define L_ibb_on_grid_reg L_IB_Reg

Provide grid region on which object should be added.

#### 6.6.1.58 #define L_ibb_r 0.25

Radius of IB body.

#### 6.6.1.59 #define L_ibb_scale_direction eXDirection

Scale in this direction (specify as enumeration)

#### 6.6.1.60 #define L_ibb_w 0.5

Width (x) of IB body.

#### 6.6.1.61 #define L_ibb_x 0.2

X Position of body centre.

#### 6.6.1.62 #define L_ibb_y 0.5

Y Position of body centre.

#### 6.6.1.63 #define L_ibb_z 0.0

Z Position of body centre.

#### 6.6.1.64 #define L_IBM_ON

Turn on IBM.

#### 6.6.1.65 #define L_INLET_ON

Turn on inlet boundary (assumed left-hand wall - default Do Nothing)

#### 6.6.1.66 #define L_IO_LITE

ASCII dump on output.

#### 6.6.1.67 #define L_K 100

Number of z lattice sites.

#### 6.6.1.68 #define L_K 1

Number of z lattice sites.

#### 6.6.1.69 #define L_LD_OUT

Write out lift and drag (all bodies)

#### 6.6.1.70 #define L_M 100

Number of y lattice sites.

#### 6.6.1.71 #define L_MPI_dir 8

#### 6.6.1.72 #define L_N 100

Number of x lattice sites.

#### 6.6.1.73 #define L_num_markers 120

Number of Lagrange points to use when building a prefab body (approximately)

#### 6.6.1.74 #define L_NumLev 0

Levels of refinement (0 = coarse grid only.

#### 6.6.1.75 #define L_NumReg 1

Number of refined regions (can be arbitrary if L_NumLev = 0)

#### 6.6.1.76 #define L_NumReg 1

Number of refined regions (can be arbitrary if L_NumLev = 0)

#### 6.6.1.77 #define L_nVels 9

#### 6.6.1.78 #define L_object_length 160

The object input is scaled based on this dimension.

#### 6.6.1.79 #define L_object_length_ref 160

Reference length to be used in the definition of Reynolds number.

#### 6.6.1.80 #define L_object_on_grid_lev 4

Provide grid level on which object should be added.

#### 6.6.1.81 #define L_object_on_grid_reg 0

Provide grid region on which object should be added.

#### 6.6.1.82 #define L_object_scale_direction eXDirection

Scale in this direction (specify as enumeration)

#### 6.6.1.83 #define L_out_every 100

How many timesteps before whole grid output.

#### 6.6.1.84 #define L_out_every_forces 100

Specific output frequency of body forces.

#### 6.6.1.85 #define L_out_every_probe 250

Write out frequency of probe output.

#### 6.6.1.86 #define L_output_precision 8

Precision of output (for text writers)

#### 6.6.1.87 #define L_PI 3.14159265358979323846

PI definition.

#### 6.6.1.88 #define L_Re 100

Desired Reynolds number.

#### 6.6.1.89 #define L_restart_out_every 100

Frequency of write out of restart file.

#### 6.6.1.90 #define L_rho_in 1

Initial density.

#### 6.6.1.91 #define L_start_BC 2

Type of boundary condition at filament start: 0 == free; 1 = simply supported; 2 == clamped.

#### 6.6.1.92 #define L_start_bfl_x 50

Index for start of object bounding box in X direction.

#### 6.6.1.93 #define L_start_bfl_y 100

Index for start of object bounding box in Y direction.

#### 6.6.1.94 #define L_start_ibb_x 0.3

Start X of object bounding box.

#### 6.6.1.95 #define L_start_ibb_y 0.2

Start Y of object bounding box.

#### 6.6.1.96 #define L_start_object_x 40

Index for start of object bounding box in X direction.

#### 6.6.1.97 #define L_start_object_y 16

Index for start of object bounding box in Y direction.

#### 6.6.1.98 #define L_Timesteps 100

Number of time steps to run simulation for.

#### 6.6.1.99 #define L_u_0x L_u_ref

Initial/inlet x-velocity.

#### 6.6.1.100 #define L_u_0y 0

Initial/inlet y-velocity.

#### 6.6.1.101 #define L_u_0z 0

Initial/inlet z-velocity.

#### 6.6.1.102 #define L_u_0z 0

Initial/inlet z-velocity.

#### 6.6.1.103 #define L_u_max L_u_ref*1.5

Max velocity of inlet profile.

#### 6.6.1.104 #define L_u_ref 0.04

Reference velocity for scaling, can be mean inelt velocity.

#### 6.6.1.105 #define L_VTK_BODY_WRITE

Write out the bodies to a VTK file.

#### 6.6.1.106 #define L_wall_thickness_back 1

Thickness of back (3D) walls in coarsest lattice units.

#### 6.6.1.107 #define L_wall_thickness_bottom 1

Thickness of walls in coarsest lattice units.

#### 6.6.1.108 #define L_wall_thickness_front 1

Thickness of front (3D) walls in coarsest lattice units.

#### 6.6.1.109 #define L_wall_thickness_top 1

Thickness of top walls in coarsest lattice units.

#### 6.6.1.110 #define L_Xcores 2

Number of MPI ranks to divide domain into in X direction.

#### 6.6.1.111 #define L_Ycores 3

Number of MPI ranks to divide domain into in Y direction

#### 6.6.1.112 #define L_Zcores 2

Number of MPI ranks to divide domain into in Z direction. Set to 1 if doing a 2D problem when using custom MPI sizes

#### 6.6.1.113 #define LUMA_VERSION "1.2.0-alpha"

LUMA version.

### 6.6.2 Variable Documentation

#### 6.6.2.1 const int nProbes[3] = {3, 3, 3} [static]

Number of probes in each direction (x, y, z)

#### 6.6.2.2 const int RefXend[1][1] = {0} [static]

#### 6.6.2.3 const int RefXstart[1][1] = {0} [static]

#### 6.6.2.4 const int RefYend[1][1] = {0} [static]

#### 6.6.2.5 const int RefYstart[1][1] = {0} [static]

#### 6.6.2.6 int RefZend[1][1] = {0} [static]

#### 6.6.2.7 int RefZstart[1][1] = {0} [static]

#### 6.6.2.8 const int xProbeLims[2] = {90, 270} [static]

Limits of X plane for array of probes.

#### 6.6.2.9 const int yProbeLims[2] = {15, 45} [static]

Limits of Y plane for array of probes.

#### 6.6.2.10 const int zProbeLims[2] = {30, 120} [static]

Limits of Z plane for array of probes.

## 6.7 GridObj.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/GridObj.h"
#include "../inc/MpiManager.h"
#include "../inc/GridUtils.h"
```

## 6.8 GridObj.h File Reference

```
#include "stdafx.h"
#include "IVector.h"
```

### Classes

- class GridObj

  *Grid class.*

## Enumerations

- enum eType {
  eSolid, eFluid, eRefined, eTransitionToCoarser,
  eTransitionToFiner, eBFL, eSymmetry, eInlet,
  eOutlet, eRefinedSolid, eRefinedSymmetry, eRefinedInlet }

  *Lattice typing labels.*
- enum eBCType {
  eBCAll, eBCSolidSymmetry, eBCInlet, eBCOutlet,
  eBCInletOutlet, eBCBFL }

  *Flag for indicating which BCs to apply.*

### 6.8.1 Enumeration Type Documentation

#### 6.8.1.1 enum **eBCType**

Flag for indicating which BCs to apply.

**Enumerator**

***eBCAll*** Apply all BCs.

***eBCSolidSymmetry*** Apply just solid and symmetry BCs.

***eBCInlet*** Apply just inlet BCs.

***eBCOutlet*** Apply just outlet BCs.

***eBCInletOutlet*** Apply inlet and outlet BCs.

***eBCBFL*** Apply just BFL BCs.

#### 6.8.1.2 enum **eType**

Lattice typing labels.

**Enumerator**

***eSolid*** Rigid, solid site.

***eFluid*** Fluid site.

***eRefined*** Fluid site which is represented on a finer grid.

***eTransitionToCoarser*** Fluid site coupled to a coarser grid.

***eTransitionToFiner*** Fluid site coupled to a finer grid.

***eBFL*** Site containing a BFL marker.

***eSymmetry*** Symmetry boundary.

***eInlet*** Inlet boundary.

***eOutlet*** Outlet boundary.

***eRefinedSolid*** Rigid, solid site represented on a finer grid.

***eRefinedSymmetry*** Symmtery boundary represented on a finer grid.

***eRefinedInlet*** Inlet site represented on a finer grid.

## 6.9 GridObj_init_grids.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/GridObj.h"
#include "../inc/MpiManager.h"
#include "../inc/GridUtils.h"
```

## 6.10 GridObj_ops_boundary.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/GridObj.h"
#include "../inc/BFLBody.h"
#include "../inc/ObjectManager.h"
#include "../inc/GridUtils.h"
```

## 6.11 GridObj_ops_io.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/GridObj.h"
#include "../inc/MpiManager.h"
#include "../inc/ObjectManager.h"
#include "../inc/GridUtils.h"
#include "../inc/hdf5luma.h"
```

## 6.12 GridObj_ops_lbm.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/GridObj.h"
#include "../inc/IVector.h"
#include "../inc/ObjectManager.h"
#include "../inc/MpiManager.h"
#include "../inc/GridUtils.h"
```

## 6.13 GridUtils.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/GridUtils.h"
#include "../inc/MpiManager.h"
#include "../inc/GridObj.h"
```

## 6.14 GridUtils.h File Reference

```
#include "stdafx.h"
#include "GridObj.h"
```

### Classes

- class GridUtils

    *Grid utility class.*

### Enumerations

- enum eCartesianDirection { eXDirection, eYDirection, eZDirection }

    *Enumeration for directional options.*
- enum eMinMax { eMinimum, eMaximum }

    *Enumeration for minimum and maximum.*

### 6.14.1 Enumeration Type Documentation

#### 6.14.1.1 enum eCartesianDirection

Enumeration for directional options.

**Enumerator**

***eXDirection*** X-direction.

***eYDirection*** Y-direction.

***eZDirection*** Z-direction.

#### 6.14.1.2 enum eMinMax

Enumeration for minimum and maximum.

Some utility methods need to know whether they should be looking at or for a maximum or minimum edge of a grid so we use this enumeration to specify.

**Enumerator**

***eMinimum*** Minimum.

***eMaximum*** Maximum.

## 6.15 hdf5luma.h File Reference

```
#include "stdafx.h"
#include "hdf5.h"
#include "MpiManager.h"
```

## Macros

- #define H5_BUILT_AS_DYNAMIC_LIB
- #define HDF5_EXT_ZLIB
- #define HDF5_EXT_SZIP

## Enumerations

- enum eHdf5SlabType {
  eScalar, eVector, eProductVector, ePosX,
  ePosY, ePosZ }

  *Defines the type of storage arrangement of the variable in memory.*

## Functions

- template<typename T >
  void hdf5_writeDataSet (hid_t &memspace, hid_t &filespace, hid_t &dataset_id, eHdf5SlabType slab_type, int N_lim, int M_lim, int K_lim, int N_mod, int M_mod, int K_mod, GridObj *g, T *data, hid_t hdf_datatype, int TL_thickness, MpiManager::phdf5_struct hdf_data)

  *Helper method to write out using HDF5.*

### 6.15.1 Macro Definition Documentation

#### 6.15.1.1 #define H5_BUILT_AS_DYNAMIC_LIB

#### 6.15.1.2 #define HDF5_EXT_SZIP

#### 6.15.1.3 #define HDF5_EXT_ZLIB

### 6.15.2 Enumeration Type Documentation

#### 6.15.2.1 enum eHdf5SlabType

Defines the type of storage arrangement of the variable in memory.

The write wrapper can then extract the data from memeory and write it to an HDF5 file using a particular hyperslab selection.

**Enumerator**

***eScalar*** 2/3D data – One variable per grid site

***eVector*** 2/3D data – L_dims variables per grid site

***eProductVector*** 1D data – 3*L_dims-3 variables per grid site

***ePosX*** 1D data – Single L_dim vector per dimension

***ePosY*** 1D data – Single L_dim vector per dimension

***ePosZ*** 1D data – Single L_dim vector per dimension

### 6.15.3 Function Documentation

#### 6.15.3.1 template<typename T > void hdf5_writeDataSet ( hid_t & *memspace*, hid_t & *filespace*, hid_t & *dataset_id*, eHdf5SlabType *slab_type*, int *N_lim*, int *M_lim*, int *K_lim*, int *N_mod*, int *M_mod*, int *K_mod*, GridObj * *g*, T * *data*, hid_t *hdf_datatype*, int *TL_thickness*, MpiManager::phdf5_struct *hdf_data* )

Helper method to write out using HDF5.

Automatically selects the correct slab arrangement and buffers the data accordingly before writing to structured file.

**Parameters**

| | |
|---|---|
| *memspace* | memory dataspace id |
| *filespace* | file dataspace id |
| *dataset_id* | dataset id |
| *slab_type* | slab type enum |
| *N_lim* | number of X-direction sites on the local grid |
| *M_lim* | number of Y-direction sites on the local grid |
| *K_lim* | number of Z-direction sites on the local grid |
| *N_mod* | number of X-direction sites excluding TL sites |
| *M_mod* | number of Y-direction sites excluding TL sites |
| *K_mod* | number of Z-direction sites excluding TL sites |
| *g* | pointer to grid which we are writing out |
| *data* | pointer to the start of the array to be written |
| *hdf_datatype* | HDF5 datatype being written |
| *TL_thickness* | the thickness of the TL on this grid level in local lattice units |
| *hdf_data* | the data structure containing information about local halos |

## 6.16 IBBody.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/IBBody.h"
#include "../inc/IBMarker.h"
#include "../inc/PCpts.h"
#include "../inc/GridUtils.h"
#include "../inc/ObjectManager.h"
```

## 6.17 IBBody.h File Reference

```
#include "stdafx.h"
#include "Body.h"
```

### Classes

- class IBBody

  *Immersed boundary body.*

## 6.18 IBMarker.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/IBMarker.h"
#include "../inc/GridUtils.h"
```

## 6.19 IBMarker.h File Reference

```
#include "stdafx.h"
#include "Marker.h"
```

### Classes

- class IBMarker

    *Immersed boundary marker.*

## 6.20 IVector.h File Reference

```
#include "stdafx.h"
```

### Classes

- class IVector< GenTyp >

    *Index-collapsing vector class.*

## 6.21 main_lbm.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/GridObj.h"
#include "../inc/MpiManager.h"
#include "../inc/ObjectManager.h"
#include "../inc/GridUtils.h"
#include "../inc/PCpts.h"
```

### Functions

- int main (int argc, char *argv[ ])

    *Entry point for the application.*

### 6.21.1 Function Documentation

#### 6.21.1.1 int main ( int *argc,* char * *argv[ ]* )

Entry point for the application.

## 6.22 Marker.h File Reference

```
#include "stdafx.h"
```

### Classes

- class Marker

  *Generic marker class.*

## 6.23 Mpi_buffer_pack.cpp File Reference

```
#include "../inc/stdafx.h"
#include <mpi.h>
#include "../inc/MpiManager.h"
#include "../inc/GridObj.h"
#include "../inc/GridUtils.h"
```

## 6.24 Mpi_buffer_size_recv.cpp File Reference

```
#include "../inc/stdafx.h"
#include <mpi.h>
#include "../inc/MpiManager.h"
#include "../inc/GridObj.h"
#include "../inc/GridUtils.h"
```

## 6.25 Mpi_buffer_size_send.cpp File Reference

```
#include "../inc/stdafx.h"
#include <mpi.h>
#include "../inc/MpiManager.h"
#include "../inc/GridObj.h"
#include "../inc/GridUtils.h"
```

## 6.26 Mpi_buffer_unpk.cpp File Reference

```
#include "../inc/stdafx.h"
#include <mpi.h>
#include "../inc/MpiManager.h"
#include "../inc/GridObj.h"
#include "../inc/GridUtils.h"
```

## 6.27 MpiManager.cpp File Reference

```
#include "../inc/stdafx.h"
#include <mpi.h>
#include "../inc/MpiManager.h"
#include "../inc/GridObj.h"
#include "../inc/GridUtils.h"
```

## 6.28 MpiManager.h File Reference

```
#include "stdafx.h"
```

### Classes

- class MpiManager

  *MPI Manager class.*
- struct MpiManager::phdf5_struct

  *Structure for storing halo information for HDF5.*
- struct MpiManager::layer_edges

  *Structure containing global positions of the edges of halos.*
- struct MpiManager::buffer_struct

  *Structure storing buffers sizes in each direction for particular grid.*

### Macros

- #define range_i_left i = 0; i < GridUtils::downToLimit((int)pow(2, g->level + 1), N_lim); i++

  *For loop definition for left halo.*
- #define range_j_down j = 0; j < GridUtils::downToLimit((int)pow(2, g->level + 1), M_lim); j++

  *For loop definition for bottom halo.*
- #define range_k_front k = 0; k < GridUtils::downToLimit((int)pow(2, g->level + 1), K_lim); k++

  *For loop definition for front halo.*
- #define range_i_right i = GridUtils::upToZero(N_lim - (int)pow(2, g->level + 1)); i < N_lim; i++

  *For loop definition for right halo.*
- #define range_j_up j = GridUtils::upToZero(M_lim - (int)pow(2, g->level + 1)); j < M_lim; j++

  *For loop definition for top halo.*
- #define range_k_back k = GridUtils::upToZero(K_lim - (int)pow(2, g->level + 1)); k < K_lim; k++

  *For loop definition for back halo.*

### 6.28.1 Macro Definition Documentation

#### 6.28.1.1 #define range_i_left i = 0; i < GridUtils::downToLimit((int)pow(2, g->level + 1), N_lim); i++

For loop definition for left halo.

#### 6.28.1.2 #define range_i_right i = GridUtils::upToZero(N_lim - (int)pow(2, g->level + 1)); i < N_lim; i++

For loop definition for right halo.

#### 6.28.1.3 #define range_j_down j = 0; j < GridUtils::downToLimit((int)pow(2, g->level + 1), M_lim); j++

For loop definition for bottom halo.

#### 6.28.1.4 #define range_j_up j = GridUtils::upToZero(M_lim - (int)pow(2, g->level + 1)); j < M_lim; j++

For loop definition for top halo.

#### 6.28.1.5 #define range_k_back k = GridUtils::upToZero(K_lim - (int)pow(2, g->level + 1)); k < K_lim; k++

For loop definition for back halo.

#### 6.28.1.6 #define range_k_front k = 0; k < GridUtils::downToLimit((int)pow(2, g->level + 1), K_lim); k++

For loop definition for front halo.

## 6.29 ObjectManager.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/ObjectManager.h"
#include "../inc/GridObj.h"
#include "../inc/GridUtils.h"
```

## 6.30 ObjectManager.h File Reference

```
#include "stdafx.h"
#include "IVector.h"
#include "IBMarker.h"
#include "IBBody.h"
#include "BFLBody.h"
```

### Classes

- class ObjectManager

    *Object Manager class.*

## Enumerations

- enum eObjectType { eBBBCloud, eBFLCloud, eIBBCloud }
  *Specifies the type of body being processed.*

### 6.30.1 Enumeration Type Documentation

#### 6.30.1.1 enum eObjectType

Specifies the type of body being processed.

**Enumerator**

***eBBBCloud*** Bounce-back body.

***eBFLCloud*** BFL body.

***eIBBCloud*** Immersed boundary body.

## 6.31 ObjectManager_init_bflbody.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/ObjectManager.h"
```

## 6.32 ObjectManager_init_ibmbody.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/ObjectManager.h"
```

## 6.33 ObjectManager_ops_ibm.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/GridObj.h"
#include "../inc/ObjectManager.h"
#include "../inc/MpiManager.h"
#include "../inc/GridUtils.h"
```

## 6.34 ObjectManager_ops_ibmflex.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/GridObj.h"
#include "../inc/ObjectManager.h"
#include "../inc/MpiManager.h"
```

### Macros

- #define SWAP(a, b) {dum=(a);(a)=(b);(b)=dum;}

    *Pointer swap definition.*
- #define TINY 1.0e-20

    *Definition of small number (could use numerics since this is C++ but nevermind)*
- #define SWAP(a, b) {dum=(a);(a)=(b);(b)=dum;}

    *Pointer swap definition.*

### 6.34.1 Macro Definition Documentation

#### 6.34.1.1 #define SWAP( *a*, *b* ) {dum=(a);(a)=(b);(b)=dum;}

Pointer swap definition.

#### 6.34.1.2 #define SWAP( *a*, *b* ) {dum=(a);(a)=(b);(b)=dum;}

Pointer swap definition.

#### 6.34.1.3 #define TINY 1.0e-20

Definition of small number (could use numerics since this is C++ but nevermind)

## 6.35 ObjectManager_ops_io.cpp File Reference

```
#include "../inc/stdafx.h"
#include "../inc/ObjectManager.h"
#include "../inc/GridUtils.h"
#include "../inc/PCpts.h"
#include "../inc/GridObj.h"
#include "../inc/MpiManager.h"
```

## 6.36 PCpts.h File Reference

```
#include "stdafx.h"
```

### Classes

- class PCpts

    *Class to hold point cloud data.*

## 6.37 stdafx.cpp File Reference

```
#include "../inc/stdafx.h"
```

### Variables

- const int c [3][L_nVels]

  *Lattice velocities.*
- const double w [L_nVels]

  *Quadrature weights.*
- const double cs = 1.0 / sqrt(3.0)

  *Lattice sound speed.*

### 6.37.1 Variable Documentation

#### 6.37.1.1 const int c[3][L_nVels]

**Initial value:**

```
=
{
    { 1, -1, 0, 0, 1, -1, 1, -1, 0 },
    { 0, 0, 1, -1, 1, -1, -1, 1, 0 },
    { 0, 0, 0, 0, 0, 0, 0, 0, 0 }
}
```

Lattice velocities.

#### 6.37.1.2 const double cs = 1.0 / sqrt(3.0)

Lattice sound speed.

#### 6.37.1.3 const double w[L_nVels]

**Initial value:**

```
=
{ 1.0 / 9.0, 1.0 / 9.0, 1.0 / 9.0, 1.0 / 9.0, 1.0 / 36.0, 1.0 / 36.0, 1.0 / 36.0, 1.0 / 36.0, 4.0 / 9.0 }
```

Quadrature weights.

## 6.38 stdafx.h File Reference

```
#include <algorithm>
#include <cmath>
#include <vector>
#include <iostream>
#include <fstream>
#include <sstream>
#include <numeric>
#include <stdlib.h>
#include <cstring>
#include <stdio.h>
#include "definitions.h"
```

### Macros

- #define LUMA_FAILED 12345

  *Error definition.*
- #define L_IS_NAN std::isnan

  *Not a Number declaration (Unix)*

### Variables

- const int c [3][L_nVels]

  *Lattice velocities.*
- const double w [L_nVels]

  *Quadrature weights.*
- const double cs

  *Lattice sound speed.*

### 6.38.1 Macro Definition Documentation

#### 6.38.1.1 #define L_IS_NAN std::isnan

Not a Number declaration (Unix)

#### 6.38.1.2 #define LUMA_FAILED 12345

Error definition.

### 6.38.2 Variable Documentation

#### 6.38.2.1 const int c[3][L_nVels]

Lattice velocities.

#### 6.38.2.2 const double cs

Lattice sound speed.

#### 6.38.2.3 const double w[L_nVels]

Quadrature weights.

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