SPlisHSPlasH

Release 2.11.0

Interactive Computer Graphics

Sep 07, 2021

INTRODUCTION:

SPlisHSPlasH is an open-source library for the physically-based simulation of fluids. The simulation in this library is based on the Smoothed Particle Hydrodynamics (SPH) method which is a popular meshless Lagrangian approach to simulate complex fluid effects. The SPH formalism allows an efficient computation of a certain quantity of a fluid particle by considering only a finite set of neighboring particles. One of the most important research topics in the field of SPH methods is the simulation of incompressible fluids. SPlisHSPlasH implements current state-of-the-art pressure solvers (WCSPH, PCISPH, PBF, IISPH, DFSPH, PF) to simulate incompressibility. Moreover, the library provides different methods to simulate viscosity, surface tension and vorticity.

CHAPTER

ONE

MAIN FEATURES

- an open-source SPH fluid simulation (2D & 3D)
- neighborhood search on CPU or GPU
- supports vectorization using AVX
- Python binding (thanks to Stefan Jeske)
- supports embedded Python scripts
- several implicit pressure solvers (WCSPH, PCISPH, PBF, IISPH, DFSPH, PF)
- explicit and implicit viscosity methods
- current surface tension approaches
- different vorticity methods
- computation of drag forces
- support for multi-phase simulations
- simulation of deformable solids
- rigid-fluid coupling with static and dynamic bodies
- two-way coupling with deformable solids
- fluid emitters
- scripted animation fields
- a json-based scene file importer
- automatic surface sampling
- a tool for volume sampling of closed geometries
- partio file export of all particle data
- VTK file export of all particle data (enables the data import in ParaView)
- rigid body export
- a Maya plugin to model and generate scene files
- a ParaView plugin to import particle data

CHAPTER

TWO

LICENSE

The MIT License (MIT)

Copyright (c) 2016-present, SPlisHSPlasH contributors

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the “Software”), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions:

The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software.

THE SOFTWARE IS PROVIDED “AS IS”, WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

CHAPTER

THREE

GETTING STARTED

This page should give you a short overview of SPlisHSPlasH.

SPlisHSPlasH currently consists of a simulators and different tools which are introduced in the following:

3.1 SPHSimulator

This application reads a SPlisHSPlasH scene file and performs a simulation of the scene.

The scene file format is explained *here.*

3.1.1 Command line options:

- -h, –help: Print help text.
- -v, –version: Print version.
- –no-cache: Disable caching of boundary samples/maps.
- –state-file: Load a simulation state of the corresponding scene.
- –output-dir: Output directory for log file and partio files.
- –no-initial-pause: Disable caching of boundary samples/maps.
- –no-gui: Disable graphical user interface. The simulation is run only in the command line without graphical output. The “stopAt” option must be set in the scene file or by the next parameter.
- –stopAt arg: Sets or overwrites the stopAt parameter of the scene.
- –param arg: Sets or overwrites a parameter of the scene.
  - Setting a fluid parameter: ::
    - Example: –param Fluid:viscosity:0.01
  - Setting a configuration parameter: :
    - Example: –param cflMethod:1

3.1.2 Hotkeys

- Space: pause/contiunue simulation
- r: reset simulation
- w: wireframe rendering of meshes
- m: recompute min and max values for color-coding the color field in the rendering process
- i: print all field information of the selected particles to the console
- s: save current simulation state
- l: load simulation state (currently only Windows)
- +: perform a single time step
- ESC: exit

3.2 Python bindings

SPlisHSPlasH implements bindings for python using pybind11. See the *getting started guide*.

3.2.1 Impatient installation guide

In order to install, simply clone the repository and run pip install on the repository. It is recommended, that you set up a **virtual environment** for this, because cache files will be stored in the directory of the python installation along with models and scene files.

```
git clone https://github.com/InteractiveComputerGraphics/SPlisHSPlasH.git
pip install SPlisHSPlasH/
```

CHAPTER

FOUR

SPLISHSPLASH SCENE FILES

A SPlisHSPlasH scene file is a json file which can contain the following blocks:

- Configuration
- FluidBlocks
- FluidModels
- Emitters
- RigidBodies
- Fluid parameter block
- Animation fields

4.1 Configuration

This part contains the general settings of the simulation and the pressure solver.

Example code:

```
"Configuration":
{
    "pause": true,
    "sim2D": false,
    "timeStepSize": 0.001,
    "numberOfStepsPerRenderUpdate": 2,
    "particleRadius": 0.025,
    "simulationMethod": 4,
    "gravitation": [0.0,-9.81,0],
    "cflMethod": 1,
    "cflFactor": 1,
    "cflMaxTimeStepSize": 0.005,
    "maxIterations": 100,
    "maxError": 0.01,
    "maxIterationsV": 100,
    "maxErrorV": 0.1,
    "stiffness": 50000,
    "exponent": 7,
    "velocityUpdateMethod": 0,
    "enableDivergenceSolver": true
}
```

4.1.1 General:

- pause (bool): Pause simulation at beginning.
- pauseAt (float): Pause simulation at the given time. When the value is negative, the simulation is not paused.
- stopAt (float): Stop simulation at the given time and exit. When the value is negative, the simulation is not stopped.
- cameraPosition (vec3): Initial position of the camera.
- cameraLookat (vec3): Lookat point of the camera.

4.1.2 Visualization:

- numberOfStepsPerRenderUpdate (int): Number of simulation steps per rendered frame
- renderWalls (int):
  - 0: None
  - 1: Particles (all)
  - 2: Particles (no walls)
  - 3: Geometry (all)
  - 4: Geometry (no walls)

4.1.3 Export

- enablePartioExport (bool): Enable/disable partio export (default: false).
- enableVTKExport (bool): Enable/disable VTK export (default: false).
- enableRigidBodyExport (bool): Enable/disable rigid body export (default: false).
- enableRigidBodyVTKExport (bool): Enable/disable rigid body VTK export (default: false).
- dataExportFPS (float): Frame rate of particle and rigid body export (default: 25).
- particleAttributes (string): A list of attribute names separated by ";" that should be exported in the particle files (e.g. "velocity;density") (default: "velocity").
- enableStateExport (bool): Enable/disable export of complete simulation state (default: false).
- stateExportFPS (float): Frame rate of simulation state export (default: 1).

4.1.4 Simulation:

- timeStepSize (float): The initial time step size used for the time integration. If you use an adaptive time stepping, this size will change during the simulation (default: 0.001).
- particleRadius (float): The radius of the particles in the simulation (all have the same radius) (default: 0.025).
- sim2D (bool): If this parameter is set to true, a 2D simulation is performend instead of a 3D simulation (default: false).
- enableZSort (bool): Enable z-sort to improve cache hits and therefore to improve the performance (default: true).
- gravitation (vec3): Vector to define the gravitational acceleration (default: [0,-9.81,0]).

- maxIterations (int): Maximal number of iterations of the pressure solver (default: 100).
- maxError (float): Maximal density error in percent which the pressure solver tolerates (default: 0.01).
- boundaryHandlingMethod (int): The boundary handling method that is used in the simulation (default: 2, Volume Maps):
  - 0: particle-based boundaries (Akinci et al. 2012)
  - 1: density maps (Koschier et al. 2017)
  - 2: volume maps (Bender et al. 2019)
- simulationMethod (int): The pressure solver method used in the simulation (default: 4, DFSPH):
  - 0: Weakly compressible SPH for free surface flows (WCSPH)
  - 1: Predictive-corrective incompressible SPH (PCISPH)
  - 2: Position based fluids (PBF)
  - 3: Implicit incompressible SPH (IISPH)
  - 4: Divergence-free smoothed particle hydrodynamics (DFSPH)
  - 5: Projective Fluids (dynamic boundaries not supported yet)
  - 6: Implicit compressible SPH (ICSPH)

4.1.5 WCSPH parameters:

- stiffness (float): Stiffness coefficient of the equation of state.
- exponent (float): Exponent in the equation of state.

4.1.6 PBF parameters:

- velocityUpdateMethod (int):
  - 0: First Order Update
  - 1: Second Order Update

4.1.7 DFSPH parameters:

- enableDivergenceSolver (bool): Turn divergence solver on/off.
- maxIterationsV (int): Maximal number of iterations of the divergence solver.
- maxErrorV (float): Maximal divergence error in percent which the pressure solver tolerates.

4.1.8 Projective Fluids parameters:

- stiffness (float): Stiffness coefficient used by the pressure solver.

4.1.9 ICSPH parameters:

- lambda (float): Stiffness coefficient of the equation of state.
- pressureClamping (bool): Enable pressure clamping.

4.1.10 Kernel:

- kernel (int): Kernel function used in the SPH model.
  - For a 3D simulation:
    - 0: Cubic spline
    - 1: Wendland quintic C2
    - 2: Poly6
    - 3: Spiky
    - 4: Precomputed cubic spline (faster than cubic spline)
  - For a 2D simulation:
    - 0: Cubic spline
    - 1: Wendland quintic C2
- gradKernel (int): Gradient of the kernel function used in the SPH model.
  - For a 3D simulation:
    - 0: Cubic spline
    - 1: Wendland quintic C2
    - 2: Poly6
    - 3: Spiky
    - 4: Precomputed cubic spline (faster than cubic spline)
  - For a 2D simulation:
    - 0: Cubic spline
    - 1: Wendland quintic C2

4.1.11 CFL:

- cflMethod (int): CFL method used for adaptive time stepping.
  - 0: No adaptive time stepping
  - 1: Use CFL condition
  - 2: Use CFL condition and consider number of pressure solver iterations
- cflFactor (float): Factor to scale the CFL time step size.
- cflMinTimeStepSize (float): Min. allowed time step size.
- cflMaxTimeStepSize (float): Max. allowed time step size.

4.2 FluidBlocks

In this part the user can define multiple axis-aligned blocks of fluid particles.

Example code:

```
"FluidBlocks": [
    {
        "denseMode": 0,
        "start": [-2.0, 0.0, -1],
        "end": [-0.5, 1.5, 1],
        "translation": [1.0, 0.0, 0.0],
        "scale": [1, 1, 1]
    }
]
```

- start (vec3): Minimum coordinate of the box which defines the fluid block.
- end (vec3): Maximum coordinate of the box which defines the fluid block.
- translation (vec3): Translation vector of the block.
- scale (vec3): Scaling vector of the block.
- denseMode (int):
  - 0: regular sampling
  - 1: more dense sampling
  - 2: dense sampling
- initialVelocity (vec3): The initial velocity is set for all particles in the block.
- initialAngularVelocity (vec3): The initial angular velocity of the block.
- id (string): This id is used in the "Fluid parameter block" (see below) to define the properties of the fluid block. If no id is defined, then the standard id "Fluid" is used.

4.3 FluidModels

This part can be used to import one or more partio particle files in the scene.

Example code:

```
"FluidModels": [
    {
        "particleFile": "../models/bunny.bgeo",
        "translation": [-2.0, 0.1, 0.0],
        "rotationAxis": [0, 1, 0],
        "rotationAngle": 3.14159265359,
        "scale": 1
    }
]
```

- particleFile (string): Path of the partio file which contains the particle data.
- translation (vec3): Translation vector of the fluid model.
- scale (vec3): Scaling vector of the fluid model.
- rotationAxis (vec3): Axis used to rotate the particle data after loading.
- rotationAngle (float): Rotation angle for the initial rotation of the particle data.
- id: This id is used in the "Fluid parameter block" (see below) to define the properties of the fluid block. If no id is defined, then the standard id "Fluid" is used.
- initialVelocity (vec3): The initial velocity is set for all particles in the fluid model.
- initialAngularVelocity (vec3): The initial angular velocity of the fluid model.

4.4 Emitters

In this part the user can define one or more emitters which generate fluid particles.

Example code:

```
"Emitters": [
    {
        "width": 5,
        "height": 5,
        "translation": [-1,0.75,0.0],
        "rotationAxis": [0, 1, 0],
                "rotationAngle": 3.14159265358979323846264338327 95,
        "velocity": 2,
        "emitStartTime": 2,
                "emitEndTime": 6,
        "type": 0
    }
]
```

- type (int): Defines the shape of the emitter (default: 0).
  - 0: box
  - 1: circle
- width (int): Width of the box or radius of the circle emitter in number of particles (default: 5).

- height (int): Height of the box in number of particles (is only used for type 0) (default: 5).
- translation (vec3): Translation vector of the emitter (default: [0,0,0]).
- rotationAxis (vec3): Axis used to rotate the emitter. Note that in 2D simulations the axis is always set to [0,0,1] (default: [0,0,1]).
- rotationAngle (float): Rotation angle for the initial rotation of the emitter (default: 0).
- velocity (float): Initial velocity of the emitted particles in direction of the emitter (default: 1).
- id: This id is used in the "Fluid parameter block" (see below) to define the properties of the fluid block. If no id is defined, then the standard id "Fluid" is used (default: "Fluid").
- emitStartTime (float): Start time of the emitter (default: 0).
- emitEndTime (float): End time of the emitter (default: REAL_MAX).

4.5 RigidBodies

Here, the static and dynamic rigid bodies are defined which define the boundary in the scene. In case of dynamic rigid bodies, the PositionBasedDynamics library is used for their simulation. Note that in this case the PositionBasedDynamics library also reads this json scene files and picks out the relevant parts. That means if you want to define for example a hinge joint or a motor, then just use the json format of PositionBasedDynamics in this scene file.

Example code:

```
"RigidBodies": [
    {
        "geometryFile": "../models/UnitBox.obj",
        "translation": [0,2,0],
        "rotationAxis": [1, 0, 0],
        "rotationAngle": 0,
        "scale": [2.5, 4, 1.0],
        "color": [0.1, 0.4, 0.6, 1.0],
        "isDynamic": false,
        "isWall": true,
        "mapInvert": true,
                "mapThickness": 0.0,
                "mapResolution": [20,20,20],
        "samplingMode": 1
    }
]
```

- geometryFile (string): Path to a OBJ file which contains the geometry of the body.
- particleFile (string): Path to a partio file which contains a surface sampling of the body. Note that the surface sampling is done automatically if this parameter is missing.
- translation (vec3): Translation vector of the rigid body.
- scale (vec3): Scaling vector of the rigid body.
- rotationAxis (vec3): Axis used to rotate the rigid body after loading.
- rotationAngle (float): Rotation angle for the initial rotation of the rigid body.
- isDynamic (bool): Defines if the body is static or dynamic.
- isWall (bool): Defines if this is a wall. Walls are typically not rendered. This is the only difference.
- color (vec4): RGBA color of the body.

- mapInvert (bool): Invert the map when using density or volume maps, flips inside/outside (default: false)
- mapThickness (float): Additional thickness of a volume or density map (default: 0.0)
- mapResolution (vec3): Resolution of a volume or density map (defaut: [20,20,20])
- samplingMode (int): Surface sampling mode. 0 Poisson disk sampling, 1 Regular triangle sampling (default: 0).

4.6 Materials

```
"Materials": [
        {
        "id": "Fluid",
        "density0": 1000,
        "colorField": "velocity",
        "colorMapType": 1,
        "renderMinValue": 0.0,
        "renderMaxValue": 5.0,
        "surfaceTension": 0.2,
        "surfaceTensionMethod": 0,
        "viscosity": 0.01,
        "viscosityMethod": 1,
        "vorticityMethod": 1,
        "vorticity": 0.15,
        "viscosityOmega": 0.05,
        "inertiaInverse": 0.5,
        "maxEmitterParticles": 1000,
        "emitterReuseParticles": false,
        "emitterBoxMin": [-4.0,-1.0,-4.0],
        "emitterBoxMax": [0.0,4,4.0]
        }
]
```

4.6.1 General

- id (string): Defines the id of the material. You have to give the same id to a FluidBlock, a FluidModel or an Emitter if they should have the defined material behavior.
- density0 (float): Rest density of the corresponding fluid.

4.6.2 Particle Coloring

- colorField (string): Choose vector or scalar field for particle coloring.
- colorMapType (int): Selection of a color map for coloring the scalar/vector field.
  - 0: None
  - 1: Jet
  - 2: Plasma
  - 3: CoolWarm
  - 4: BlueWhiteRed

  - 5: Seismic
- renderMinValue (float): Minimal value used for color-coding the color field in the rendering process.
- renderMaxValue (float): Maximal value used for color-coding the color field in the rendering process.

4.6.3 Viscosity

- viscosityMethod (int): Viscosity method
  - 0: None
  - 1: Standard
  - 2: XSPH
  - 3: Bender and Koschier 2017
  - 4: Peer et al. 2015
  - 5: Peer et al. 2016
  - 6: Takahashi et al. 2015 (improved)
  - 7: Weiler et al. 2018
- viscosity (float): Coefficient for the viscosity force computation
  - "Standard" and "Weiler et al. 2018" use the kinematic viscosity as parameter
  - "Bender and Koschier 2017" and "Peer et al. 2015/2016" use a coefficient in [0,1]
  - For "XSPH" the coefficient is the smoothing parameter in [0,1]
- viscoMaxIter (int): (Implicit solvers) Max. iterations of the viscosity solver.
- viscoMaxError (float): (Implicit solvers) Max. error of the viscosity solver.
- viscoMaxIterOmega (int): (Peer et al. 2016) Max. iterations of the vorticity diffusion solver.
- viscoMaxErrorOmega (float): (Peer et al. 2016) Max. error of the vorticity diffusion solver.
- viscosityBoundary (float): (Weiler et al. 2018) Coefficient for the viscosity force computation at the boundary.

4.6.4 Vorticity

- vorticityMethod (int): Vorticity method
  - 0: None
  - 1: Micropolar model
  - 2: Vorticity confinement
- vorticity (float): Coefficient for the vorticity force computation
- viscosityOmega (float): (Micropolar model) Viscosity coefficient for the angular velocity field.
- inertiaInverse (float): (Micropolar model) Inverse microinertia used in the micropolar model.

4.6.5 Drag force

- dragMethod (int): Drag force method
  - 0: None
  - 1: Macklin et al. 2014
  - 2: Gissler et al. 2017
- drag (float): Coefficient for the drag force computation

4.6.6 Surface tension

- surfaceTensionMethod (int): Surface tension method
  - 0: None
  - 1: Becker & Teschner 2007
  - 2: Akinci et al. 2013
  - 3: He et al. 2014
- surfaceTension (float): Coefficient for the surface tension computation

4.6.7 Elasticity

- elasticityMethod (int): Elasticity method
  - 0: None
  - 1: Becker et al. 2009
  - 2: Peer et al. 2018
- youngsModulus (float): Young's modulus - coefficient for the stiffness of the material (default: 100000.0)
- poissonsRatio (float): Poisson's ratio - measure of the Poisson effect (default: 0.3)
- alpha (float): Coefficent for zero-energy modes suppression method (default: 0.0)
- elasticityMaxIter (int): (Peer et al. 2018) Maximum solver iterations (default: 100)
- elasticityMaxError (float): (Peer et al. 2019) Maximum elasticity error allowed by the solver (default: 1.0e-4)

4.6.8 Emitters

- maxEmitterParticles (int): Maximum number of particles the emitter generates. Note that reused particles (see below) are not counted here.
- emitterReuseParticles (bool): Reuse particles if they are outside of the bounding box defined by emitterBoxMin, emitterBoxMax
- emitterBoxMin (vec3): Minimum coordinates of an axis-aligned box (used in combination with emitterReuseParticles)
- emitterBoxMax (vec3): Maximum coordinates of an axis-aligned box (used in combination with emitterReuseParticles)

4.7 Animation fields

In this part the user can define one or more animation fields which animate fluid particles. The user can define math expressions for the components of the field quantity. The typical math terms like cos,sin,... can be used.

Available expression variables:

- t: Current time.
- dt: Current time step size.
- x, y, z: Position of the particle which is in the animation field.
- vx, vy, vz: Velocity of the particle which is in the animation field.
- valuex, valuey, valuez: Value of the field quantity of the particle which is in the animation field.

Example:

```
"particleField": "angular velocity",
"expression_x": "valuex + cos(2*t)"
```

This means that in each step we add cos(2*t) to the x-component of the angular velocity.

Example code:

```
"AnimationFields": [
    {
        "particleField": "velocity",
        "translation": [-0.5, -0.5, 0],
        "rotationAxis": [0, 0, 1],
        "rotationAngle": 0.0,
        "scale": [0.5, 0.25, 0.8],
        "shapeType": 0,
        "expression_x": "cos(2*t)*0.1",
        "expression_y": "",
        "expression_z": ""
    }
]
```

- shapeType (int): Defines the shape of the animation field (default: 0).
  - 0: box
  - 1: sphere
  - 2: cylinder
- particleField (string): Defines the field quantity that should be modified by the field (e.g. velocity, angular velocity, position) (default: velocity)
- translation (vec3): Translation vector of the animation field (default: [0,0,0]).
- rotationAxis (vec3): Axis used to rotate the animation field (default: [0,0,1]).
- rotationAngle (float): Rotation angle for the initial rotation of the animation field (default: 0).
- scale (vec3): Scaling vector of the animation field.
  - shapeType=0 (box): This vector defines the width, height, depth of the box.
  - shapeType=1 (sphere): The x-component of the vector defines the radius of the sphere. The other components are ignored.

  - shapeType=2 (cylinder): The x- and y-component of the vector defines the height and radius of the cylinder, repectively. The z-component is ignored.

- expression_x (string): Math expression for the x-component of the field quantity (default="").
- expression_y (string): Math expression for the y-component of the field quantity (default="").
- expression_z (string): Math expression for the z-component of the field quantity (default="").

CHAPTER

FIVE

REPLICABILITY

The SPlisHSPlasH library implements the SPH methods developed by our and other research groups (build instructions can be found *here*). This allows to reproduce the research results of the corresponding publications. Inspired by the Graphics Replicability Stamp Initiative we started to add scenes to the repository to reproduce some of the results in our papers:

Jan Bender, Tassilo Kugelstadt, Marcel Weiler, Dan Koschier, "Implicit Frictional Boundary Handling for SPH", IEEE Transactions on Visualization and Computer Graphics, 2020

- Figure 7.a) can be replicated by loading the scene: data/Scenes/GridModel_Akinci2012.json
- Figure 7.b) can be replicated by loading the scene: data/Scenes/GridModel_Bender2019.json

CHAPTER

SIX

INSTALLATION INSTRUCTIONS - LINUX

6.1 Ubuntu Fresh Install

6.1.1 Installation List

```
sudo apt install git cmake xorg-dev freeglut3-dev build-essential
```

6.1.2 Python Bindings

If you plan on using the python bindings by specifying `-DUSE_PYTHON_BINDINGS=On`, then you should also have a working python installation in your path. This installs an additional tool `pipx`, which allows the installation of packages as executables in virtualized environments.

```
sudo apt install python3-dev python3-pip python3-venv
python3 -m pip install pipx
python3 -m pipx ensurepath
```

Alternatively to this you may also install other Python Distributions such as Anaconda (personal preference).

6.1.3 Building Instructions

```
git clone https://github.com/InteractiveComputerGraphics/SPlisHSPlasH.git
cd SPlisHSPlasH
mkdir build && cd build
cmake -DCMAKE_BUILD_TYPE=Release -DUSE_PYTHON_BINDINGS=<On|Off> ..
make -j 4
```

6.1.4 Run Executable

```
cd ../bin
./SPHSimulator ../data/Scenes/DoubleDamBreak.json
```

On some systems it may be necessary to define an OpenGL override like so

```
cd ../bin
MESA_GL_VERSION_OVERRIDE=3.3 ./SPHSimulator ../data/Scenes/DoubleDamBreak.json
```

The command loads the selected scene. To start the simulation disable the pause mode by clicking the checkbox or pressing [Space]. More hotkeys are listed *here*.

6.1.5 Using Bindings

Assuming that the python bindings were generated in the default location `Project Root/build/lib/pysplishsplash.cpython-38-x86_64-linux-gnu.so`, you can use the bindings by adding this path to `sys.path` within your python script, or by calling your scripts within the directory containing the `.so` file. You can test that the bindings work using the following command.

```
cd lib
python3 -c "import pysplishsplash"
```

6.1.6 Installing Bindings

If you followed the above instructions for building SPlisHSPlasH using CMake and generated the python bindings, then these commands should work automatically.

Note: You don't have to clone the repository again. This only shows, that the command should be run in the project root directory. It is also recommended, that you create and activate a virtual environment before installing, so that your base python installation is not affected by any new generated files.

```
git clone https://github.com/InteractiveComputerGraphics/SPlisHSPlasH.git
cd SPlisHSPlasH
python setup.py bdist_wheel
pip install build/dist/*.whl
```

If you specified any additional CMake variables in the form of `-DVAR_NAME=Value`, you can just append them after `bdist_wheel`

Alternatively you may also run the following command, which essentially combines all of the above commands into a single command.

```
pip install git+https://github.com/InteractiveComputerGraphics/SPlisHSPlasH.git
```

Drawbacks: You lose the ability for incremental rebuilds, i.e. if you want to modify the source code and build the bindings anew, you would have to build the entire project every time.

CHAPTER

SEVEN

INSTALLATION INSTRUCTIONS - WINDOWS

7.1 Visual Studio

7.1.1 Dependencies

To build SPlisHSPlasH on Windows you need to install CMake and git.

7.1.2 Python Bindings

If you plan on using the python bindings by specifying `-DUSE_PYTHON_BINDINGS=On`, then you should also have a working Python installation in your path. Moreover, you require the Python Package Installer (pip).

7.1.3 Building Instructions

First, clone the repository by

```
git clone https://github.com/InteractiveComputerGraphics/SPlisHSPlasH.git
```

Then run cmake-gui and set "Where is the source code:" to the [SPlisHSPlasH-dir] and "Where to build the binaries:" to [SPlisHSPlasH-dir]/build.

Now run Configure and select the correct Visual Studio version. Ensure that you choose a x64 build on a 64bit system. Finally, run Generate and open the project. Now you can build the project in Visual Studio. Note that you have to select the "Release" build, if you want to have an optimized executable.

7.1.4 Run Executable

Execute "bin/SPHSimulator.exe" to start the simulator and select a scene file to run the simulation. Alternatively, you can start the simulation in the command line:

```
./SPHSimulator ../data/Scenes/DoubleDamBreak.json
```

The command loads the selected scene. To start the simulation disable the pause mode by clicking the checkbox or pressing [Space]. More hotkeys are listed *here*.

7.1.5 Using Bindings

Assuming that the python bindings were generated in the default location [SPlisHSPlasH-dir]/build/lib/pysplishsplash.cp37-win_amd64.pyd, you can use the bindings by adding this path to `sys.path` within your python script, or by calling your scripts within the directory containing the `.pyd` file. You can test that the bindings work using the following command.

```
cd lib
python3 -c "import pysplishsplash"
```

7.1.6 Installing Bindings

If you followed the above instructions for building SPlisHSPlasH using CMake and generated the python bindings, then these commands should work automatically.

Note: You don't have to clone the repository again. This only shows, that the command should be run in the project root directory. It is also recommended, that you create and activate a virtual environment before installing, so that your base python installation is not affected by any new generated files.

```
git clone https://github.com/InteractiveComputerGraphics/SPlisHSPlasH.git
cd SPlisHSPlasH
python setup.py bdist_wheel
pip install build/dist/pySPlisHSPlasH-2.8.3-cp37-cp37m-win_amd64.whl
```

If you specified any additional CMake variables in the form of `-DVAR_NAME=Value`, you can just append them after `bdist_wheel`

Alternatively you may also run the following command, which essentially combines all of the above commands into a single command.

```
pip install git+https://github.com/InteractiveComputerGraphics/SPlisHSPlasH.git
```

Drawbacks: You lose the ability for incremental rebuilds, i.e. if you want to modify the source code and build the bindings anew, you would have to build the entire project every time.

CHAPTER

EIGHT

CMAKE OPTIONS

This page should give you a short overview over the CMake options of SPlisHSPlasH.

8.1 USE_DOUBLE_PRECISION

If this flag is enabled, then all computations with floating point values are performed using double precision (double). Otherwise single precision (float) is used.

8.2 USE_AVX

SPlishSPlasH supports the usage of AVX (Advanced Vector Extensions) which is an extension of modern CPUs to perform a single instruction on multiple data. The extension allows to perform eight floating point operations in parallel. Enabling AVX significantly improves the performance of the simulator. Currently, the following methods have AVS support:

- DFSPH
- the micropolar vorticity model
- the standard viscosity model
- the viscosity model of Weiler et al.

8.3 USE_OpenMP

Enable the OpenMP parallelization which lets the simulation run in parallel on all available cores of the CPU.

8.4 USE_GPU_NEIGHBORHOOD_SEARCH

As default SPlisHSPlasH uses CompactNSearch as neighborhood search which performs all operations on the CPU. However, with this flag you can switch to cuNSearch which is our GPU neighborhood search. In case you want to use the GPU method, you have to install Cuda.

8.5 USE_IMGUI

We just reimplemented the GUI using imgui instead of AntTweakBar. If you want to try out the new GUI, enable this flag.

8.6 USE_PYTHON_BINDINGS

Generate a shared library object which can be imported into python scripts and exposes C++ functionality to the python interpreter. *Default:On Options:<On|Off>*

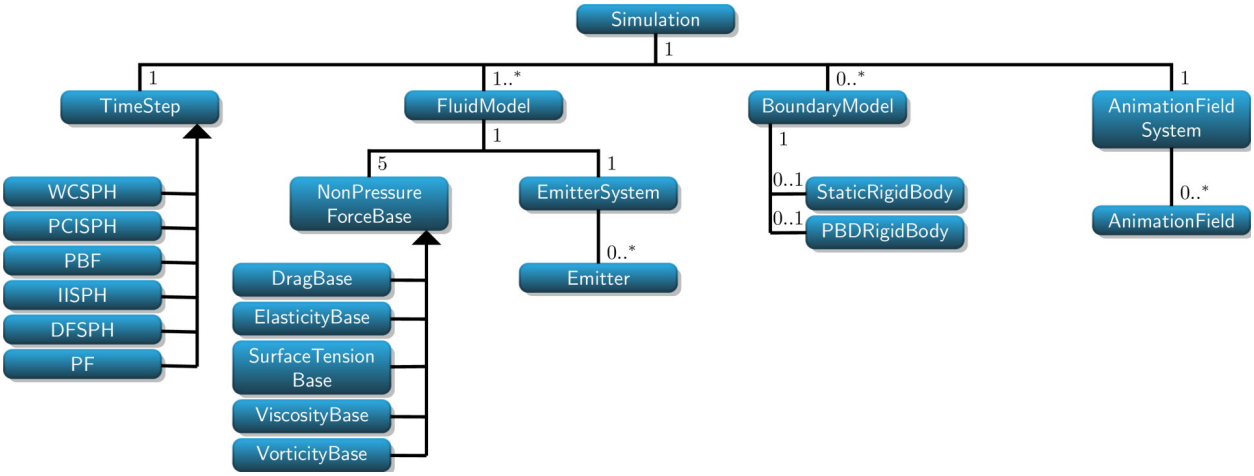
8.7 USE_DEBUG_TOOLS

Adds a debug tools tab to the graphical user interface which allows to generate additional particle data for debugging. Note that generating the additional data will slightly decrease the performance of the simulation.

CHAPTER

NINE

SOFTWARE ARCHITECTURE



SPlisHSPlasH follows a very intuitive and modular design approach. We want to illustrate part of the software architecture in conjunction with the simplified class diagram above. Note, that this documentation only covers the simulation part of SPlisHSPlasH. The whole software architecture follows a similar design pattern as the **Model View Controller**.

9.1 The Simulation class

The simulation class is the main part of the software. It contains the currently used simulation method (`TimeStep`), all fluids (`FluidModel`), all boundaries (`BoundaryModel`), and a `AnimationFieldSystem`. It is defined as a **singleton**, thus only one simulation instance exists during the runtime. The simulation instance contains:

- exactly one `TimeStep` instance, which defines the simulation loop and contains the pressure solver
- any number of `FluidModel` instances each defining a different fluid phase
- any number of `BoundaryModel` instances representing either dynamic rigid bodies or static boundaries
- exactly one `AnimationFieldSystem` instance which allows to animate particles in a predefined area

The simulation class also implements the following:

- evaluation of the SPH kernel methods
- update of the time step size using a CFL condition
- uniform invocation of all `EmitterSystem` instances
- invocation of `AnimationFieldSystem` instance

- saving & loading the current simulation state

Lastly, the simulation class also contains a well defined interface for the neighborhood search functionalities defined in CompactNSearch or cuNSearch, which are further needed in the respective algorithm implementations in e.g. the TimeStep or NonPressureForces.

9.2 The TimeStep class

The TimeStep class is a **abstract base class** for any subsequent derived simulation method one wants to implement. It implements the required interface for the simulation class, noteably the `step()` function containing the simulation algorithm called in the main loop. During execution there exists exactly one instance of a TimeStep class. By default SPlisHSPlasH currently implements the following pressure solvers and the corresponding simulation algorithms:

- WCSPH
- PCISPH
- PBF
- IISPH
- DFSPH
- Projective Fluids

9.3 The FluidModel class

A FluidModel instance represents a fluid phase with its respective properties and applied effects to it. SPlisHSPlasH allows for arbitrary many FluidModels inside a simulation as long as there is at least one and they all have a different id (see scene file format). One FluidModel contains the following:

- Physical parameters like rest density, mass, position, velocity, acceleration and current density
- Simulation parameters like the number of particles, their state and ID
- References to the applied non-pressure effects, one for each:
  - Drag
  - Elasticity
  - Surface tension
  - Viscosity
  - Vorticity
- Emitter systems

Concerning the non-pressure effects, each FluidModel can *only* utilize up to one method per non-pressure effect, which will be directly included in the computation inside the `computeNonPressureForces()` method of the `Simulation` class. Thus having e.g. two different surface tension algorithms inside one FluidModel is **not** possible. However, it is possible to define e.g. two phases, which have a different viscosity model and only one regarding surface tension effects.

The emitters are only stored inside the FluidModels since they are assigned to a fixed FluidModel. Their functionalities are uniformly executed by the Simulation class in the `emitParticles()` step usually invoked at the end of the simulation loop of the current TimeStep instance.

9.4 The BoundaryModel class

The BoundaryModel class provides a useful base class for any boundary handling methods. It stores a `RigidBodyObject` reference representing the object of the boundary. This can be a stationary or dynamic rigid body, whose coupling effects are handled uniformly. Note that `RigidBodyObject` is an abstract class providing an interface for the two derived classes `StaticRigidBody` and `PBDRigidBody`. The first is handled internally and represent stationary objects. The latter describes a moving rigid body which is simulated externally by the PositionBasedDynamics library. SPlisHSPlasH implements three different boundary models:

- Particle-based rigid-fluid coupling [Akinci et al. 2012]
- Density maps [Koschier and Bender 2017]
- Volume maps [Bender et al. 2019]

Finally, SPlisHSPlasH defines a boundary as a list of rigid bodies in conjunction with a rigid-fluid coupling algorithm.

CHAPTER

TEN

IMPLEMENTING A NEW NON-PRESSURE FORCE METHOD

Non-pressure forces (e.g. viscosity, vorticity, surface tension or drag forces) are all implemented in the same way in SPlisHSPlasH. In the following we explain the implementation of such a method using as example a new viscosity method.

SPlisHSPlasH organizes the viscosities in `/SPlisHSPlasH/Viscosity/` and thus any changes or additions are intended to take place in this directory. The user can add new viscosity methods by creating new or copying and modifying existing viscosity class files and registering these inside the build system and the source code.

10.1 Creating a new class

If you want to create a new viscosity class from scratch, you should consider reading the doxygen documentation on the `ViscosityBase` class and several of its derived classes. In short, every viscosity method inherits from the base class `ViscosityBase`, which itself inherits from `NonPressureForceBase`. A minimal working derived class would look like this:

MyViscosity.h

```
#ifndef __MyViscosity_h__
#define __MyViscosity_h__

#include "SPlisHSPlasH/Common.h"
#include "SPlisHSPlasH/FluidModel.h"
#include "ViscosityBase.h"

namespace SPH
{
	class MyViscosity : public ViscosityBase
	{
	protected:
		virtual void initParameters();

	public:
		MyViscosity(FluidModel *model);
		virtual ~MyViscosity(void);

		static NonPressureForceBase* creator(FluidModel* model) { return new
↪MyViscosity(model); }

		virtual void step();
		virtual void reset();
	};
}
```

(continues on next page)

(continued from previous page)

```
#endif
```

MyViscosity.cpp

```
#include "MyViscosity.h"

MyViscosity::MyViscosity(FluidModel *model) :
        ViscosityBase(model)
{
        [...]
}

MyViscosity::~MyViscosity(void)
{
        [...]
}

void MyViscosity::initParameters()
{
        ViscosityBase::initParameters();

        [...]
}

void MyViscosity::step()
{
        [...]
}

void MyViscosity::reset()
{
        [...]
}
```

including the following:

- a constructor with `FluidModel*` as the sole parameter `MyViscosity(FluidModel *model)`
- a `initParameters()` method calling the base class method for parameter setup
- a step function `void step()` called in each timestep for the associated fluid
- a reset function `void reset()` called on every reset of the simulation

10.1.1 Customizing your class

Neighborhood search sort

The user is also free to add and save additional per particle data inside the viscosity method, but has to ensure that these are also included in the *neighborhood search sort*. Sorting is required if the data is used over multiple simulations steps. The neighborhood search performs a z-sort every n steps to improve the number of cache hits. Since all particles are resorted, also their data must be resorted. For this, the user has to override the `performNeighborhoodSearchSort()` method. A minimal example would look like the following:

```
void MyViscosity::performNeighborhoodSearchSort()
{
        Simulation *sim = Simulation::getCurrent();
        auto const& d = sim->getNeighborhoodSearch()->point_set(m_model->
↪getPointSetIndex());
        d.sort_field(&m_myParticleViscosityData[0]);
}
```

Additional particle fields

For visualization and/or debugging purposes, the user may also want to subject the particle data to SPlisHSPlasH's particle informations. To do this, the user has to add the particle data field to the list of fields inside each `FluidModel`. This can be for example done in the constructor by adding the `addField(const FieldDescription &field)` of the corresponding `FluidModel`. The fields can be used to define the color of a particle, they can be exported to bgeo or ParaView and in the simulator the user can output the field data of the selected particles by pressing "i".

For more information, please refer to the doxygen documentation and maybe take a look at the already existing implementations. Adding a field has the following form:

```
model->addField({ "myFieldName", <FieldType>, <lambda expression returning reference␣
↪to the data field>}, <save state (boolean)>);
```

Here is an example:

```
model->addField({ "myFieldName", FieldType::Vector3, [&](const unsigned int i) ->␣
↪Real* { return &m_myFieldValues[i][0]; }, true });
```

The field name is used in the GUI and when exporting the data. The boolean at the end determines if this field should be stored when the simulation state is saved. This should only be done if the value is not recomputed in each simulation step so that the value of the last step is required.

Also don't forget to remove the field, when the instance of the viscosity method is destroyed:

```
m_model->removeFiledByName("myFieldName");
```

Deferred initialization

The user can override the `deferredInit()` method. This function is called after the simulation scene is loaded and all parameters are initialized. While reading a scene file several parameters can change. The `deferredInit()` function should initialize all values which depend on these parameters.

```
void MyViscosity::deferredInit()
{
        initMyViscosity();
}
```

10.2 Registering the viscosity method

To add our new viscosity method, we have to integrate it into the build process and the source code.

10.2.1 Adding to the build process

Simply add the class files `MyViscosity.h` and `MyViscosity.cpp` to the `CMakeLists.txt` in the `/SPlisHSPlasH/` directory. This can be done by adding the relative file paths to the respective variables `VISCOSITY_HEADER_FILES` and `VISCOSITY_SOURCE_FILES`:

```
set(VISCOSITY_HEADER_FILES
        [...]
        Viscosity/MyViscosity.h
)

set(VISCOSITY_SOURCE_FILES
        [...]
        Viscosity/MyViscosity.cpp
)
```

10.2.2 Integration in the source code

Any non-pressure force method is registered in the file `NonPressureForceRegistration.cpp`, which can be found in the `/SPlisHSPlasH/` directory. Adding our new viscosity method is done by adding the following line to the function `void Simulation::registerNonpressureForces()`:

```
addViscosityMethod("My viscosity method", MyViscosity::creator);
```

and including `Viscosity/MyViscosity.h`.

After these additions and building SPlisHSPlasH, our new viscosity method is available inside the simulation.

CHAPTER

ELEVEN

IMPLEMENTING A NEW PARTICLE/RIGID BODY DATA EXPORTER

All exporters are implemented in the same way in SPlisHSPlasH. In the following we explain the implementation of such an exporter method using as example a new rigid body exporter.

SPlisHSPlasH organizes the exporters in `/Simulator/Exporter/` and thus any changes or additions are intended to take place in this directory. The user can add new data exporters by creating new or copying and modifying existing exporter class files and registering these inside the build system and the source code.

11.1 Creating a new class

If you want to create a new exporter class from scratch, you should take a look at existing exporters in SPlisHSPlasH. In short, every exporter inherits from the base class `ExporterBase`. A minimal working derived class would look like this:

RigidBodyExporter_MyFormat.h

```
#ifndef __RigidBodyExporter_MyFormat_h__
#define __RigidBodyExporter_MyFormat_h__

#include "ExporterBase.h"

namespace SPH
{
        /** \brief Rigid body exporter for the OBJ format.
        */
        class RigidBodyExporter_MyFormat : public ExporterBase
        {
        protected:
                bool m_isFirstFrame;
                std::string m_exportPath;

        public:
                RigidBodyExporter_MyFormat(SimulatorBase* base);
                RigidBodyExporter_MyFormat(const RigidBodyExporter_MyFormat&) =␣
↪delete;
         RigidBodyExporter_MyFormat& operator=(const RigidBodyExporter_MyFormat&) =␣
↪delete;
                virtual ~RigidBodyExporter_MyFormat(void);

                virtual void init(const std::string& outputPath);
                virtual void step(const unsigned int frame);
                virtual void reset();
                virtual void setActive(const bool active);
```

(continues on next page)

(continued from previous page)

```
        };
}
#endif
```

RigidBodyExporter_MyFormat.cpp

```
#include "RigidBodyExporter_MyFormat.h"
#include <Utilities/Logger.h>
#include <Utilities/FileSystem.h>
#include "SPlisHSPlasH/Simulation.h"

using namespace SPH;
using namespace Utilities;

RigidBodyExporter_MyFormat::RigidBodyExporter_MyFormat(SimulatorBase* base) :
        ExporterBase(base)
{
        m_isFirstFrame = true;
}

RigidBodyExporter_MyFormat::~RigidBodyExporter_MyFormat(void)
{
}

void RigidBodyExporter_MyFormat::init(const std::string& outputPath)
{
    // define output path for the data
        m_exportPath = FileSystem::normalizePath(outputPath + "/my_format");
}

void RigidBodyExporter_MyFormat::step(const unsigned int frame)
{
    // check if the exporter is active
        if (!m_active)
                return;

        // check if we have a static model
        bool isStatic = true;
        for (unsigned int i = 0; i < sim->numberOfBoundaryModels(); i++)
        {
                BoundaryModel* bm = sim->getBoundaryModel(i);
                if (bm->getRigidBodyObject()->isDynamic())
                {
                        isStatic = false;
                        break;
                }
        }

    // If we have a static model, write the data only for the first frame.
    // Otherwise each frame is exported.
        if (m_isFirstFrame || !isStatic)
        {
        [...]
    }
           m_isFirstFrame = false;
}
```

(continues on next page)

(continued from previous page)

```
void RigidBodyExporter_MyFormat::reset()
{
        m_isFirstFrame = true;
}

void RigidBodyExporter_MyFormat::setActive(const bool active)
{
        ExporterBase::setActive(active);
    // create output folder
        if (m_active)
                FileSystem::makeDirs(m_exportPath);
}
```

including the following:

- a constructor with `SimulatorBase*` as the sole parameter `RigidBodyExporter_MyFormat(SimulatorBase* base)`
- a `init(const std::string& outputPath)` method which should define the export path, `outputPath` contains the path of the current output directory of SPlisHSPlasH
- a step function `void step()` called for each frame that should be exported
- a reset function `void reset()` called on every reset of the simulation
- a function `void setActive(const bool active)` which is called when the user activates the exporter

In our example the exporter path is defined int the function `init`. When the user activates the exporter, e.g. in the GUI, the corresponding directory is created. In the function `step` the rigid body data can be written. Note that we added some code so that static rigid bodies are only exported once and not for each frame since they never change.

11.2 Registering the exporter

To add our new exporter, we have to integrate it into the build process and the source code.

11.2.1 Adding to the build process

Simply add the class files `RigidBodyExporter_MyFormat.h` and `RigidBodyExporter_MyFormat.cpp` to the `CMakeLists.txt` in the `/Simulator/` directory. This can be done by adding the relative file paths to the respective variables `EXPORTER_HEADRE_FILES` and `EXPORTER_SOURCE_FILES`:

```
set(EXPORTER_HEADER_FILES
        [...]
        Exporter/RigidBodyExporter_MyFormat.h
)

set(EXPORTER_SOURCE_FILES
        [...]
        Exporter/RigidBodyExporter_MyFormat.cpp
)
```

11.2.2 Integration in the source code

Any exporter is registered in the file `ExporterRegistration.cpp`, which can be found in the `/Simulator/` directory. Adding our new exporter is done by adding the following line to the function `void SimulatorBase::createExporters()`:

```
addRigidBodyExporter("enableRigidBodyMyFormatExport", "Rigid Body MyFormat Exporter",
↪"Enable/disable rigid body My Format export.", new RigidBodyExporter_
↪MyFormat(this));
```

and including `Exporter/RigidBodyExporter_MyFormat.h`. The first string defines a key which can be used in the json scene files to activate your exporter. The second string defines the name of your exporter which will appear in the GUI. This name can also be used to activate your exporter in C++ or Python. The last string contains a description of the exporter which is used as tool tip in the GUI.

After these additions and building SPlisHSPlasH, our new exporter is available inside the simulation.

11.3 Implementing a new exporter in Python

You can also implement a new exporter using our Python interface. You can find an example here: `pySPlisHSPlasH\examples\custom_exporter.py`.

CHAPTER

TWELVE

CREATING PRESSURE SOLVERS

SPlisHSPlasH organizes the pressure solvers in their respective folders inside the `/SPlisHSPlasH/` directory. For example DFSPH can be found inside `/SPlisHSPlasH/DFSPH/`. We highly suggest the user to follow our file organization scheme. The user can also add new pressure solvers by by creating new or copying and modifying existing classes and then adding them to the build system plus additionally registering in the source code.

Note that we do not strictly distinguish the pressure solver from the simulation algorithm. Each `TimeStep` class implements a whole time step including the pressure solver. The non-pressure forces are decoupled in their respective classes and only implicitly called. Thus for implementing a new pressure solver, we suggest copying the files from for example WCSPH and replacing the pressure solver by your own one. Note further, that we usually decouple data from the algorithm with the `SimulationData` classes. We strongly recommend doing the same with your implementation.

12.1 Creating a new class

Again, we want to stress that copying and modifying existent methods is easier than writing a new class from scratch. However, if you want to do so, be sure to implement every abstract method inherited from `TimeStep`. These include:

- `void step()`, the simulation step function
- `void resize()`, a method to initialize and resize any used field

Albeit being not necessary, the user may also want to override/redefine the following methods:

- `void init()`, the initialization method. It is **important to call** `TimeStep::init()` inside this method
- `void reset()`, the method invoked on every reset command
- `void computeDensities()`, if the user does not want to utilize the given density computation

A minimal working example of a derive class is shown below:

TimeStepMyPressureSolver.h

```
#ifndef __TimeStepMyPressureSolver_h__
#define __TimeStepMyPressureSolver_h__

#include "SPlisHSPlasH/Common.h"
#include "SPlisHSPlasH/TimeStep.h"
#include "SPlisHSPlasH/SPHKernels.h"

namespace SPH
{
        class TimeStepMyPressureSolver : public TimeStep
        {
```

(continues on next page)

(continued from previous page)

```
    public:
        TimeStepMyPressureSolver();
        virtual ~TimeStepMyPressureSolver();

        virtual void step();

        virtual void resize();
    };
}

#endif
```

TimeStepMyPressureSolve.cpp

```
#include "TimeStepMyPressureSolve.h"

using namespace SPH;
using namespace GenParam;

TimeStepMyPressureSolve::TimeStepMyPressureSolve() :
    TimeStep()
{
    [...]
}

TimeStepMyPressureSolve::~TimeStepMyPressureSolve(void)
{
    [...]
}

void TimeStepMyPressureSolve::step()
{
    [...]
}

void TimeStepMyPressureSolve::resize()
{
    [...]
}
```

SPlisHSPlasH assumes your simulation method allows for operator splitting, thus usually dividing the simulation into non-pressure forces and the pressure solver plus advection. The latter is subject of the TimeStep class. It is still possible to implement these together inside your own TimeStep class, but it contradicts SPlisHSPlasH's design principles. Since the `step()` method is forwarded to the main loop by the simulation class, its purpose is to define the simulation algorithm. For guidance, we also provide a simple SPH simulation algorithm outline:

```
void TimeStepWCSPH::step()
{
        Simulation *sim = Simulation::getCurrent();
        const unsigned int nModels = sim->numberOfFluidModels();
        TimeManager *tm = TimeManager::getCurrent ();
        const Real h = tm->getTimeStepSize();

    // 1. Perform a neighborhood search
        performNeighborhoodSearch();
```

(continues on next page)

(continued from previous page)

```
    // 2. Compute non-pressure forces and SPH densities
        for (unsigned int fluidModelIndex = 0; fluidModelIndex < nModels;␣
↪fluidModelIndex++)
        {
                clearAccelerations(fluidModelIndex);
                computeDdensities(fluidModelIndex);
        }
        sim->computeNonPressureForces();

    // 3. Compute pressure forces
        computePressureForces();

    // 4. Update time step tize with CFL condition
        sim->updateTimeStepSize();

    // 5. Advect particles
        advectParticles();

    // 6. Emit and/or animate particles if necessary
        sim->emitParticles();
        sim->animateParticles();

    // 7. Advect time
        tm->setTime(tm->getTime() + h);
}
```

where `computeDensities(...)` and `clearAcceleration(...)` are already defined by the base class.

We recommend the user to split the simulation algorithm and its data into two separate classes as it is the case for our already implemented ones.

12.2 Registering the pressure solver

To add our new simulation method, we have to integrate it into the build process and the source code.

12.2.1 Adding to the build process

Simply add all of your class files to the `CMakeLists.txt` in the `/SPlisHSPlasH/` directory. We suggest creating new variables for the header and source files and adding these to the `add_library()` as well as to new `source_group()` calls. A possible implementation following our class file conventions would look like the following:

```
set(MYPRESSURESOLVER_HEADER_FILES
    MyPressureSolver/SimulationDataMyPressureSolver.h
    MyPressureSolver/TimeStepMyPressureSolver.h
)

set(MYPRESSURESOLVER_SOURCE_FILES
    MyPressureSolver/SimulationDataMyPressureSolver.cpp
    MyPressureSolver/TimeStepMyPressureSolver.cpp
)

add_library(SPlisHPlasH
```

(continues on next page)

(continued from previous page)

```
    [...]

    ${MYPRESSURESOLVER_HEADER_FILES}
    ${MYPRESSURESOLVER_SOURCE_FILES}
)

source_group("Header Files\\MyPressureSolver" FILES ${MYPRESSURESOLVER_HEADER_FILES})
source_group("Source Files\\MyPressureSolver" FILES ${MYPRESSURESOLVER_SOURCE_FILES})
```

12.2.2 Integration in the source code

Any timestep method and thus any pressure solver is registered in the `Simulation.h` and `Simulation.cpp` files, which can be found in the `/SPlisHSPlasH/` directory. Adding a new method comprises of the following steps:

- Adding a new enum in `SimulationMethods`
- Creating a new static variable `static int ENUM_SIMULATION_MYPRESSURESOLVER` for the Generic-Parameter system and initializing it in `Simulation.cpp`
- Including `SPlisHSPlasH/MyPressureSolver/TimeStepMyPressureSolver.h` in `Simulation.cpp`
- Adding a new enum value for `SIMULATION_METHOD` inside `Simulation::initParameters()` using the following line:

```
enumParam->addEnumValue("MyPressureSolverName", ENUM_SIMULATION_MYPRESSURESOLVER);
```

- Adding the pressure solver to `Simulation::setSimulationMethod(...)`, thus making it available for the simulation using the following:

```
else if (method == SimulationMethods::MyPressureSolver)
{
    m_timeStep = new TimeStepMyPressureSolver();
    m_timeStep->init();
    setValue(Simulation::KERNEL_METHOD, <desired standard SPH kernel>);
    setValue(Simulation::GRAD_KERNEL_METHOD, <desired standard SPH gradient kernel>);
}
```

After these additions and building SPlisHSPlasH, our new pressure solver is available inside the simulation.

CHAPTER

THIRTEEN

MACROS

SPlisHSPlasH defines useful macros to e.g. iterate over all neighboring particles inside the neighborhood of the current one. These can be found in `Simulation.h`. In the following, we want to give a short overview over these macros. For further information, please refer to the api documentation.

13.1 Looping over fluid neighbors

An essential part of SPH computation is to use the properties of neighboring particles to compute the desired value. SPlisHSPlasH provides macros iterating over every fluid neighbor, which can be used like predefined for-loop constructs. These include the following:

13.1.1 forall_fluid_neigbors

```
#define forall_fluid_neighbors(code) \
        for (unsigned int pid = 0; pid < nFluids; pid++) \
        { \
                FluidModel *fm_neighbor = sim->getFluidModelFromPointSet(pid); \
                for (unsigned int j = 0; j < sim->numberOfNeighbors(fluidModelIndex,␣
↪pid, i); j++) \
                { \
                        const unsigned int neighborIndex = sim->
↪getNeighbor(fluidModelIndex, pid, i, j); \
                        const Vector3r &xj = fm_neighbor->getPosition(neighborIndex);␣
↪\
                        code \
                } \
        }
```

`forall_fluid_neigbors` loops over every fluid particle (in all fluid phases) in the neighborhood region of the current one. Note that this does **not** include boundary particles. The user can use this macro by writing the desired code inside the brackets. For the usage of most of the macros, some additional variables have to be predefined. These include in this case:

- `Simulation *sim = Simulation::getCurrent()`, the current simulation instance
- `unsigned int nFluids`, the amount of FluidModel instances
- `unsigned int fluidModelIndex`, the index of the FluidModel of the current particle
- `unsigned int i`, the index of the current particle inside the FluidModel with index fluidModelIndex

Further, this macro also defines certain variables, which can be accessed inside the code given to the macro:

- `unsigned int pid`, the index of the FluidModel of the neighboring particle
- `FluidModel *fm_neighbor`, the FluidModel reference of the neighboring particle
- `const unsigned int neighborIndex`, the particle index of the neighboring particle
- `const Vector3r &xj`, the position of the neighboring particle

Henceforth, we denote the required additional variables by **Requires** and the by the macro defined ones by **Defines**.

13.1.2 forall_fluid_neighbors_in_same_phase

```
#define forall_fluid_neighbors_in_same_phase(code) \
        for (unsigned int j = 0; j < sim->numberOfNeighbors(fluidModelIndex,␣
↪fluidModelIndex, i); j++) \
        { \
                const unsigned int neighborIndex = sim->getNeighbor(fluidModelIndex,␣
↪fluidModelIndex, i, j); \
                const Vector3r &xj = model->getPosition(neighborIndex); \
                code \
        }
```

`forall_fluid_neighbors_in_same_phase` loops over every fluid particle in the neighborhood region considering only neighbors from the **same** FluidModel as the current one.

- **Requires**:
  - `Simulation *sim = Simulation::getCurrent()`
  - `unsigned int fluidModelIndex`
  - `unsigned int i`
- **Defines**:
  - `const unsigned int neighborIndex`
  - `const Vector3r &xj`

13.2 Looping over boundaries

13.2.1 forall_boundary_neighbors

```
#define forall_boundary_neighbors(code) \
    for (unsigned int pid = nFluids; pid < sim->numberOfPointSets(); pid++) \
    { \
            BoundaryModel_Akinci2012 *bm_neighbor = static_cast<BoundaryModel_
↪Akinci2012*>(sim->getBoundaryModelFromPointSet(pid)); \
            for (unsigned int j = 0; j < sim->numberOfNeighbors(fluidModelIndex, pid,␣
↪i); j++) \
            { \
                    const unsigned int neighborIndex = sim->
↪getNeighbor(fluidModelIndex, pid, i, j); \
                    const Vector3r &xj = bm_neighbor->getPosition(neighborIndex); \
                    code \
            } \
    }
```

`forall_boundary_neighbors` loops over all boundary neighbors casting them to the Akinci 2012 boundary model.

- **Requires**:
  - `Simulation *sim = Simulation::getCurrent()`
  - `unsigned int nFluids`
  - `unsigned int fluidModelIndex`
  - `unsigned int i`
- **Defines**:
  - `unsigned int pid`, the index of the FluidModel associated with the BoundaryModel
  - `BoundaryModel_Akinci2012 *bm_neighbor`, the BoundaryModel reference of the neighboring particle
  - `const unsigned int neighborIndex`, the particle index of the neighboring particle
  - `const Vector3r &xj`, the position of the neigboring particle

13.2.2 forall_density_maps

```
#define forall_density_maps(code) \
for (unsigned int pid = 0; pid < nBoundaries; pid++) \
{ \
        BoundaryModel_Koschier2017 *bm_neighbor = static_cast<BoundaryModel_
↪Koschier2017*>(sim->getBoundaryModel(pid)); \
        const Real rho = bm_neighbor->getBoundaryDensity(fluidModelIndex, i); \
        if (rho != 0.0) \
        { \
                const Vector3r &gradRho = bm_neighbor->
↪getBoundaryDensityGradient(fluidModelIndex, i).cast<Real>(); \
                const Vector3r &xj = bm_neighbor->getBoundaryXj(fluidModelIndex, i); \
                code \
        } \
}
```

`forall_density_maps` loops over all boundary neighbors casting them to the Koschier 2017 boundary model.

- **Requires**:
  - `Simulation *sim = Simulation::getCurrent()`
  - `unsigned int nBoundaries`
  - `unsigned int fluidModelIndex`
  - `unsigned int i`
- **Defines**:
  - `unsigned int pid`
  - `BoundaryModel_Koschier2017 *bm_neighbor`
  - `const Real rho`, the boundary density given by the density map
  - `const Vector3r &gradRho`, the boundary density gradient
  - `const Vector3r &xj`

13.2.3 forall_volume_maps

```
#define forall_volume_maps(code) \
    for (unsigned int pid = 0; pid < nBoundaries; pid++) \
    { \
            BoundaryModel_Bender2019 *bm_neighbor = static_cast<BoundaryModel_
↪Bender2019*>(sim->getBoundaryModel(pid)); \
            const Real Vj = bm_neighbor->getBoundaryVolume(fluidModelIndex, i);  \
            if (Vj > 0.0) \
            { \
                    const Vector3r &xj = bm_neighbor->getBoundaryXj(fluidModelIndex,␣
↪i); \
                    code \
            } \
    }
```

`forall_volume_maps` loops over all boundary neighbors casting them to the Bender 2019 boundary model.

- **Requires**:
  - `Simulation *sim = Simulation::getCurrent()`
  - `unsigned int nBoundaries`
  - `unsigned int fluidModelIndex`
  - `unsigned int i`
- **Defines**:
  - `unsigned int pid`
  - `BoundaryModel_Koschier2019 *bm_neighbor`
  - `const Real Vj`, the boundary volume given by the volume map
  - `const Vector3r &xj`

13.3 AVX variants

SPlisHSPlasH also defines versions using AVX optimizations for some of the macros. These can be used if the respective CMake option is set in the building process. Note that many of the aforementioned by the macro defined variables are given in AVX compatible data types, if you choose to use the AVX version of these macros.

CHAPTER

FOURTEEN

PYSPLISHSPLASH

14.1 Python bindings for the SPlisHSPlasH library

14.2 Requirements

Currently the generation of python bindings is only tested on

- Linux Debian, gcc 8.3, Python 3.7/3.8 (Anaconda), CMake 3.13
- Windows 10, Visual Studio 15/17/19, Python 3.7/3.8 (Anaconda), CMake 3.13

Note that the compiler, the python installation as well as cmake have to be available from the command line for the installation process to work. MacOS builds should work but have not been tested.

14.3 Installation

In order to install it is advised that you create a new virtual environment so that any faults during installation can not mess up your python installation. This is done as follows for

conda

```
conda create --name venv python=3.7
conda activate venv
```

virtualenv

```
python3 -m virtualenv venv --python=python3.7
source venv/bin/activate
```

Now you can clone the repository by

```
git clone https://github.com/InteractiveComputerGraphics/SPlisHSPlasH.git
```

And finally you should be able to install SPlisHSPlasH using pip. **The trailing slash is important** otherwise pip will try to download the package, which is not supported yet at least. Also note, that `pip install SPlisHSPlasH` should be called from **one directory above** the cloned source directory and **not within** the directory itself.

```
pip install SPlisHSPlasH/
```

While `pip install` is useful if SPlisHSPlasH should only be installed once, for development purposes it might be more sensible to build differently. Change into the SPlisHSPlasH directory and build a python wheel file as follows

```
cd SPlisHSPlasH
python setup.py bdist_wheel
pip install -I build/dist/*.whl
```

When building a new version of SPlisHSPlasH simply run these commands again and the installation will be updated. The compile times will be lower, because the build files from previous installations remain. If you are getting compile errors please try to compile the pysplishsplash target of the CMake project separately.

Now check your installation by running

```
python -c "import pysplishsplash"
```

Note: You may have to install numpy. Future releases may already contain numpy as a dependency.

```
pip install numpy
```

14.4 I want to see something very very quickly

If you're very impatient, just run the following command after installing

```
splash
```

You will be prompted to select a preconfigured scene file which will then be run in a User Interface. For more options and functionality run. The keybindings in the GUI are the same as for the regular SPlisHSPlasH version.

```
splash --help
```

14.5 Minimal working example

The following examples should work, if SPlisHSPlasH was installed correctly. If you want to load other scene files, be sure to place them into the SPlisHSPlasH data directory structure.

With GUI

```
import pysplishsplash as sph

def main():
    base = sph.Exec.SimulatorBase()
    base.init()
    gui = sph.GUI.Simulator_GUI_TweakBar(base)
    base.setGui(gui)
    base.run()

if __name__ == "__main__":
    main()
```

Without GUI

```
import pysplishsplash as sph

def main():
    base = sph.Exec.SimulatorBase()
```

(continues on next page)

(continued from previous page)

```
    base.init(useGui=False)
    base.setValueFloat(base.STOP_AT, 10.0) # Important to have the dot to denote a␣
↪float
    base.run()

if __name__ == "__main__":
    main()
```

Outputting the results to a specific directory without GUI

```
import pysplishsplash as sph
from pysplishsplash.Extras import Scenes
import os

def main():
    base = sph.Exec.SimulatorBase()
    output_dir = os.path.abspath("where/you/want/the/data")
    base.init(useGui=False, outputDir=output_dir, sceneFile=Scenes.DoubleDamBreak)
    base.setValueFloat(base.STOP_AT, 20.0) # Important to have the dot to denote a␣
↪float
    base.setValueBool(base.VTK_EXPORT, True)
    # Uncomment the next line to set the output FPS value (must be float)
    # base.setValueFloat(base.DATA_EXPORT_FPS, 10000.)
    base.run()

if __name__ == "__main__":
    main()
```

14.6 SPHSimulator.py

If you want to start the simulator in the same way as the C++ version, just use the SPHSimulator.py in the examples directory.

14.7 Modifying other properties

The bindings cover most of the public interface of the SPlisHSPlasH library. As such, it is possible to change components of the simulation dynamically. In the following example, the second cube in the well known double dam break scenario is replaced with a slightly larger cube.

```
import pysplishsplash
import pysplishsplash.Utilities.SceneLoaderStructs as Scene

def main():
    base = pysplishsplash.Exec.SimulatorBase()
    args = base.init()
    gui = pysplishsplash.GUI.Simulator_GUI_TweakBar(base)
    base.setGui(gui)
    scene = base.getScene()
    add_block = Scene.FluidBlock('Fluid', Scene.Box([0.0, 0.0, 0.0], [1.0, 1.0, 1.0]),
↪ 0, [0.0, 0.0, 0.0])
    scene.fluidBlocks[1] = add_block # In Place construction not supported yet
    base.run()
```

(continues on next page)

(continued from previous page)

```
if __name__ == "__main__":
    main()
```

CHAPTER

FIFTEEN

EMBEDDED PYTHON

15.1 Build with embedded Python support

To enable the embedded Python support just activate the CMake option USE_EMBEDDED_PYTHON which is by default turned off. Please ensure that CMake finds the Python interpreter. This can be achieved by setting the PYTHON_EXECUTABLE to the file path of the python interpreter.

15.2 Run simulator with embedded Python support

Make sure that the environment variables PYTHONHOME and PYTHONPATH are set to the directory of your Python installation. Also make sure that the pythonXX.dll (where XX defines the version) is in your path.

When running the simulator with embedded Python support, the new tab 'Scripts' should appear in the GUI. Here you can load a script file or reload it.

Alternatively, you can load the Python script directly in a scene. Just use the json key `scriptFile` in the scene file to define the location of the script. If a relative path is used, the simulator assumes that it is relative to the scene file.

15.3 Writing a script

First, you have to import the module `splishsplash`, e.g. by: `import splishsplash as sph`

When the script is loaded, the simulator will call the function `init()` automatically. If you defined a function `step()`, it will be called in each simulation step. If you defined a function `reset()`, it will be called when the simulation is reset. Moreover, you can define additional functions that can be called using the GUI.

15.3.1 init(base)

If this function is defined, it is called automatically when the script is loaded or reloaded. The parameter base contains the current SimulationBase object.

15.3.2 step()

If this function is defined, it is called automatically in each simulation step.

15.3.3 reset()

If this function is defined, it is called automatically in each simulation reset.

15.3.4 Additional commands

Additional commands that can be executed via the GUI (buttons will be added) can be defined by a list of strings. The list must be called `function_list` and must contain the names of functions that should be called, e.g.

```
function_list = ['command', 'command2']
```

15.4 Example

This is a simple example script which prints the current simulation time, the position of particle 0 and a counter value in each step:

```
import splishsplash as sph
import numpy as np

counter = 0
function_list = ['command', 'command2']

def init(base):
    global counter
    print("init test")
    counter = 1

def step():
    global counter
    sim = sph.Simulation.getCurrent()
    fluid = sim.getFluidModel(0)
    tm = sph.TimeManager.getCurrent()
    print(fluid.getPosition(0))
    print(tm.getTime())
    print(counter)
    counter += 1
    print("---")

def reset():
    print("reset test")

def command():
    print("tst cmd")

def command2():
    print("tst cmd2")
```

CHAPTER

SIXTEEN

CREATING SCENES

16.1 Loading the empty scene

Right now the easiest way to create a custom scene without specifying a `Scene.json` file, is to load the predefined empty scene.

```
import pysplishsplash as sph
import pysplishsplash.Utilities.SceneLoaderStructs as Scenes

base = sph.Exec.SimulatorBase()
base.init(sceneFile=Scenes.Empty)
```

This scene will set the default simulation method to be `DFSPH` and some other default values, which can all be changed later on.

16.2 Recreating the double dam break scenario

In order to recreate the double dam break scenario, we need to add a bounding box as well as two fluid cubes. The bounding box can be added as follows

```
scene = base.getScene()
scene.boundaryModels.append(Scenes.BoundaryData(meshFile="../models/UnitBox.obj",␣
↪translation=[0., 3.0, 0.], scale=[4., 6., 4.], color=[0.1, 0.4, 0.5, 1.0],␣
↪isWall=True, mapInvert=True, mapResolution=[25, 25, 25]))
```

The two fluid blocks can at the end be added using

```
scene.fluidBlocks.append(Scenes.FluidBlock(id='Fluid', box=Scenes.Box([-1.5, 0.0, -1.
↪5], [-0.5, 2.0, -0.5]), mode=0, initialVelocity=[0.0, 0.0, 0.0]))
scene.fluidBlocks.append(Scenes.FluidBlock(id='Fluid', box=Scenes.Box([0.5, 0.0, 0.5],
↪ [1.5, 2.0, 1.5]), mode=0, initialVelocity=[0.0, 0.0, 0.0]))
```

This will recreate a somewhat larger scene than the default double dam break

16.3 Putting it all together

The following shows a script detailing how to build and run a custom double dam break. Follow the instruction from before to activate/ deactivate the GUI.

```
import pysplishsplash as sph
import pysplishsplash.Utilities.SceneLoaderStructs as Scenes

def main():
    # Set up the simulator
    base = sph.Exec.SimulatorBase()
    base.init(useGui=True,  sceneFile=sph.Extras.Scenes.Empty)

    # Create a tweak bar simulator
    gui = sph.GUI.Simulator_GUI_TweakBar(base)
    base.setGui(gui)

    # Get the scene and add objects
    scene = base.getScene()
    scene.boundaryModels.append(Scenes.BoundaryData(meshFile="../models/UnitBox.obj",␣
↪translation=[0., 3.0, 0.], scale=[4., 6., 4.], color=[0.1, 0.4, 0.5, 1.0],␣
↪isWall=True, mapInvert=True, mapResolution=[25, 25, 25]))
    scene.fluidBlocks.append(Scenes.FluidBlock(id='Fluid', box=Scenes.Box([-1.5, 0.0,␣
↪-1.5], [-0.5, 2.0, -0.5]), mode=0, initialVelocity=[0.0, 0.0, 0.0]))
    scene.fluidBlocks.append(Scenes.FluidBlock(id='Fluid', box=Scenes.Box([0.5, 0.0,␣
↪0.5], [1.5, 2.0, 1.5]), mode=0, initialVelocity=[0.0, 0.0, 0.0]))

    # Run the GUI
    base.run()

if __name__ == "__main__":
    main()
```

16.4 Loading a scene from file

Loading a scene from a file is as simple as simply specifying a custom scene file in the init function. This must be an **absolute path**!

```
custom_scene = os.path.abspath("scene.json")
base.init(sceneFile=custom_scene)
```

If you want to use a gui to locate the scene file you may want to use tkinter

```
import tkinter as tk
from tkinter import filedialog

tk.Tk().withdraw() # Dont show main window
custom_scene = filedialog.askopenfilename()
base.init(sceneFile=custom_scene)
```

CHAPTER

SEVENTEEN

RESTRICTIONS

- When modifying simulation parameters this is the recommended structure, as modification will only work after `base.initSimulation()` has been called.

```
base.initSimulation()
sim = sph.Simulation.getCurrent()
sim.setValue...()
base.runSimulation()
base.cleanup()
```

- `setValue...()` and `getValue...()` functions cannot accept vectors as arguments yet

CHAPTER

EIGHTEEN

FOAMGENERATOR

The foam generator is a command line tool to generate spray, foam and bubble particles in a postprocessing step which improves the visual realism of the simulation results. It takes a sequences of particle files and generates a sequence of new particles representing spray, foam and air bubbles. These additional particles are advected using the velocity field of the fluid. Below are two examples which were generated using the foam generator tool:

|| | —- | —- |

The tool implements the methods of:

- Markus Ihmsen, Nadir Akinci, Gizem Akinci, Matthias Teschner. Unified spray, foam and air bubbles for particle-based fluids. The Visual Computer 28(6), 2012
- Jan Bender, Dan Koschier, Tassilo Kugelstadt and Marcel Weiler. Turbulent Micropolar SPH Fluids with Foam. IEEE Transactions on Visualization and Computer Graphics 25(6), 2019

18.1 Parameters for foam generation

The foam generator first analyzes the complete simulation data before the generation starts. During this analysis the tool determines the maximum values per frame for the potentials as proposed by Bender et al. [2019]. The resulting values are used for an automatic configuration of the parameters –ta, –wc, –vo and the limits. If you want to set these parameters manually (like in the original method of Ihmsen et al. [2012]), then you have to use the command line parameter "–no-auto" and set the parameters –ta, –wc, –vo and –limits.

18.2 Bounding box

Moreover, it is possible to define a bounding box for the foam particles. Foam particles are advected only using the velocity field of the fluid. However, there is no boundary handling since this would be quite expensive. Hence, particles can go through the boundary. A simple solution is to define a bounding box and clamp the particles which leave the box or kill these particles or steal their lifetime.

18.3 Frame rate

We recommend to generate the fluid sequence with 50 fps. Therefore, by default the time step size of the generator is set to 0.02s. If you use another frame rate, you have to adapt this parameter.

18.4 Further parameters

- The parameter –buoyancy defines the buoyancy of air bubbles. Higher values let them go up faster.
- The parameter –drag defines the coefficient of a drag force between the fluid particles and the foam particles.
- The parameter –foamscale defines how many foam particles are generated per frame.
- The parameter –lifetime defines the minimum and maximum lifetime of the foam particles in seconds.
- The parameter –skipframes allows you the skip frames when writing the foam data, e.g. if you have a 50fps fluid sequence and want to write a 25fps foam sequence.
- The parameters –splittypes and –splitgenerators can be used if you want to split the output in spray, foam and air bubble particles.

18.4.1 Command line options:

- -h, –help: Print help
- -i, –input arg: Input file (partio)
- -o, –output arg: Output file (partio or vtk)
- -q, –query: Query mode: determines max/avg values
- –no-auto: Disable automatic mode. Limits and factors ta, wc, vo must be set manually.
- –splittypes: Output each foam type to a different file
- –splitgenerators: Output different foam files depending on which potential generated the foam. Overrides –splittypes.
- -s, –startframe arg: Start frame (default: 1)
- -e, –endframe arg: End frame
- -r, –radius arg: Particle radius (default: 0.025)
- -t, –timestepsize arg: Time step size (default: 0.02)
- -k, –kernel arg: 0: Cubic spline, 1: Ihmsen et al. 2012 (default: 0)
- -l, –limits arg: Limits (min/max) for potentials (trapped air, wave crest, vorticity, kinetic energy) (default: 5,20,2,8,5,20,5,50)

- –lifetime arg: Lifetime (min/max) (default: 2.0,5.0)
- -b, –buoyancy arg: Buoyancy (default: 2.0)
- -d, –drag arg: Drag (default: 0.8)
- –ta arg: Trapped air factor (default: 4000)
- –wc arg: Wave crest factor (default: 50000)
- –vo arg: Vorticity factor (default: 4000)
- –bbsize arg: minimum and maximum coordinates of and axis aligned bounding-box (minX, minY, minZ, maxX, maxY, maxZ)
- –bbtype arg: chose how the bounding-box is used [kill | lifesteal | clamp]. Use in combination with –bbsize.
- –skipframes arg: number of frames to skip when writing foam (default: 0)
- -f, –foamscale arg: Global multiplier for number of generated foam particles (default: 1000)

18.4.2 Example:

```
FoamGenerator -s 1 -e 500 -r 0.025 --foamscale 1000 -i output\DamBreakModelDragons\
↪partio\ParticleData_Fluid_#.bgeo -o output\DamBreakModelDragons\foam\foam_#.bgeo
```

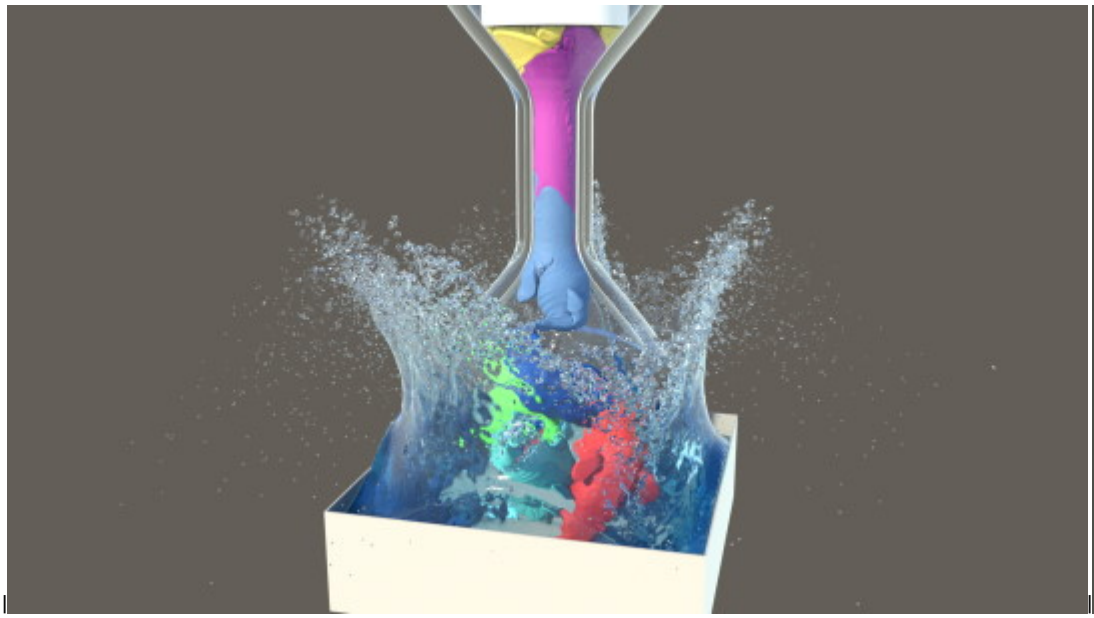
CHAPTER

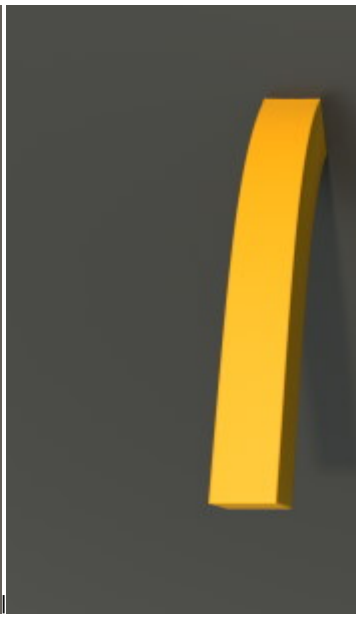
NINETEEN

MESHSKINNING

MeshSkinning is a command line tool to generate a sequence of deformed meshes from a sequence of particle files of an elastic model. When simulating an elastic solid using SPlisHSPlasH, we only get particle data. If this data is exported using the PartioExported, the MeshSkinning tool is able to generate deformed triangle meshes in a post-processing step. The tool requires a triangle mesh of the reference configuration of the deformable solid. This mesh is then deformed according to the particle data.

Below are two examples which were generated using the mesh skinning tool:





| —- | —- |

The tool implements the methods of:

- Tassilo Kugelstadt, Jan Bender, José Antonio Fernández-Fernández, Stefan Rhys Jeske, Fabian Löschner, and Andreas Longva. Fast Corotated Elastic SPH Solids with Implicit Zero-Energy Mode Control. Proceedings of the ACM on Computer Graphics and Interactive Techniques, 2021

19.1 Parameters

The mesh skinning tool can either use the scene file as input. Then you have to define the required triangle mesh in the scene file for each elastic model:

```
"visMesh": "../models/beam.obj"
```

All transformations and required info is then automatically extracted from the scene file (assuming that the partio files are located in the output folder) which is the simplest way to use this tool.

Alternatively you can also define everything manually. Then you have to provide the partio path, mesh file as well as translation, rotation and scaling of the mesh file to fit the reference configuration of the particles.

19.1.1 Command line options:

- -i, –input arg: Input file
- -o, –output arg: Output file
- -m, –mesh arg: Mesh file
- –scene arg: Scene file (all settings are imported from the scene file)
- –partioPath arg: Path of the partio files (when using a scene file). If not set, it is assumed that the files are in the standard output path.
- –scale arg: Scaling of input geometry (e.g. –scale “2 1 2”) (default: 1 1 1)
- -t, –translation arg: Translation of input geometry (e.g. –translation “2 1 2”) (default: 1 1 1)
- –axis arg: Rotation axis of input geometry (e.g. –axis “1 0 0”) (default: 1 0 0)
- –angle arg: Angle of input geometry (e.g. –angle 1) (default: 0.0)
- -s, –startframe arg: Start frame (default: 1)
- -e, –endframe arg: End frame
- -r, –radius arg: Particle radius (default: 0.025)
- –supportRadiusFactor arg: The support radius is defined as factor*particleRadius (default: 6.0)
- –maxNeighbors arg: The maximum number of neighbors that are used for the interpolation. (default: 60)
- –splitting: Read a scene which used the object splitting export option.
- –overwrite: Overwrite existing files.
- -h, –help: Print help

19.1.2 Example:

```
MeshSkinning --splitting --overwrite --scene ..\data\Scenes\Beam.json
```

CHAPTER

TWENTY

PARTIO2VTK

A tool to convert partion files in vtk files. In this way the particle data which is exported from SPlisHSPlasH can be converted to the vtk format. This is useful to import the data in ParaView for visualization.

CHAPTER

TWENTYONE

PARTIOVIEWER

The simulators can export the particle simulation data using the partio file format. The PartioViewer can read such a file and render the particle data using OpenGL. This tool is able to handle multiphase data and rigid body data. It can create image sequences and movies (using ffmpeg).

To visualize a sequence of partio files or a single file, call (the index in the file name is used for the sequence):

```
PartioViewer fluid_data_1.bgeo
```

This tool is also able to read a complete output directory:

```
PartioViewer output/DamBreakModel
```

In this case the tool searches for the partio files of multiple phases in the subdirectory "partio" and for rigid body data in "rigid_bodies".

Note: To generate videos you must tell PartioViewer where it can find the ffmpeg executable.

21.1 Command line options:

- -h, –help: Print help
- –renderSequence: Render a sequence from startFrame to endFrame as jpeg.
- –renderVideo: Render a sequence from startFrame to endFrame as video.This function requires ffmpeg which must be in the PATH or the ffmpegPath parameter must be set.
- –noOverwrite: Do not overwrite existing frames when using –renderSequence option. Existing frames are not loaded at all which accelerates the image sequence generation.
- -o, –outdir arg: Output directory for images
- –rbData arg: Rigid body data to visualize (bin file)
- –ffmpegPath arg: Path of the ffmpeg excutable.
- –width arg: Width of the image in pixels. (default: 1024)
- –height arg: Height of the image in pixels. (default: 768)
- –fps arg: Frame rate of video. (default: 25)
- -r, –radius arg: Particle radius (default: 0.025)
- -s, –startFrame arg: Start frame (only used if value is >= 0) (default: -1)
- -e, –endFrame arg: End frame (only used if value is >= 0) (default: -1)

- –colorField arg: Name of field that is used for the color. (default: velocity)
- –colorMapType arg: Color map (0=None, 1=Jet, 2=Plasma) (default: 1)
- –renderMinValue arg: Min value of field. (default: 0.0)
- –renderMaxValue arg: Max value of field. (default: 10.0)
- –camPos arg: Camera position (e.g. –camPos “0 1 5”) (default: 0 3 10)
- –camLookat arg: Camera lookat (e.g. –camLookat “0 0 0”) (default: 0 0 0)

21.2 Hotkeys

- Space: pause/contiunue simulation
- r: reset simulation
- w: wireframe rendering of meshes
- i: print all field information of the selected particles to the console
- s: save current frame as jpg image
- v: generate video
- j: generate image sequence
- +: step to next frame
- -: step to previous frame
- ESC: exit

CHAPTER

TWENTYTWO

SURFACESAMPLING

A popular boundary handling method which is also implemented in SPlisHSPlasH uses a particle sampling of the surfaces of all boundary objects. This command line tool can generate such a surface sampling. Note that the same surface sampling is also integrated in the simulators and the samplings are generated automatically if they are required. However, if you want to generate a surface sampling manually, then you can use this tool.

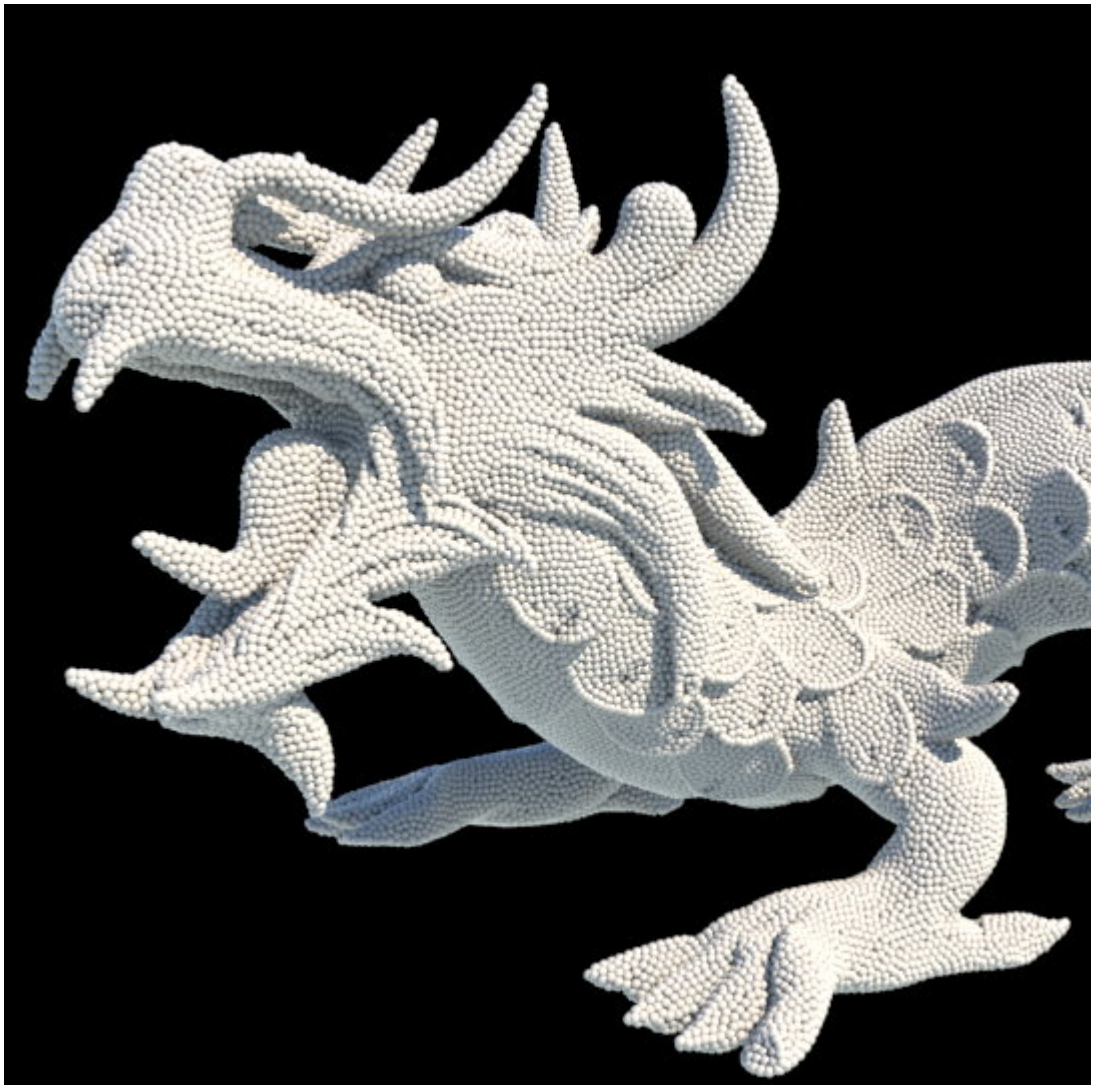
CHAPTER

TWENTYTHREE

VOLUMESAMPLING

The simulator can load particle data from partio files. This particle data then defines the initial configuration of the particles in the simulation. The VolumeSampling tool allows you to sample a volumetric object with particle data. This means you can load an OBJ file with a closed surface geometry and sample the interior with particles using different methods. Especially when simulating elastic solids a good sampling is beneficial as shown by Kugelstadt et al. [2021].

Below are two examples which were generated using the volume sampling tool:



| | ——————————————————— | ——————————————————— |

The tool implements the methods of:

- M. Jiang, Y. Zhou, R. Wang, R. Southern, J. J. Zhang. Blue noise sampling using an SPH-based method. ACM Transactions on Graphics, 2015
- Tassilo Kugelstadt, Jan Bender, José Antonio Fernández-Fernández, Stefan Rhys Jeske, Fabian Löschner, and Andreas Longva. Fast Corotated Elastic SPH Solids with Implicit Zero-Energy Mode Control. Proceedings of the ACM on Computer Graphics and Interactive Techniques, 2021

23.1 Command line options:

- -h, –help: Print help
- -i, –input arg: Input file (obj)
- -o, –output arg: Output file (bgeo or vtk)
- -r, –radius arg: Particle radius (default: 0.025)
- -s, –scale arg: Scaling of input geometry (e.g. –scale “2 1 2”) (default: 1 1 1)
- -m, –mode arg: Mode (regular=0, almost dense=1, dense=2, Jiang et al. 2015=3, Kugelstadt et al. 2021=4) (default: 4)
- –region arg: Region to fill with particles (e.g. –region “0 0 0 1 1 1”)
- –steps arg: SPH time steps (default: 100)
- –cflFactor arg: CFL factor (default: 0.25)
- –viscosity arg: Viscosity coefficient (XSPH) (default: 0.25)
- –cohesion arg: Cohesion coefficient
- –adhesion arg: Adhesion coefficient
- –stiffness arg: Stiffness coefficient (only mode 3) (default: 10000.0)
- –dt arg: Time step size (only mode 3) (default: 0.0005)
- –res arg: Resolution of the Signed Distance Field (e.g. –res “30 30 30”)
- –invert: Invert the SDF to sample the outside of the object in the bounding box/region
- –no-cache: Disable caching of SDF.

23.2 Example:

```
VolumeSampling.exe --mode 4 -i ..\data\models\bunny.obj -o bunny.vtk
```

CHAPTER

TWENTYFOUR

LIBRARY API

24.1 Full API

24.1.1 Namespaces

Namespace @63

Namespace chrono

Namespace Eigen

Contents

Namespaces

Namespace Eigen::internal

Contents

Classes

- *Template Struct generic_product_impl< MatrixReplacement, Rhs, SparseShape, DenseShape, GemvProduct >*
- *Template Struct traits< SPH::MatrixReplacement >*

Namespace GenParam

Namespace SPH

Contents

Classes

- *Struct Elasticity_Kugelstadt2021::ElasticObject*
- *Struct Elasticity_Kugelstadt2021::Factorization*
- *Struct FieldDescription*
- *Struct PoissonDiskSampling::CellPosHasher*
- *Struct PoissonDiskSampling::HashEntry*
- *Struct PoissonDiskSampling::InitialPointInfo*
- *Struct Simulation::FluidInfo*
- *Struct Simulation::NonPressureForceMethod*
- *Class AdhesionKernel*
- *Class AnimationField*
- *Class AnimationFieldSystem*
- *Class BinaryFileReader*
- *Class BinaryFileWriter*
- *Class BlockJacobiPreconditioner3D*
- *Class BoundaryModel*
- *Class BoundaryModel_Akinci2012*
- *Class BoundaryModel_Bender2019*
- *Class BoundaryModel_Koschier2017*
- *Class CholeskyAVXSolver*
- *Class CholeskySparseMatrixfAVX*
- *Class CohesionKernel*

Enums

- *Enum BoundaryHandlingMethods*
- *Enum FieldType*
- *Enum ParticleState*
- *Enum SimulationMethods*
- *Enum SurfaceSamplingMode*

Variables

- *Variable SPH::gaussian_abscissae_1*
- *Variable SPH::gaussian_n_1*
- *Variable SPH::gaussian_weights_1*

Namespace std

Namespace Utilities

Contents

Classes

- *Struct AverageCount*
- *Struct AverageTime*
- *Struct MeshFaceIndices*
- *Struct SceneLoader::AnimationFieldData*
- *Struct SceneLoader::BoundaryData*
- *Struct SceneLoader::Box*
- *Struct SceneLoader::EmitterData*
- *Struct SceneLoader::FluidBlock*
- *Struct SceneLoader::FluidData*
- *Struct SceneLoader::MaterialData*
- *Struct SceneLoader::Scene*
- *Struct TimingHelper*
- *Class ConsoleSink*

- *Class Counting*
- *Class FileSink*
- *Class FileSystem*
- *Class IDFactory*
- *Class Logger*
- *Class LogSink*
- *Class LogStream*
- *Class OBJLoader*
- *Class PartioReaderWriter*
- *Class SceneLoader*
- *Class SDFFunctions*
- *Class StringTools*
- *Class SystemInfo*
- *Class Timing*
- *Class VolumeSampling*
- *Class WindingNumbers*

Enums

- *Enum LogLevel*

Variables

- *Variable Utilities::logger*

24.1.2 Classes and Structs

Template Struct AlignmentAllocator::rebind

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Nested Relationships

This struct is a nested type of *Template Class AlignmentAllocator*.

Struct Documentation

template<typename **T2**>
struct AlignmentAllocator::**rebind**

Public Types

typedef AlignmentAllocator<*T2*, N> **other**

Template Struct generic_product_impl< MatrixReplacement, Rhs, SparseShape, DenseShape, GemvProduct >

- Defined in file_SPlisHSPlasH_Utilities_MatrixFreeSolver.h

Inheritance Relationships

Base Type

- public generic_product_impl_base< MatrixReplacement, Rhs, generic_product_impl< MatrixReplacement, Rhs > >

Struct Documentation

template<typename **Rhs**>
struct Eigen::internal::**generic_product_impl**<MatrixReplacement, *Rhs*, SparseShape, DenseShape, GemvProduct>
Implementation of the matrix-free matrix vector product

Public Types

typedef Product<MatrixReplacement, *Rhs*>::Scalar **Scalar**

Public Static Functions

template<typename **Dest**>
static inline void **scaleAndAddTo**(*Dest* &*dst*, **const** MatrixReplacement &*lhs*, **const** *Rhs* &*rhs*, **const** *Scalar* &*alpha*)

Template Struct traits< SPH::MatrixReplacement >

- Defined in file_SPlisHSPlasH_Utilities_MatrixFreeSolver.h

Inheritance Relationships

Base Type

- `public Eigen::internal::traits< SystemMatrixType >`

Struct Documentation

template<>
struct traits<SPH::*MatrixReplacement*> : **public** Eigen::internal::traits<*SystemMatrixType*>

Struct Elasticity_Kugelstadt2021::ElasticObject

- Defined in file_SPlisHSPlasH_Elasticity_Elasticity_Kugelstadt2021.h

Nested Relationships

This struct is a nested type of *Class Elasticity_Kugelstadt2021*.

Struct Documentation

struct SPH::*Elasticity_Kugelstadt2021*::**ElasticObject**

Public Functions

inline ElasticObject()

inline ~ElasticObject()

Public Members

std::string **m_md5**

std::vector<unsigned int> **m_particleIndices**

unsigned int **m_nFixed**

std::shared_ptr<*Factorization*> **m_factorization**

std::vector<*Scalarf8*, *AlignmentAllocator*<*Scalarf8*, 32>> **m_f_avx**

std::vector<*Scalarf8*, *AlignmentAllocator*<*Scalarf8*, 32>> **m_sol_avx**

std::vector<*Scalarf8*, *AlignmentAllocator*<*Scalarf8*, 32>> **m_v_avx**

std::vector<*Scalarf8*, *AlignmentAllocator*<*Scalarf8*, 32>> **m_RHS**

std::vector<*Quaternion8f*, *AlignmentAllocator*<*Quaternion8f*, 32>> **m_quats**

VectorXr **m_rhs**

VectorXr **m_sol**

Struct Elasticity_Kugelstadt2021::Factorization

- Defined in file_SPlisHSPlasH_Elasticity_Elasticity_Kugelstadt2021.h

Nested Relationships

This struct is a nested type of *Class Elasticity_Kugelstadt2021*.

Struct Documentation

struct SPH::*Elasticity_Kugelstadt2021*::**Factorization**

Public Functions

inline **Factorization**()

inline **~Factorization**()

Public Members

Real **m_dt**

Real **m_mu**

Eigen::SparseMatrix<*Real*, Eigen::RowMajor> **m_DT_K**

Eigen::SparseMatrix<*Real*, Eigen::RowMajor> **m_D**

Eigen::SparseMatrix<*Real*, Eigen::ColMajor> **m_dampingMatrix**

Eigen::SparseMatrix<*Real*, Eigen::ColMajor> **m_matHTH**

CholeskyAVXSolver ***m_cholesky**

Struct FieldDescription

- Defined in file_SPlisHSPlasH_FluidModel.h

Struct Documentation

struct SPH::**FieldDescription**

Public Functions

inline **FieldDescription**(**const** std::string &*n*, **const** *FieldType* &*t*, **const** std::function<void*) **const** unsigned int > &*fct*, **const** bool *s* = false

Public Members

std::string **name**

FieldType **type**

std::function<void* (**const** unsigned int)> **getFct**

bool **storeData**

Struct PoissonDiskSampling::CellPosHasher

- Defined in file_SPlisHSPlasH_Utilities_PoissonDiskSampling.h

Nested Relationships

This struct is a nested type of *Class PoissonDiskSampling*.

Struct Documentation

struct SPH::*PoissonDiskSampling*::**CellPosHasher**

Public Functions

inline std::size_t **operator()**(**const** CellPos &*k*) **const**

Struct PoissonDiskSampling::HashEntry

- Defined in file_SPlisHSPlasH_Utilities_PoissonDiskSampling.h

Nested Relationships

This struct is a nested type of *Class PoissonDiskSampling*.

Struct Documentation

struct SPH::*PoissonDiskSampling*::**HashEntry**

Struct to store the hash entry (spatial hashing)

Public Functions

inline **HashEntry**()

Public Members

std::vector<unsigned int> **samples**

unsigned int **startIndex**

Struct PoissonDiskSampling::InitialPointInfo

- Defined in file_SPlisHSPlasH_Utilities_PoissonDiskSampling.h

Nested Relationships

This struct is a nested type of *Class PoissonDiskSampling*.

Struct Documentation

struct SPH::*PoissonDiskSampling*::**InitialPointInfo**
Struct to store the information of the initial points.

Public Members

CellPos **cP**

Vector3r **pos**

unsigned int **ID**

Struct Simulation::FluidInfo

- Defined in file_SPlisHSPlasH_Simulation.h

Nested Relationships

This struct is a nested type of *Class Simulation*.

Struct Documentation

struct SPH::*Simulation*::**FluidInfo**
Fluid object information

Public Functions

inline bool **hasSameParticleSampling**(**const** *FluidInfo* &*other*)

Public Members

int **type**

int **numParticles**

AlignedBox3r **box**

std::string **id**

std::string **samplesFile**

std::string **visMeshFile**

Vector3r **translation**

Matrix3r **rotation**

Vector3r **scale**

Vector3r **initialVelocity**

Vector3r **initialAngularVelocity**

unsigned char **mode**

bool **invert**

std::array<unsigned int, 3> **resolutionSDF**

unsigned int **emitter_width**

unsigned int **emitter_height**

Real **emitter_velocity**

Real **emitter_emitStartTime**

Real **emitter_emitEndTime**

unsigned int **emitter_type**

Struct Simulation::NonPressureForceMethod

- Defined in file_SPlisHSPlasH_Simulation.h

Nested Relationships

This struct is a nested type of *Class Simulation*.

Struct Documentation

struct SPH::*Simulation*::**NonPressureForceMethod**

Public Members

std::string **m_name**

std::function<*NonPressureForceBase** (*FluidModel**)> **m_creator**

int **m_id**

Struct AverageCount

- Defined in file_Utilities_Counting.h

Struct Documentation

struct Utilities::**AverageCount**

Public Members

Real **sum**

unsigned int **numberOfCalls**

Struct AverageTime

- Defined in file_Utilities_Timing.h

Struct Documentation

struct Utilities::**AverageTime**

Struct to store the total time and the number of steps in order to compute the average time.

Public Members

double **totalTime**

unsigned int **counter**

std::string **name**

Struct MeshFaceIndices

- Defined in file_Utilities_OBJLoader.h

Struct Documentation

struct Utilities::**MeshFaceIndices**
Struct to store the position and normal indices.

Public Members

int **posIndices**[3]

int **texIndices**[3]

int **normalIndices**[3]

Struct SceneLoader::AnimationFieldData

- Defined in file_SPlisHSPlasH_Utilities_SceneLoader.h

Nested Relationships

This struct is a nested type of *Class SceneLoader*.

Struct Documentation

struct Utilities::*SceneLoader*::**AnimationFieldData**
Struct to store an animation field object.

Public Members

std::string **particleFieldName**

std::string **expression**[3]

unsigned int **shapeType**

Vector3r **x**

Matrix3r **rotation**

Vector3r **scale**

Real **startTime**

Real **endTime**

Struct SceneLoader::BoundaryData

- Defined in file_SPlisHSPlasH_Utilities_SceneLoader.h

Nested Relationships

This struct is a nested type of *Class SceneLoader*.

Struct Documentation

struct Utilities::*SceneLoader*::**BoundaryData**

Struct to store a boundary object.

Public Members

std::string **samplesFile**

std::string **meshFile**

Vector3r **translation**

Matrix3r **rotation**

Vector3r **scale**

Real **density**

bool **dynamic**

bool **isWall**

Eigen::Matrix<float, 4, 1, Eigen::DontAlign> **color**

void ***rigidBody**

std::string **mapFile**

bool **mapInvert**

Real **mapThickness**

Eigen::Matrix<unsigned int, 3, 1, Eigen::DontAlign> **mapResolution**

unsigned int **samplingMode**

bool **isAnimated**

Struct SceneLoader::Box

- Defined in file_SPlisHSPlasH_Utilities_SceneLoader.h

Nested Relationships

This struct is a nested type of *Class SceneLoader*.

Struct Documentation

struct Utilities::*SceneLoader*::**Box**
Struct for an AABB.

Public Members

Vector3r **m_minX**

Vector3r **m_maxX**

Struct SceneLoader::EmitterData

- Defined in file_SPlisHSPlasH_Utilities_SceneLoader.h

Nested Relationships

This struct is a nested type of *Class SceneLoader*.

Struct Documentation

struct Utilities::*SceneLoader*::**EmitterData**
Struct to store an emitter object.

Public Members

std::string **id**

unsigned int **width**

unsigned int **height**

Vector3r **x**

Real **velocity**

Matrix3r **rotation**

Real **emitStartTime**

Real **emitEndTime**

unsigned int **type**

Struct SceneLoader::FluidBlock

- Defined in file_SPlisHSPlasH_Utilities_SceneLoader.h

Nested Relationships

This struct is a nested type of *Class SceneLoader*.

Struct Documentation

struct Utilities::*SceneLoader*::**FluidBlock**
Struct to store a fluid block.

Public Members

std::string **id**

std::string **visMeshFile**

Box **box**

unsigned char **mode**

Vector3r **initialVelocity**

Vector3r **initialAngularVelocity**

Struct SceneLoader::FluidData

- Defined in file_SPlisHSPlasH_Utilities_SceneLoader.h

Nested Relationships

This struct is a nested type of *Class SceneLoader*.

Struct Documentation

struct Utilities::*SceneLoader*::**FluidData**
Struct to store a fluid object.

Public Members

std::string **id**

std::string **samplesFile**

std::string **visMeshFile**

Vector3r **translation**

Matrix3r **rotation**

Vector3r **scale**

Vector3r **initialVelocity**

Vector3r **initialAngularVelocity**

unsigned char **mode**

bool **invert**

std::array<unsigned int, 3> **resolutionSDF**

Struct SceneLoader::MaterialData

- Defined in file_SPlisHSPlasH_Utilities_SceneLoader.h

Nested Relationships

This struct is a nested type of *Class SceneLoader*.

Struct Documentation

struct Utilities::*SceneLoader*::**MaterialData**

Struct to store particle coloring information.

Public Members

std::string **id**

std::string **colorField**

unsigned int **colorMapType**

Real **minVal**

Real **maxVal**

unsigned int **maxEmitterParticles**

bool **emitterReuseParticles**

Vector3r **emitterBoxMin**

Vector3r **emitterBoxMax**

Struct SceneLoader::Scene

- Defined in file_SPlisHSPlasH_Utilities_SceneLoader.h

Nested Relationships

This struct is a nested type of *Class SceneLoader*.

Struct Documentation

struct Utilities::*SceneLoader*::**Scene**
Struct to store scene information.

Public Members

std::vector<*BoundaryData**> **boundaryModels**

std::vector<*FluidData**> **fluidModels**

std::vector<*FluidBlock**> **fluidBlocks**

std::vector<*EmitterData**> **emitters**

std::vector<*AnimationFieldData**> **animatedFields**

std::vector<*MaterialData**> **materials**

Real **particleRadius**

bool **sim2D**

Real **timeStepSize**

Vector3r **camPosition**

Vector3r **camLookat**

Struct TimingHelper

- Defined in file_Utilities_Timing.h

Struct Documentation

struct Utilities::**TimingHelper**
Struct to store a time measurement.

Public Members

std::chrono::time_point<std::chrono::high_resolution_clock> **start**

std::string **name**

Template Class AlignmentAllocator

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Nested Relationships

Nested Types

- *Template Struct AlignmentAllocator::rebind*

Class Documentation

template<typename **T**, std::size_t **N** = 32>
class AlignmentAllocator

Public Types

typedef *T* **value_type**

typedef std::size_t **size_type**

typedef std::ptrdiff_t **difference_type**

typedef *T* ***pointer**

typedef const *T* ***const_pointer**

typedef *T* **&reference**

typedef const *T* **&const_reference**

Public Functions

inline AlignmentAllocator()

template<typename **T2**>
inline AlignmentAllocator(**const** *AlignmentAllocator*<*T2*, *N*>&)

inline ~AlignmentAllocator()

inline *pointer* **adress**(*reference r*)

inline *const_pointer* **adress**(*const_reference r*) **const**

inline *pointer* **allocate**(*size_type n*)

inline void **deallocate**(*pointer p*, *size_type*)

inline void **construct**(*pointer p*, **const** *value_type &wert*)

inline void **destroy**(*pointer p*)

inline *size_type* **max_size**() **const**

inline bool **operator!=**(**const** *AlignmentAllocator*<*T*, *N*> *&other*) **const**

inline bool **operator==**(**const** *AlignmentAllocator*<*T*, *N*> *&other*) **const**

template<typename **T2**>

struct rebind

Public Types

typedef *AlignmentAllocator*<*T2*, *N*> **other**

Class Matrix3f8

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Class Documentation

class Matrix3f8

Public Functions

inline **Matrix3f8**()

inline **Matrix3f8**(**const** *Matrix3f* &*x*)

inline **Matrix3f8**(**const** *Vector3f8* &*m1*, **const** *Vector3f8* &*m2*, **const** *Vector3f8* &*m3*)

inline void **setZero**()

inline *Scalarf8* &**operator()** (int *i*, int *j*)

inline void **setCol** (int *i*, **const** *Vector3f8* &*v*)

inline void **setCol** (int *i*, **const** *Scalarf8* &*x*, **const** *Scalarf8* &*y*, **const** *Scalarf8* &*z*)

inline *Matrix3f8* **operator*** (**const** *Scalarf8* &*b*) **const**

inline *Vector3f8* **operator*** (**const** *Vector3f8* &*b*) **const**

inline *Matrix3f8* **operator*** (**const** *Matrix3f8* &*b*) **const**

inline *Matrix3f8* &**operator+=** (**const** *Matrix3f8* &*a*)

inline *Matrix3f8* **transpose**() **const**

inline *Scalarf8* **determinant**() **const**

inline void **store** (std::vector<*Matrix3r*> &*Mf*) **const**

inline *Matrix3r* **reduce**() **const**

Public Members

Scalarf8 **m**[3][3]

Class Quaternion8f

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Class Documentation

class Quaternion8f

Public Functions

inline Quaternion8f()

inline Quaternion8f(*Scalarf8* *x*, *Scalarf8* *y*, *Scalarf8* *z*, *Scalarf8* *w*)

inline Quaternion8f(*Vector3f8* &*v*)

inline *Scalarf8* &**operator[]**(int *i*)

inline *Scalarf8* **operator[]**(int *i*) **const**

inline *Scalarf8* &**x**()

inline *Scalarf8* &**y**()

inline *Scalarf8* &**z**()

inline *Scalarf8* &**w**()

inline *Scalarf8* **x**() **const**

inline *Scalarf8* **y**() **const**

inline *Scalarf8* **z**() **const**

inline *Scalarf8* **w**() **const**

inline const *Quaternion8f* **operator***(**const** *Quaternion8f* &*a*) **const**

inline void **toRotationMatrix**(*Matrix3f8* &*R*)

inline void **toRotationMatrix**(*Vector3f8* &*R1*, *Vector3f8* &*R2*, *Vector3f8* &*R3*)

inline void **store**(std::vector<*Quaternionr*> &*qf*) **const**

inline void **set**(**const** *Quaternionr* **qf*)

Public Members

Scalarf8 **q**[4]

Class Scalarf8

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Class Documentation

class Scalarf8

Public Functions

inline Scalarf8()

inline Scalarf8(float *f*)

inline Scalarf8(*Real f0*, *Real f1*, *Real f2*, *Real f3*, *Real f4*, *Real f5*, *Real f6*, *Real f7*)

inline Scalarf8(float **const** **p*)

inline Scalarf8(__m256 **const** &*x*)

inline void **setZero**()

inline *Scalarf8* &**operator=**(__m256 **const** &*x*)

inline *Scalarf8* **sqrt**() **const**

inline *Scalarf8* **rsqrt**() **const**

inline *Scalarf8* &**load**(float **const** **p*)

inline void **store**(float **p*) **const**

inline float **reduce**() **const**

Public Members

__m256 **v**

Class AdhesionKernel

- Defined in file_SPlisHSPlasH_SPHKernels.h

Class Documentation

class SPH::**AdhesionKernel**

Adhesion kernel used for the surface tension method of Akinci el al. [ATT13].

References:

- [AAT13] Nadir Akinci, Gizem Akinci, and Matthias Teschner. Versatile surface tension and adhesion for sph fluids. ACM Trans. Graph., 32(6):182:1-182:8, November 2013. URL: http://doi.acm.org/10.1145/2508363.2508395

Public Static Functions

static inline *Real* **getRadius** ( )

static inline void **setRadius** (*Real val*)

static inline *Real* **W** (**const** *Real r*)
W(r,h) = (0.007/h^3.25)(-4r^2/h + 6r -2h)^0.25 if h/2 < r <= h

static inline *Real* **W** (**const** *Vector3r* &*r*)

static inline *Real* **W_zero** ( )

Protected Static Attributes

static *Real* **m_radius**

static *Real* **m_k**

static *Real* **m_W_zero**

Class AnimationField

- Defined in file_SPlisHSPlasH_AnimationField.h

Class Documentation

class SPH::**AnimationField**

Public Functions

AnimationField (**const** std::string &*particleFieldName*, **const** *Vector3r* &*pos*, **const** *Matrix3r* &*rotation*, **const** *Vector3r* &*scale*, **const** std::string *expression*[3], **const** unsigned int *type* = 0)

virtual ~AnimationField ( )

inline void **setStartTime** (*Real val*)

inline void **setEndTime** (*Real val*)

void **step** ( )

virtual void **reset** ( )

Protected Functions

inline FORCE_INLINE bool inBox (const Vector3r &x, const Vector3r &xBox, const Matrix3

inline FORCE_INLINE bool inCylinder (const Vector3r &x, const Vector3r &xCyl, const Ma

inline FORCE_INLINE bool inSphere (const Vector3r &x, const Vector3r &pos, const Matri

inline FORCE_INLINE bool inShape (const int type, const Vector3r &x, const Vector3r &p

Protected Attributes

std::string **m_particleFieldName**

Vector3r **m_x**

Matrix3r **m_rotation**

Vector3r **m_scale**

std::string **m_expression**[3]

unsigned int **m_type**

Real **m_startTime**

Real **m_endTime**

Class AnimationFieldSystem

- Defined in file_SPlisHSPlasH_AnimationFieldSystem.h

Class Documentation

class SPH::**AnimationFieldSystem**

Public Functions

AnimationFieldSystem()

virtual ~AnimationFieldSystem()

void **addAnimationField**(**const** std::string *&particleFieldName*, **const** *Vector3r* *&pos*, **const** *Matrix3r* *&rotation*, **const** *Vector3r* *&scale*, **const** std::string *expression*[3], **const** unsigned int *type*)

inline unsigned int **numAnimationFields**() **const**

inline std::vector<*AnimationField**> &**getAnimationFields**()

void **step**()

void **reset**()

Protected Attributes

std::vector<*AnimationField**> **m_fields**

Class BinaryFileReader

- Defined in file_Utilities_BinaryFileReaderWriter.h

Class Documentation

class SPH::**BinaryFileReader**

Public Functions

inline bool **openFile**(**const** std::string &*fileName*)

inline void **closeFile**()

inline void **readBuffer**(char ***buffer*, size_t *size*)

template<typename **T**>
inline void **read**(*T* &*v*)

inline void **read**(std::string &*str*)

template<typename **T**>
inline void **readMatrix**(*T* &*m*)

template<typename **T**, int **Rows**, int **Cols**>
inline void **readMatrixX**(Eigen::Matrix<*T*, *Rows*, *Cols*> &*m*)

template<typename **T**, int **Options**, typename **StorageIndex**>
inline void **readSparseMatrix**(Eigen::SparseMatrix<*T*, *Options*, *StorageIndex*> &*m*)

template<typename **T**>
inline void **readVector**(std::vector<*T*> &*m*)

Public Members

std::ifstream **m_file**

Class BinaryFileWriter

- Defined in file_Utilities_BinaryFileReaderWriter.h

Class Documentation

class SPH::**BinaryFileWriter**

Public Functions

inline bool **openFile**(**const** std::string &*fileName*)

inline void **closeFile**()

inline void **writeBuffer**(**const** char **buffer*, size_t *size*)

template<typename **T**>
inline void **write**(**const** *T* &*v*)

inline void **write**(**const** std::string &*str*)

template<typename **T**>
inline void **writeMatrix**(**const** *T* &*m*)

template<typename **T**, int **Rows**, int **Cols**>
inline void **writeMatrixX**(**const** Eigen::Matrix<*T*, *Rows*, *Cols*> &*m*)

template<typename **T**, int **Options**, typename **StorageIndex**>
inline void **writeSparseMatrix**(Eigen::SparseMatrix<*T*, *Options*, *StorageIndex*> &*m*)

template<typename **T**>
inline void **writeVector**(**const** std::vector<*T*> &*m*)

Public Members

std::ofstream **m_file**

Class BlockJacobiPreconditioner3D

- Defined in file_SPlisHSPlasH_Utilities_MatrixFreeSolver.h

Class Documentation

class SPH::**BlockJacobiPreconditioner3D**
Matrix-free 3x3 block Jacobi preconditioner

Public Types

enum **[anonymous]**
Values:

enumerator ColsAtCompileTime

enumerator MaxColsAtCompileTime

typedef *SystemMatrixType*::StorageIndex **StorageIndex**

typedef void (***DiagonalMatrixElementFct**)(**const** unsigned int, *Matrix3r*&, void*)

Public Functions

inline BlockJacobiPreconditioner3D()

inline void **init**(**const** unsigned int *dim*, *DiagonalMatrixElementFct* *fct*, void **userData*)

inline Eigen::Index **rows**() **const**

inline Eigen::Index **cols**() **const**

inline Eigen::ComputationInfo **info**()

template<typename **MatType**>
inline *BlockJacobiPreconditioner3D* &**analyzePattern**(**const** *MatType*&)

template<typename **MatType**>
inline *BlockJacobiPreconditioner3D* &**factorize**(**const** *MatType* &*mat*)

template<typename **MatType**>
inline *BlockJacobiPreconditioner3D* &**compute**(**const** *MatType* &*mat*)

template<typename **Rhs**, typename **Dest**>
inline void **_solve_impl**(**const** *Rhs* &*b*, *Dest* &*x*) **const**

template<typename **Rhs**>
inline const Eigen::Solve<*BlockJacobiPreconditioner3D*, *Rhs*> **solve**(**const** Eigen::MatrixBase<*Rhs*> &*b*) **const**

Protected Attributes

unsigned int **m_dim**

DiagonalMatrixElementFct **m_diagonalElementFct**
diagonal matrix element callback

void ***m_userData**

std::vector<*Matrix3r*> **m_invDiag**

Class BoundaryModel

- Defined in file_SPlisHSPlasH_BoundaryModel.h

Inheritance Relationships

Derived Types

- `public SPH::BoundaryModel_Akinci2012` (*Class BoundaryModel_Akinci2012*)
- `public SPH::BoundaryModel_Bender2019` (*Class BoundaryModel_Bender2019*)
- `public SPH::BoundaryModel_Koschier2017` (*Class BoundaryModel_Koschier2017*)

Class Documentation

class SPH::**BoundaryModel**

The boundary model stores the information required for boundary handling.

Subclassed by *SPH::BoundaryModel_Akinci2012*, *SPH::BoundaryModel_Bender2019*, *SPH::BoundaryModel_Koschier2017*

Public Functions

BoundaryModel()

virtual ~BoundaryModel()

virtual void **reset**()

inline virtual void **performNeighborhoodSearchSort**()

inline virtual void **saveState**(*BinaryFileWriter* &*binWriter*)

inline virtual void **loadState**(*BinaryFileReader* &*binReader*)

inline *RigidBodyObject* ***getRigidBodyObject**()

inline FORCE_INLINE void addForce (const Vector3r &pos, const Vector3r &f)

inline FORCE_INLINE void getPointVelocity (const Vector3r &x, Vector3r &res)

void **getForceAndTorque**(*Vector3r* &*force*, *Vector3r* &*torque*)

void **clearForceAndTorque**()

Protected Attributes

RigidBodyObject ***m_rigidBody**

std::vector<*Vector3r*> **m_forcePerThread**

std::vector<*Vector3r*> **m_torquePerThread**

Class BoundaryModel_Akinci2012

- Defined in file_SPlisHSPlasH_BoundaryModel_Akinci2012.h

Inheritance Relationships

Base Type

- `public SPH::BoundaryModel` (*Class BoundaryModel*)

Class Documentation

class SPH::**BoundaryModel_Akinci2012** : **public** SPH::*BoundaryModel*

The boundary model stores the information required for boundary handling using the approach of Akinci et al. 2012 [AIA+12].

References:

- [AIA+12] Nadir Akinci, Markus Ihmsen, Gizem Akinci, Barbara Solenthaler, and Matthias Teschner. Versatile rigid-fluid coupling for incompressible SPH. ACM Trans. Graph., 31(4):62:1-62:8, July 2012. URL: http://doi.acm.org/10.1145/2185520.2185558

Public Functions

BoundaryModel_Akinci2012()

virtual **~BoundaryModel_Akinci2012**()

inline unsigned int **numberOfParticles**() **const**

inline unsigned int **getPointSetIndex**() **const**

inline bool **isSorted**() **const**

void **computeBoundaryVolume**()

void **resize**(**const** unsigned int *numBoundaryParticles*)

virtual void **reset**()

virtual void **performNeighborhoodSearchSort**()

virtual void **saveState**(*BinaryFileWriter* &*binWriter*)

virtual void **loadState**(*BinaryFileReader* &*binReader*)

void **initModel**(*RigidBodyObject* **rbo*, **const** unsigned int *numBoundaryParticles*, *Vector3r* **boundaryParticles*)

inline FORCE_INLINE Vector3r & getPosition0 (const unsigned int i)

inline FORCE_INLINE const Vector3r & getPosition0 (const unsigned int i) const

inline FORCE_INLINE void setPosition0 (const unsigned int i, const Vector3r &pos)

inline FORCE_INLINE Vector3r & getPosition (const unsigned int i)

inline FORCE_INLINE const Vector3r & getPosition (const unsigned int i) const

inline FORCE_INLINE void setPosition (const unsigned int i, const Vector3r &pos)

inline FORCE_INLINE Vector3r & getVelocity (const unsigned int i)

inline FORCE_INLINE const Vector3r & getVelocity (const unsigned int i) const

inline FORCE_INLINE void setVelocity (const unsigned int i, const Vector3r &vel)

inline FORCE_INLINE const Real & getVolume (const unsigned int i) const

inline FORCE_INLINE Real & getVolume (const unsigned int i)

inline FORCE_INLINE void setVolume (const unsigned int i, const Real &val)

Protected Attributes

bool **m_sorted**

unsigned int **m_pointSetIndex**

std::vector<*Vector3r*> **m_x0**

std::vector<*Vector3r*> **m_x**

std::vector<*Vector3r*> **m_v**

std::vector<*Real*> **m_V**

Class BoundaryModel_Bender2019

- Defined in file_SPlisHSPlasH_BoundaryModel_Bender2019.h

Inheritance Relationships

Base Type

- `public SPH::BoundaryModel` (*Class BoundaryModel*)

Class Documentation

class `SPH::`**BoundaryModel_Bender2019** : **public** SPH::*BoundaryModel*

The boundary model stores the information required for boundary handling using the approach of Bender et al. 2019 [BKWK19].

References:

- [BKWK19] Jan Bender, Tassilo Kugelstadt, Marcel Weiler, and Dan Koschier. Volume maps: an implicit boundary representation for SPH. In Proceedings of ACM SIGGRAPH Conference on Motion, Interaction and Games, MIG '19. ACM, 2019. URL: https://dl.acm.org/doi/10.1145/3359566.3360077

Public Functions

BoundaryModel_Bender2019()

virtual **~BoundaryModel_Bender2019**()

void **initModel**(*RigidBodyObject* **rbo*)

virtual void **reset**()

inline Discregrid::DiscreteGrid ***getMap**()

inline void **setMap**(Discregrid::DiscreteGrid **map*)

inline *Real* **getMaxDist**() **const**

inline void **setMaxDist**(*Real val*)

inline *Real* **getMaxVel**() **const**

inline void **setMaxVel**(*Real val*)

inline FORCE_INLINE const Real & getBoundaryVolume (const unsigned int fluidIndex, con

inline FORCE_INLINE Real & getBoundaryVolume (const unsigned int fluidIndex, const uns

inline FORCE_INLINE void setBoundaryVolume (const unsigned int fluidIndex, const unsig

inline FORCE_INLINE Vector3r & getBoundaryXj (const unsigned int fluidIndex, const uns

inline FORCE_INLINE const Vector3r & getBoundaryXj (const unsigned int fluidIndex, con

inline FORCE_INLINE void setBoundaryXj (const unsigned int fluidIndex, const unsigned

Protected Attributes

Discregrid::DiscreteGrid ***m_map**

std::vector<std::vector<*Real*>> **m_boundaryVolume**

std::vector<std::vector<*Vector3r*>> **m_boundaryXj**

Real **m_maxDist**

Real **m_maxVel**

Class BoundaryModel_Koschier2017

- Defined in file_SPlisHSPlasH_BoundaryModel_Koschier2017.h

Inheritance Relationships

Base Type

- `public SPH::BoundaryModel` (*Class BoundaryModel*)

Class Documentation

class `SPH::`**BoundaryModel_Koschier2017** : **public** SPH::*BoundaryModel*

The boundary model stores the information required for boundary handling using the approach of Koschier and Bender 2017 [KB17].

References:

- [KB17] Dan Koschier and Jan Bender. Density maps for improved SPH boundary handling. In ACM SIGGRAPH/Eurographics Symposium on Computer Animation, 1-10. July 2017. URL: http://dx.doi.org/10.1145/3099564.3099565

Public Functions

BoundaryModel_Koschier2017()

virtual ~BoundaryModel_Koschier2017()

void **initModel**(*RigidBodyObject* **rbo*)

virtual void **reset**()

inline Discregrid::DiscreteGrid ***getMap**()

inline void **setMap**(Discregrid::DiscreteGrid **map*)

inline *Real* **getMaxDist** () **const**

inline void **setMaxDist** (*Real val*)

inline *Real* **getMaxVel** () **const**

inline void **setMaxVel** (*Real val*)

inline FORCE_INLINE const Real & getBoundaryDensity (const unsigned int fluidIndex, co

inline FORCE_INLINE Real & getBoundaryDensity (const unsigned int fluidIndex, const un

inline FORCE_INLINE void setBoundaryDensity (const unsigned int fluidIndex, const unsi

inline FORCE_INLINE Vector3r & getBoundaryDensityGradient (const unsigned int fluidInd

inline FORCE_INLINE const Vector3r & getBoundaryDensityGradient (const unsigned int fl

inline FORCE_INLINE void setBoundaryDensityGradient (const unsigned int fluidIndex, co

inline FORCE_INLINE Vector3r & getBoundaryXj (const unsigned int fluidIndex, const uns

inline FORCE_INLINE const Vector3r & getBoundaryXj (const unsigned int fluidIndex, con

inline FORCE_INLINE void setBoundaryXj (const unsigned int fluidIndex, const unsigned

Protected Attributes

Discregrid::DiscreteGrid ***m_map**

std::vector<std::vector<*Real*>> **m_boundaryDensity**

std::vector<std::vector<*Vector3r*>> **m_boundaryDensityGradient**

std::vector<std::vector<*Vector3r*>> **m_boundaryXj**

Real **m_maxDist**

Real **m_maxVel**

Class CholeskyAVXSolver

- Defined in file_SPlisHSPlasH_Elasticity_CholeskyAVXSolver.h

Class Documentation

class SPH::**CholeskyAVXSolver**

Cholesky solver which uses AVX instructions. Written by José Antonio Fernández-Fernández.

Public Functions

CholeskyAVXSolver () = default

~CholeskyAVXSolver () = default

CholeskyAVXSolver (**const** Eigen::SparseMatrix<float> &*lhs*)

CholeskyAVXSolver (**const** Eigen::SparseMatrix<double> &*lhs*)

void **solve** (float **solution*, **const** float **rhs*, **const** int *stride*)

void **save** (SPH::*BinaryFileWriter* &*binWriter*)

void **load**(SPH::*BinaryFileReader* &*binReader*)

Public Members

CholeskySparseMatrixfAVX **L**

CholeskySparseMatrixfAVX **LT**

std::vector<int> **perm**

std::vector<int> **perm_inv**

int **n_rhs_lines** = -1

int **ndofs** = -1

Class CholeskySparseMatrixfAVX

- Defined in file_SPlisHSPlasH_Elasticity_CholeskyAVXSolver.h

Class Documentation

class SPH::**CholeskySparseMatrixfAVX**

Public Functions

inline **CholeskySparseMatrixfAVX**()

CholeskySparseMatrixfAVX(**const** Eigen::SparseMatrix<float, Eigen::RowMajor> &*lhs*)

void **save**(SPH::*BinaryFileWriter* &*binWriter*)

void **load**(SPH::*BinaryFileReader* &*binReader*)

Public Members

std::vector<*Scalarf8*, *AlignmentAllocator*<*Scalarf8*, 32>> **vals**

std::vector<int> **cols**

std::vector<int> **rows_offset**

std::vector<float> **diagonal_inv**

int **n_rhs_lines** = -1

Class CohesionKernel

- Defined in file_SPlisHSPlasH_SPHKernels.h

Class Documentation

class SPH::**CohesionKernel**

Cohesion kernel used for the surface tension method of Akinci el al. [ATT13].

References:

- [AAT13] Nadir Akinci, Gizem Akinci, and Matthias Teschner. Versatile surface tension and adhesion for sph fluids. ACM Trans. Graph., 32(6):182:1-182:8, November 2013. URL: http://doi.acm.org/10.1145/2508363.2508395

Public Static Functions

static inline *Real* **getRadius**()

static inline void **setRadius**(*Real val*)

static inline *Real* **W**(**const** *Real r*)

W(r,h) = (32/(pi h^9))(h-r)^3*r^3 if h/2 < r <= h (32/(pi h^9))(2*(h-r)^3*r^3 - h^6/64 if 0 < r <= h/2

static inline *Real* **W**(**const** *Vector3r &r*)

static inline *Real* **W_zero**()

Protected Static Attributes

static *Real* **m_radius**

static *Real* **m_k**

static *Real* **m_c**

static *Real* **m_W_zero**

Class CubicKernel

- Defined in file_SPlisHSPlasH_SPHKernels.h

Class Documentation

class SPH::**CubicKernel**

Cubic spline kernel.

Public Static Functions

static inline *Real* **getRadius**()

static inline void **setRadius**(*Real* *val*)

static inline *Real* **W**(**const** *Real* *r*)

static inline *Real* **W**(**const** *Vector3r* &*r*)

static inline *Vector3r* **gradW**(**const** *Vector3r* &*r*)

static inline *Real* **W_zero**()

Protected Static Attributes

static *Real* **m_radius**

static *Real* **m_k**

static *Real* **m_l**

static *Real* **m_W_zero**

Class CubicKernel2D

- Defined in file_SPlisHSPlasH_SPHKernels.h

Class Documentation

class SPH::**CubicKernel2D**
Cubic spline kernel (2D).

Public Static Functions

static inline *Real* **getRadius**()

static inline void **setRadius**(*Real* *val*)

static inline *Real* **W**(**const** *Real* *r*)

static inline *Real* **W**(**const** *Vector3r* &*r*)

static inline *Vector3r* **gradW**(**const** *Vector3r* &*r*)

static inline *Real* **W_zero**()

Protected Static Attributes

static *Real* **m_radius**

static *Real* **m_k**

static *Real* **m_l**

static *Real* **m_W_zero**

Class DebugTools

- Defined in file_SPlisHSPlasH_Utilities_DebugTools.h

Inheritance Relationships

Base Type

- `public ParameterObject`

Class Documentation

class `SPH::DebugTools` : **public** ParameterObject

Public Functions

DebugTools()

~DebugTools()

void **init**()

void **cleanup**()

void **step**()

void **reset**()

void **performNeighborhoodSearchSort**()

void **emittedParticles**(*FluidModel* **model*, **const** unsigned int *startIndex*)

Public Static Attributes

static int **DETERMINE_THREAD_IDS** = -1

static int **DETERMINE_NUM_NEIGHBORS** = -1

static int **DETERMINE_VELOCITY_CHANGES** = -1

Protected Functions

virtual void **initParameters**()

void **determineThreadIds**()

void **determineNumNeighbors**()

void **determineVelocityChanges**()

Protected Attributes

bool **m_determineThreadIds**

std::vector<std::vector<unsigned int>> **m_threadIds**

bool **m_determineNumNeighbors**

std::vector<std::vector<unsigned int>> **m_numNeighbors**

bool **m_determineVelocityChanges**

std::vector<std::vector<*Vector3r*>> **m_vOld**

std::vector<std::vector<*Vector3r*>> **m_velocityChanges**

Class DragBase

- Defined in file_SPlisHSPlasH_Drag_DragBase.h

Inheritance Relationships

Base Type

- `public SPH::NonPressureForceBase` (*Class NonPressureForceBase*)

Derived Types

- `public SPH::DragForce_Gissler2017` (*Class DragForce_Gissler2017*)
- `public SPH::DragForce_Macklin2014` (*Class DragForce_Macklin2014*)

Class Documentation

class `SPH::`**DragBase** : **public** SPH::*NonPressureForceBase*

Base class for all drag force methods.

Subclassed by *SPH::DragForce_Gissler2017*, *SPH::DragForce_Macklin2014*

Public Functions

DragBase (*FluidModel* *model)

virtual ~DragBase (void)

Public Static Attributes

static int **DRAG_COEFFICIENT** = -1

Protected Functions

virtual void **initParameters** ()

Protected Attributes

Real **m_dragCoefficient**

Class DragForce_Gissler2017

- Defined in file_SPlisHSPlasH_Drag_DragForce_Gissler2017.h

Inheritance Relationships

Base Type

- `public SPH::DragBase` (*Class DragBase*)

Class Documentation

class `SPH::DragForce_Gissler2017` : **public** SPH::*DragBase*

This class implements the drag force computation introduced by Gissler et al. [GBP+17].

References:

- [GPB+17] Christoph Gissler, Stefan Band, Andreas Peer, Markus Ihmsen, and Matthias Teschner. Approximate air-fluid interactions for SPH. In Virtual Reality Interactions and Physical Simulations, 1-10. April 2017. URL: http://dx.doi.org/10.2312/vriphys.20171081

Public Functions

DragForce_Gissler2017 (*FluidModel* *model)

virtual ~DragForce_Gissler2017 (void)

virtual void **step** ()

virtual void **reset** ()

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* *model*)

Protected Attributes

const *Real* **rho_a** = static_cast<*Real*>(1.2041)

const *Real* **sigma** = static_cast<*Real*>(0.0724)

const *Real* **mu_l** = static_cast<*Real*>(0.00102)

const *Real* **C_F** = static_cast<*Real*>(1.0 / 3.0)

const *Real* **C_k** = static_cast<*Real*>(8.0)

const *Real* **C_d** = static_cast<*Real*>(5.0)

const *Real* **C_b** = static_cast<*Real*>(0.5)

const *Real* **mu_a** = static_cast<*Real*>(0.00001845)

Class DragForce_Macklin2014

- Defined in file_SPlisHSPlasH_Drag_DragForce_Macklin2014.h

Inheritance Relationships

Base Type

- `public SPH::DragBase` (*Class DragBase*)

Class Documentation

class `SPH::`**DragForce_Macklin2014** : **public** SPH::*DragBase*

This class implements the drag force computation introduced by Macklin et al. [MMCK14].

References:

- [MMCK14] Miles Macklin, Matthias Müller, Nuttapong Chentanez, and Tae-Yong Kim. Unified Particle Physics for Real-Time Applications. ACM Trans. Graph., 33(4):1-12, 2014. URL: http://doi.acm.org/10.1145/2601097.2601152

Public Functions

DragForce_Macklin2014 (*FluidModel* *model*)

virtual ~DragForce_Macklin2014 (void)

virtual void **step** ()

virtual void **reset** ()

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* *model*)

Class Elasticity_Becker2009

- Defined in file_SPlisHSPlasH_Elasticity_Elasticity_Becker2009.h

Inheritance Relationships

Base Type

- `public SPH::ElasticityBase` (*Class ElasticityBase*)

Class Documentation

class `SPH::`**Elasticity_Becker2009** : **public** SPH::*ElasticityBase*

This class implements the corotated SPH method for deformable solids introduced by Becker et al. [BIT09].

References:

- [BIT09] Markus Becker, Markus Ihmsen, and Matthias Teschner. Corotated SPH for deformable solids. In Proceedings of Eurographics Conference on Natural Phenomena, 27-34. 2009. URL: http://dx.doi.org/10.2312EG/DL/conf/EG2009/nph/027-034

Public Functions

Elasticity_Becker2009 (*FluidModel* *model*)

virtual ~Elasticity_Becker2009 (void)

virtual void **step** ()

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

virtual void **saveState** (*BinaryFileWriter* &*binWriter*)

virtual void **loadState** (*BinaryFileReader* &*binReader*)

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* *model*)

Public Static Attributes

static int **ALPHA** = -1

Protected Functions

void **initValues** ( )

void **computeRotations** ( )

void **computeStress** ( )

void **computeForces** ( )

virtual void **initParameters** ( )

inline FORCE_INLINE void symMatTimesVec (const Vector6r &M, const Vector3r &v, Vector3

Protected Attributes

std::vector<unsigned int> **m_current_to_initial_index**

std::vector<unsigned int> **m_initial_to_current_index**

std::vector<std::vector<unsigned int>> **m_initialNeighbors**

std::vector<*Real*> **m_restVolumes**

std::vector<*Matrix3r*> **m_rotations**

std::vector<*Vector6r*> **m_stress**

std::vector<*Matrix3r*> **m_F**

Real **m_alpha**

Class Elasticity_Kugelstadt2021

- Defined in file_SPlisHSPlasH_Elasticity_Elasticity_Kugelstadt2021.h

Nested Relationships

Nested Types

- *Struct Elasticity_Kugelstadt2021::ElasticObject*
- *Struct Elasticity_Kugelstadt2021::Factorization*

Inheritance Relationships

Base Type

- `public SPH::ElasticityBase` (*Class ElasticityBase*)

Class Documentation

class `SPH::`**Elasticity_Kugelstadt2021** : **public** SPH::*ElasticityBase*

This class implements the implicit SPH formulation for incompressible linearly elastic solids introduced by Kugelstadt et al. [KBF+21].

References:

- [KBF+21] Tassilo Kugelstadt, Jan Bender, José Antonio Fernández-Fernández, Stefan Rhys Jeske, Fabian Löschner, Andreas Longva. Fast Corotated Elastic SPH Solids with Implicit Zero-Energy Mode Control. Proceedings of the ACM on Computer Graphics and Interactive Techniques, 2021. URL: http://dx.doi.org/10.1145/3480142

Public Functions

Elasticity_Kugelstadt2021 (*FluidModel* *model)

virtual ~Elasticity_Kugelstadt2021 (void)

virtual void **step** ()
Perform a step of the elasticity solver.

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

virtual void **saveState** (*BinaryFileWriter* &*binWriter*)

virtual void **loadState** (*BinaryFileReader* &*binReader*)

void **computeRotations** ()
Extract rotation matrices from deformation gradients.

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* *model)

static void **matrixVecProd** (**const** *Real* *vec, *Real* *result, void *userData)
Matrix vector product used by the matrix-free conjugate gradient solver to solve the system in Eq. 30.

Public Static Attributes

static int **ITERATIONS_V** = -1

static int **MAX_ITERATIONS_V** = -1

static int **MAX_ERROR_V** = -1

static int **ALPHA** = -1

static int **MASS_DAMPING_COEFF** = -1

static int **STIFFNESS_DAMPING_COEFF** = -1

static int **MAX_NEIGHBORS** = -1

Protected Types

typedef Eigen::ConjugateGradient<*MatrixReplacement*, Eigen::Lower | Eigen::Upper, Eigen::IdentityPreconditioner> **Solve**

Protected Functions

void **computeRHS**(VectorXr &*rhs*)
Compute right hand side of the linear system of the volume solver (Eq. 30).

std::string **computeMD5**(**const** unsigned int *objIndex*)
Compute an MD4 check sum using the neighborhood structure in order to recognize known particle models (cache).

void **initValues**()
Initialize the particle neighborhoods in the reference configuration. Fix particles which lie in the user-defined bounding box. Find out if there are multiple separate objects in the phase. Finally, compute kernel gradient correction matrices and factorization.

void **initSystem**()
Initialize the solver for the linear system by either computing a factorization or loading a factorization from the cache.

void **initFactorization**(std::shared_ptr<*Factorization*> *factorization*, std::vector<unsigned int> &*particleIndices*, **const** unsigned int *nFixed*, **const** *Real dt*, **const** *Real mu*)
Compute the factorization of the linear system matrix. This is only done once at the beginning of the simulation.

void **findObjects**()
Find separate objects by object id.

void **computeMatrixL**()
Compute kernel gradient correction matrices (Eq. 8).

inline void **APD_Newton_AVX**(**const** *Vector3f8* &*F1*, **const** *Vector3f8* &*F2*, **const** *Vector3f8* &*F3*, *Quaternion8f* &*q*)

void **precomputeValues**()
Precompute some values and products to improve the performance of the solvers.

void **stepElasticitySolver**()
Solve the linear system for the stretching forces including zero energy mode control using the precomputed matrix factorization.

void **stepVolumeSolver** ( )
Solver for the volume conservation forces (Eq. 30).

virtual void **initParameters** ( )

virtual void **deferredInit** ( )
This function is called after the simulation scene is loaded and all parameters are initialized. While reading a scene file several parameters can change. The deferred init function should initialize all values which depend on these parameters.

inline FORCE_INLINE void symMatTimesVec (const Vector6r &M, const Vector3r &v, Vector3

void **rotationMatricesToAVXQuaternions** ( )
Convert all rotation matrices to AVX quaternions.

Protected Attributes

std::vector<unsigned int> **m_current_to_initial_index**

std::vector<unsigned int> **m_initial_to_current_index**

std::vector<std::vector<unsigned int>> **m_initialNeighbors**

std::vector<*Real*> **m_restVolumes**

std::vector<*Matrix3r*> **m_rotations**

std::vector<*Real*> **m_stress**

std::vector<*Matrix3r*> **m_L**

std::vector<*Matrix3r*> **m_F**

std::vector<*Vector3r*> **m_vDiff**

std::vector<*Matrix3r*> **m_RL**

unsigned int **m_iterationsV**

unsigned int **m_maxIterV**

Real **m_maxErrorV**

Real **m_alpha**

Real **m_massDampingCoeff**

Real **m_stiffnessDampingCoeff**

int **m_maxNeighbors**

unsigned int **m_totalNeighbors**

std::vector<*ElasticObject**> **m_objects**

Real **m_lambda**

Real **m_mu**

std::vector<*Vector3r*, Eigen::aligned_allocator<*Vector3r*>> **m_precomp_RL_gradW**

std::vector<*Vector3r*, Eigen::aligned_allocator<*Vector3r*>> **m_precomp_RLj_gradW**

std::vector<unsigned int> **m_precomputed_indices**

Solver **m_solver**

Protected Static Functions

static inline void **computeF**(**const** unsigned int *i*, **const** *Real* *x, *Elasticity_Kugelstadt2021* *e)

struct ElasticObject

Public Functions

inline ElasticObject()

inline ~ElasticObject()

Public Members

std::string **m_md5**

std::vector<unsigned int> **m_particleIndices**

unsigned int **m_nFixed**

std::shared_ptr<*Factorization*> **m_factorization**

std::vector<*Scalarf8*, *AlignmentAllocator*<*Scalarf8*, 32>> **m_f_avx**

std::vector<*Scalarf8*, *AlignmentAllocator*<*Scalarf8*, 32>> **m_sol_avx**

std::vector<*Scalarf8*, *AlignmentAllocator*<*Scalarf8*, 32>> **m_v_avx**

std::vector<*Scalarf8*, *AlignmentAllocator*<*Scalarf8*, 32>> **m_RHS**

std::vector<*Quaternion8f*, *AlignmentAllocator*<*Quaternion8f*, 32>> **m_quats**

VectorXr **m_rhs**

VectorXr **m_sol**

struct Factorization

Public Functions

inline Factorization()

inline ~Factorization()

Public Members

Real **m_dt**

Real **m_mu**

Eigen::SparseMatrix<*Real*, Eigen::RowMajor> **m_DT_K**

Eigen::SparseMatrix<*Real*, Eigen::RowMajor> **m_D**

Eigen::SparseMatrix<*Real*, Eigen::ColMajor> **m_dampingMatrix**

Eigen::SparseMatrix<*Real*, Eigen::ColMajor> **m_matHTH**

CholeskyAVXSolver ***m_cholesky**

Class Elasticity_Peer2018

- Defined in file_SPlisHSPlasH_Elasticity_Elasticity_Peer2018.h

Inheritance Relationships

Base Type

- `public SPH::ElasticityBase` (*Class ElasticityBase*)

Class Documentation

class `SPH::`**Elasticity_Peer2018** : **public** SPH::*ElasticityBase*

This class implements the implicit SPH formulation for incompressible linearly elastic solids introduced by Peer et al. [PGBT17].

References:

- [PGBT17] Andreas Peer, Christoph Gissler, Stefan Band, and Matthias Teschner. An implicit SPH formulation for incompressible linearly elastic solids. Computer Graphics Forum, 2017. URL: http://dx.doi.org/10.1111/cgf.13317

Public Functions

Elasticity_Peer2018 (*FluidModel* *model)

virtual **~Elasticity_Peer2018** (void)

virtual void **step** ()

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

virtual void **saveState** (*BinaryFileWriter* &*binWriter*)

virtual void **loadState** (*BinaryFileReader* &*binReader*)

Public Static Functions

static **inline** *NonPressureForceBase* ***creator** (*FluidModel* *model)

static void **matrixVecProd** (**const** *Real* *vec, *Real* *result, void *userData)

Public Static Attributes

static int **ITERATIONS** = -1

static int **MAX_ITERATIONS** = -1

static int **MAX_ERROR** = -1

static int **ALPHA** = -1

Protected Types

typedef Eigen::ConjugateGradient<*MatrixReplacement*, Eigen::Lower | Eigen::Upper, Eigen::IdentityPreconditioner> **Solve**

Protected Functions

void **initValues** ()

void **computeMatrixL** ()

void **computeRotations** ()

void **computeRHS** (VectorXr &*rhs*)

virtual void **initParameters** ()

virtual void **deferredInit** ()
This function is called after the simulation scene is loaded and all parameters are initialized. While reading a scene file several parameters can change. The deferred init function should initialize all values which depend on these parameters.

inline FORCE_INLINE void symMatTimesVec (const Vector6r &M, const Vector3r &v, Vector3

Protected Attributes

std::vector<unsigned int> **m_current_to_initial_index**

std::vector<unsigned int> **m_initial_to_current_index**

std::vector<std::vector<unsigned int>> **m_initialNeighbors**

std::vector<*Real*> **m_restVolumes**

std::vector<*Matrix3r*> **m_rotations**

std::vector<*Vector6r*> **m_stress**

std::vector<*Matrix3r*> **m_L**

std::vector<*Matrix3r*> **m_RL**

std::vector<*Matrix3r*> **m_F**

unsigned int **m_iterations**

unsigned int **m_maxIter**

Real **m_maxError**

Real **m_alpha**

Solver **m_solver**

Class ElasticityBase

- Defined in file_SPlisHSPlasH_Elasticity_ElasticityBase.h

Inheritance Relationships

Base Type

- `public SPH::NonPressureForceBase` (*Class NonPressureForceBase*)

Derived Types

- `public SPH::Elasticity_Becker2009` (*Class Elasticity_Becker2009*)
- `public SPH::Elasticity_Kugelstadt2021` (*Class Elasticity_Kugelstadt2021*)
- `public SPH::Elasticity_Peer2018` (*Class Elasticity_Peer2018*)

Class Documentation

class `SPH::`**ElasticityBase** : **public** SPH::*NonPressureForceBase*

Base class for all elasticity methods.

Subclassed by *SPH::Elasticity_Becker2009*, *SPH::Elasticity_Kugelstadt2021*, *SPH::Elasticity_Peer2018*

Public Functions

ElasticityBase(*FluidModel* **model*)

virtual ~ElasticityBase(void)

Public Static Attributes

static int **YOUNGS_MODULUS** = -1

static int **POISSON_RATIO** = -1

static int **FIXED_BOX_MIN** = -1

static int **FIXED_BOX_MAX** = -1

Protected Functions

virtual void **initParameters**()

void **determineFixedParticles**()

Mark all particles in the bounding box as fixed.

Protected Attributes

Real **m_youngsModulus**

Real **m_poissonRatio**

Vector3r **m_fixedBoxMin**

Vector3r **m_fixedBoxMax**

Class Emitter

- Defined in file_SPlisHSPlasH_Emitter.h

Class Documentation

class SPH::**Emitter**

Public Functions

Emitter(*FluidModel* **model*, **const** unsigned int *width*, **const** unsigned int *height*, **const** *Vector3r* &*pos*, **const** *Matrix3r* &*rotation*, **const** *Real velocity*, **const** unsigned int *type* = 0)

virtual **~Emitter**()

void **emitParticles**(std::vector<unsigned int> &*reusedParticles*, unsigned int &*indexReuse*, unsigned int &*numEmittedParticles*)

void **emitParticlesCircle**(std::vector<unsigned int> &*reusedParticles*, unsigned int &*indexReuse*, unsigned int &*numEmittedParticles*)

inline *Real* **getNextEmitTime**() **const**

inline void **setNextEmitTime**(*Real val*)

inline void **setEmitStartTime**(*Real val*)

inline void **setEmitEndTime**(*Real val*)

void **step**(std::vector<unsigned int> &*reusedParticles*, unsigned int &*indexReuse*, unsigned int &*numEmittedParticles*)

virtual void **reset**()

void **saveState**(*BinaryFileWriter* &*binWriter*)

void **loadState**(*BinaryFileReader* &*binReader*)

inline **const** *Vector3r* &**getPosition**() **const**

inline void **setPosition**(**const** *Vector3r* &*x*)

inline **const** *Matrix3r* &**getRotation**() **const**

inline void **setRotation**(**const** *Matrix3r* &*r*)

inline **const** *Real* **getVelocity**() **const**

inline void **setVelocity**(**const** *Real v*)

inline **const** unsigned int **getObjectId**() **const**

inline void **setObjectId**(**const** unsigned int *v*)

Public Static Functions

static *Vector3r* **getSize**(**const** *Real* *width*, **const** *Real* *height*, **const** int *type*)

Protected Functions

inline FORCE_INLINE bool inBox (const Vector3r &x, const Vector3r &xBox, const Matrix3

inline FORCE_INLINE bool inCylinder (const Vector3r &x, const Vector3r &xCyl, const Ma

Protected Attributes

FluidModel ***m_model**

unsigned int **m_width**

unsigned int **m_height**

Vector3r **m_x**

Matrix3r **m_rotation**

Real **m_velocity**

unsigned int **m_type**

Real **m_nextEmitTime**

Real **m_emitStartTime**

Real **m_emitEndTime**

unsigned int **m_emitCounter**

unsigned int **m_objectId**

Class EmitterSystem

- Defined in file_SPlisHSPlasH_EmitterSystem.h

Class Documentation

class SPH::**EmitterSystem**

Public Functions

EmitterSystem(*FluidModel* **model*)

virtual ~EmitterSystem()

void **enableReuseParticles**(**const** *Vector3r* &*boxMin* = *Vector3r*(-1, -1, -1), **const** *Vector3r* &*boxMax* = *Vector3r*(1, 1, 1))

void **disableReuseParticles**()

void **addEmitter**(**const** unsigned int *width*, **const** unsigned int *height*, **const** *Vector3r* &*pos*, **const** *Matrix3r* &*rotation*, **const** *Real* *velocity*, **const** unsigned int *type*)

inline unsigned int **numEmitters**() **const**

inline std::vector<*Emitter**> &**getEmitters**()

inline unsigned int **numReusedParticles**() **const**

inline unsigned int **numEmittedParticles**() **const**

void **step**()

void **reset**()

void **saveState**(*BinaryFileWriter* &*binWriter*)

void **loadState**(*BinaryFileReader* &*binReader*)

Protected Functions

void **reuseParticles**()

Protected Attributes

FluidModel ***m_model**

bool **m_reuseParticles**

Vector3r **m_boxMin**

Vector3r **m_boxMax**

unsigned int **m_numberOfEmittedParticles**

unsigned int **m_numReusedParticles**

std::vector<unsigned int> **m_reusedParticles**

std::vector<*Emitter**> **m_emitters**

Protected Static Attributes

static const unsigned int **m_maxParticlesToReusePerStep** = 50000

Class FluidModel

- Defined in file_SPlisHSPlasH_FluidModel.h

Inheritance Relationships

Base Type

- `public ParameterObject`

Class Documentation

class SPH::**FluidModel** : **public** ParameterObject

The fluid model stores the particle and simulation information.

Public Functions

FluidModel()

FluidModel(**const** *FluidModel*&) = delete

FluidModel &**operator=**(**const** *FluidModel*&) = delete

virtual **~FluidModel**()

void **init**()

void **deferredInit**()

This function is called after the simulation scene is loaded and all parameters are initialized. While reading a scene file several parameters can change. The deferred init function should initialize all values which depend on these parameters.

inline std::string **getId**() **const**

inline **FORCE_INLINE** **Real** **getDensity0** () **const**

void **setDensity0**(**const** *Real* *v*)

inline unsigned int **getPointSetIndex**() **const**

void **addField**(**const** *FieldDescription* &*field*)

inline **const** std::vector<*FieldDescription*> &**getFields**()

inline **const** *FieldDescription* &**getField**(**const** unsigned int *i*)

const *FieldDescription* &**getField**(**const** std::string &*name*)

inline **const** unsigned int **numberOfFields**()

void **removeFieldByName**(**const** std::string &*fieldName*)

void **setNumActiveParticles**(**const** unsigned int *num*)

inline unsigned int **numberOfParticles**() **const**

inline *EmitterSystem* ***getEmitterSystem**()

virtual void **reset**()

void **performNeighborhoodSearchSort**()

void **initModel**(**const** std::string &*id*, **const** unsigned int *nFluidParticles*, *Vector3r* **fluidParticles*, *Vector3r* **fluidVelocities*, unsigned int **fluidObjectIds*, **const** unsigned int *nMaxEmitterParticles*)

inline **const** unsigned int **numParticles**() **const**

unsigned int **numActiveParticles**() **const**

inline unsigned int **getNumActiveParticles0**() **const**

inline void **setNumActiveParticles0**(unsigned int *val*)

void **emittedParticles**(**const** unsigned int *startIndex*)

inline unsigned int **getSurfaceTensionMethod**() **const**

void **setSurfaceTensionMethod**(**const** std::string &*val*)

void **setSurfaceTensionMethod**(**const** unsigned int *val*)

inline unsigned int **getViscosityMethod**() **const**

void **setViscosityMethod**(**const** std::string &*val*)

void **setViscosityMethod**(**const** unsigned int *val*)

inline unsigned int **getVorticityMethod**() **const**

void **setVorticityMethod**(**const** std::string &*val*)

void **setVorticityMethod**(**const** unsigned int *val*)

inline unsigned int **getDragMethod**() **const**

void **setDragMethod**(**const** std::string &*val*)

void **setDragMethod**(**const** unsigned int *val*)

inline unsigned int **getElasticityMethod**() **const**

void **setElasticityMethod**(**const** std::string &*val*)

void **setElasticityMethod**(**const** unsigned int *val*)

inline *SurfaceTensionBase* ***getSurfaceTensionBase**()

inline *ViscosityBase* ***getViscosityBase**()

inline *VorticityBase* ***getVorticityBase**()

inline *DragBase* ***getDragBase**()

inline *ElasticityBase* ***getElasticityBase**()

void **setDragMethodChangedCallback**(std::function<void) > **const** &*callBackFct*

void **setSurfaceMethodChangedCallback**(std::function<void) > **const** &*callBackFct*

void **setViscosityMethodChangedCallback**(std::function<void) > **const** &*callBackFct*

void **setVorticityMethodChangedCallback**(std::function<void) > **const** &*callBackFct*

void **setElasticityMethodChangedCallback**(std::function<void) > **const** &*callBackFct*

void **computeSurfaceTension**()

void **computeViscosity**()

void **computeVorticity**()

void **computeDragForce**()

void **computeElasticity**()

void **saveState**(*BinaryFileWriter* &*binWriter*)

void **loadState**(*BinaryFileReader* &*binReader*)

inline FORCE_INLINE Vector3r & getPosition0 (const unsigned int i)

inline FORCE_INLINE const Vector3r & getPosition0 (const unsigned int i) const

```
inline FORCE_INLINE void setPosition0 (const unsigned int i, const Vector3r &pos)
inline FORCE_INLINE Vector3r & getPosition (const unsigned int i)
inline FORCE_INLINE const Vector3r & getPosition (const unsigned int i) const
inline FORCE_INLINE void setPosition (const unsigned int i, const Vector3r &pos)
inline FORCE_INLINE Vector3r & getVelocity (const unsigned int i)
inline FORCE_INLINE const Vector3r & getVelocity (const unsigned int i) const
inline FORCE_INLINE void setVelocity (const unsigned int i, const Vector3r &vel)
inline FORCE_INLINE Vector3r & getVelocity0 (const unsigned int i)
inline FORCE_INLINE const Vector3r & getVelocity0 (const unsigned int i) const
inline FORCE_INLINE void setVelocity0 (const unsigned int i, const Vector3r &vel)
inline FORCE_INLINE Vector3r & getAcceleration (const unsigned int i)
inline FORCE_INLINE const Vector3r & getAcceleration (const unsigned int i) const
inline FORCE_INLINE void setAcceleration (const unsigned int i, const Vector3r &accel)
inline FORCE_INLINE const Real getMass (const unsigned int i) const
inline FORCE_INLINE Real & getMass (const unsigned int i)
inline FORCE_INLINE void setMass (const unsigned int i, const Real mass)
inline FORCE_INLINE const Real & getDensity (const unsigned int i) const
inline FORCE_INLINE Real & getDensity (const unsigned int i)
inline FORCE_INLINE void setDensity (const unsigned int i, const Real &val)
inline FORCE_INLINE unsigned int & getParticleId (const unsigned int i)
inline FORCE_INLINE const unsigned int & getParticleId (const unsigned int i) const
inline FORCE_INLINE unsigned int & getObjectId (const unsigned int i)
inline FORCE_INLINE const unsigned int & getObjectId (const unsigned int i) const
inline FORCE_INLINE void setObjectId (const unsigned int i, const unsigned int val)
inline FORCE_INLINE const ParticleState & getParticleState (const unsigned int i) cons
inline FORCE_INLINE ParticleState & getParticleState (const unsigned int i)
inline FORCE_INLINE void setParticleState (const unsigned int i, const ParticleState &
inline FORCE_INLINE const Real getVolume (const unsigned int i) const
inline FORCE_INLINE Real & getVolume (const unsigned int i)
```

Public Static Attributes

static int **NUM_PARTICLES** = -1

static int **NUM_REUSED_PARTICLES** = -1

static int **DENSITY0** = -1

static int **DRAG_METHOD** = -1

static int **SURFACE_TENSION_METHOD** = -1

static int **VISCOSITY_METHOD** = -1

static int **VORTICITY_METHOD** = -1

static int **ELASTICITY_METHOD** = -1

Protected Functions

virtual void **initParameters** ( )

void **initMasses** ( )

virtual void **resizeFluidParticles** (**const** unsigned int *newSize*)
Resize the arrays containing the particle data.

virtual void **releaseFluidParticles** ( )
Release the arrays containing the particle data.

Protected Attributes

std::string **m_id**

EmitterSystem ***m_emitterSystem**

std::vector<*Real*> **m_masses**

std::vector<*Vector3r*> **m_a**

std::vector<*Vector3r*> **m_v0**

std::vector<*Vector3r*> **m_x0**

std::vector<*Vector3r*> **m_x**

std::vector<*Vector3r*> **m_v**

std::vector<*Real*> **m_density**

std::vector<unsigned int> **m_particleId**

std::vector<unsigned int> **m_objectId**

std::vector<unsigned int> **m_objectId0**

std::vector<*ParticleState*> **m_particleState**

Real **m_V**

unsigned int **m_surfaceTensionMethod**

SurfaceTensionBase ***m_surfaceTension**

unsigned int **m_viscosityMethod**

ViscosityBase ***m_viscosity**

unsigned int **m_vorticityMethod**

VorticityBase ***m_vorticity**

unsigned int **m_dragMethod**

DragBase ***m_drag**

unsigned int **m_elasticityMethod**

ElasticityBase ***m_elasticity**

std::vector<*FieldDescription*> **m_fields**

std::function<void ( ) > **m_dragMethodChanged**

std::function<void ( ) > **m_surfaceTensionMethodChanged**

std::function<void ( ) > **m_viscosityMethodChanged**

std::function<void ( ) > **m_vorticityMethodChanged**

std::function<void ( ) > **m_elasticityMethodChanged**

Real **m_density0**

unsigned int **m_pointSetIndex**

unsigned int **m_numActiveParticles**

unsigned int **m_numActiveParticles0**

Class GaussQuadrature

- Defined in file_SPlisHSPlasH_Utilities_GaussQuadrature.h

Class Documentation

class SPH::**GaussQuadrature**

Public Types

using Integrand = std::function<double (Eigen::Vector3d **const**&) >

using Domain = Eigen::AlignedBox3d

Public Static Functions

static double **integrate** (*Integrand integrand*, *Domain* **const** &*domain*, unsigned int *p*)

static void **exportSamples** (unsigned int *p*)

Class JacobiPreconditioner1D

- Defined in file_SPlisHSPlasH_Utilities_MatrixFreeSolver.h

Class Documentation

class SPH::**JacobiPreconditioner1D**

Matrix-free Jacobi preconditioner

Public Types

enum [anonymous]

Values:

enumerator ColsAtCompileTime

enumerator MaxColsAtCompileTime

typedef *SystemMatrixType*::StorageIndex **StorageIndex**

typedef void (***DiagonalMatrixElementFct**)(**const** unsigned int, *Real*&, void*)

Public Functions

inline JacobiPreconditioner1D()

inline void **init**(**const** unsigned int *dim*, *DiagonalMatrixElementFct* *fct*, void **userData*)

inline Eigen::Index **rows**() **const**

inline Eigen::Index **cols**() **const**

inline Eigen::ComputationInfo **info**()

template<typename **MatType**>
inline *JacobiPreconditioner1D* &**analyzePattern**(**const** *MatType*&)

template<typename **MatType**>
inline *JacobiPreconditioner1D* &**factorize**(**const** *MatType* &*mat*)

template<typename **MatType**>
inline *JacobiPreconditioner1D* &**compute**(**const** *MatType* &*mat*)

template<typename **Rhs**, typename **Dest**>
inline void **_solve_impl**(**const** *Rhs* &*b*, *Dest* &*x*) **const**

template<typename **Rhs**>
inline const Eigen::Solve<*JacobiPreconditioner1D*, *Rhs*> **solve**(**const** Eigen::MatrixBase<*Rhs*> &*b*) **const**

Protected Attributes

unsigned int **m_dim**

DiagonalMatrixElementFct **m_diagonalElementFct**
diagonal matrix element callback

void ***m_userData**

VectorXr **m_invDiag**

Class JacobiPreconditioner3D

- Defined in file_SPlisHSPlasH_Utilities_MatrixFreeSolver.h

Class Documentation

class SPH::**JacobiPreconditioner3D**
Matrix-free Jacobi preconditioner

Public Types

enum [anonymous]
Values:

enumerator ColsAtCompileTime

enumerator MaxColsAtCompileTime

typedef *SystemMatrixType*::StorageIndex **StorageIndex**

typedef void (***DiagonalMatrixElementFct**)(**const** unsigned int, *Vector3r*&, void*)

Public Functions

inline JacobiPreconditioner3D()

inline void **init**(**const** unsigned int *dim*, *DiagonalMatrixElementFct* *fct*, void **userData*)

inline Eigen::Index **rows**() **const**

inline Eigen::Index **cols**() **const**

inline Eigen::ComputationInfo **info**()

template<typename **MatType**>
inline *JacobiPreconditioner3D* &**analyzePattern**(**const** *MatType*&)

template<typename **MatType**>
inline *JacobiPreconditioner3D* &**factorize**(**const** *MatType* &*mat*)

template<typename **MatType**>
inline *JacobiPreconditioner3D* &**compute**(**const** *MatType* &*mat*)

template<typename **Rhs**, typename **Dest**>
inline void **_solve_impl**(**const** *Rhs* &*b*, *Dest* &*x*) **const**

template<typename **Rhs**>

inline const Eigen::Solve<*JacobiPreconditioner3D*, *Rhs*> **solve**(**const** Eigen::MatrixBase<*Rhs*> &*b*) **const**

Protected Attributes

unsigned int **m_dim**

DiagonalMatrixElementFct **m_diagonalElementFct**
diagonal matrix element callback

void ***m_userData**

VectorXr **m_invDiag**

Class MathFunctions

- Defined in file_SPlisHSPlasH_Utilities_MathFunctions.h

Class Documentation

class SPH::**MathFunctions**

Public Static Functions

static void **extractRotation**(**const** *Matrix3r* &*A*, *Quaternionr* &*q*, **const** unsigned int *maxIter*)

Implementation of the paper:

Matthias Müller, Jan Bender, Nuttapong Chentanez and Miles Macklin, "A Robust Method to Extract the Rotational Part of Deformations", ACM SIGGRAPH Motion in Games, 2016

static void **pseudoInverse**(**const** *Matrix3r* &*a*, *Matrix3r* &*res*)

static void **svdWithInversionHandling**(**const** *Matrix3r* &*A*, *Vector3r* &*sigma*, *Matrix3r* &*U*, *Matrix3r* &*VT*)
Perform a singular value decomposition of matrix A: A = U * sigma * V^T. This function returns two proper rotation matrices U and V^T which do not contain a reflection. Reflections are corrected by the inversion handling proposed by Irving et al. 2004.

static void **eigenDecomposition**(**const** *Matrix3r* &*A*, *Matrix3r* &*eigenVecs*, *Vector3r* &*eigenVals*)

static void **jacobiRotate**(*Matrix3r* &*A*, *Matrix3r* &*R*, int *p*, int *q*)

static void **getOrthogonalVectors**(**const** *Vector3r* &*vec*, *Vector3r* &*x*, *Vector3r* &*y*)
Returns two orthogonal vectors to vec which are also orthogonal to each other.

Class MatrixReplacement

- Defined in file_SPlisHSPlasH_Utilities_MatrixFreeSolver.h

Inheritance Relationships

Base Type

- `public Eigen::EigenBase< MatrixReplacement >`

Class Documentation

class `SPH::`**MatrixReplacement** : **public** Eigen::EigenBase<*MatrixReplacement*>

Replacement of the matrix in the linear system which is required for a matrix-free solver.

Public Types

enum [anonymous]

Values:

enumerator ColsAtCompileTime

enumerator MaxColsAtCompileTime

enumerator IsRowMajor

typedef *Real* **Scalar**

typedef *Real* **RealScalar**

typedef int **StorageIndex**

typedef void (***MatrixVecProdFct**)(**const** *Real**, *Real**, void*)

Public Functions

inline Index **rows**() **const**

inline Index **cols**() **const**

template<typename **Rhs**>
inline Eigen::Product<*MatrixReplacement*, *Rhs*, Eigen::AliasFreeProduct> **operator***(**const** Eigen::MatrixBase<*Rhs*> &*x*) **const**

inline **MatrixReplacement**(**const** unsigned int *dim*, *MatrixVecProdFct* *fct*, void **userData*)

inline void ***getUserData**()

inline *MatrixVecProdFct* **getMatrixVecProdFct**()

Protected Attributes

unsigned int **m_dim**

void ***m_userData**

MatrixVecProdFct **m_matrixVecProdFct**
matrix vector product callback

Class MicropolarModel_Bender2017

- Defined in file_SPlisHSPlasH_Vorticity_MicropolarModel_Bender2017.h

Inheritance Relationships

Base Type

- `public SPH::VorticityBase` (*Class VorticityBase*)

Class Documentation

class `SPH::`**MicropolarModel_Bender2017** : **public** SPH::*VorticityBase*
This class implements the micropolar material model introduced by Bender et al. [BKKW17].

References:

- [BKKW17] Jan Bender, Dan Koschier, Tassilo Kugelstadt, and Marcel Weiler. A micropolar material model for turbulent SPH fluids. In ACM SIGGRAPH / Eurographics Symposium on Computer Animation, SCA '17. ACM, 2017. URL: http://doi.acm.org/10.1145/3099564.3099578

Public Functions

MicropolarModel_Bender2017 (*FluidModel* **model*)

virtual ~MicropolarModel_Bender2017 (void)

virtual void **step** ()

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

inline FORCE_INLINE const Vector3r & getAngularAcceleration (const unsigned int i) con

inline FORCE_INLINE Vector3r & getAngularAcceleration (const unsigned int i)

inline FORCE_INLINE void setAngularAcceleration (const unsigned int i, const Vector3r

inline FORCE_INLINE const Vector3r & getAngularVelocity (const unsigned int i) const

inline FORCE_INLINE Vector3r & getAngularVelocity (const unsigned int i)

inline FORCE_INLINE void setAngularVelocity (const unsigned int i, const Vector3r &val

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* **model*)

Public Static Attributes

static int **VISCOSITY_OMEGA** = -1

static int **INERTIA_INVERSE** = -1

Protected Functions

virtual void **initParameters** ()

Protected Attributes

std::vector<*Vector3r*> **m_angularAcceleration**

std::vector<*Vector3r*> **m_omega**

Real **m_viscosityOmega**

Real **m_inertiaInverse**

Class NonPressureForceBase

- Defined in file_SPlisHSPlasH_NonPressureForceBase.h

Inheritance Relationships

Base Type

- `public ParameterObject`

Derived Types

- `public SPH::DragBase` (*Class DragBase*)
- `public SPH::ElasticityBase` (*Class ElasticityBase*)
- `public SPH::SurfaceTensionBase` (*Class SurfaceTensionBase*)
- `public SPH::ViscosityBase` (*Class ViscosityBase*)
- `public SPH::VorticityBase` (*Class VorticityBase*)

Class Documentation

class SPH::**NonPressureForceBase** : **public** ParameterObject

Base class for all non-pressure force methods.

Subclassed by *SPH::DragBase*, *SPH::ElasticityBase*, *SPH::SurfaceTensionBase*, *SPH::ViscosityBase*, *SPH::VorticityBase*

Public Functions

NonPressureForceBase(*FluidModel* *model)

NonPressureForceBase(**const** *NonPressureForceBase*&) = delete

NonPressureForceBase &**operator=**(**const** *NonPressureForceBase*&) = delete

virtual **~NonPressureForceBase**(void)

virtual void **step**() = 0

inline **virtual** void **reset**()

inline **virtual** void **performNeighborhoodSearchSort**()

inline **virtual** void **emittedParticles**(**const** unsigned int *startIndex*)

inline **virtual** void **saveState**(*BinaryFileWriter* &*binWriter*)

inline **virtual** void **loadState**(*BinaryFileReader* &*binReader*)

inline *FluidModel* ***getModel**()

virtual void **init**()

inline **virtual** void **deferredInit**()

This function is called after the simulation scene is loaded and all parameters are initialized. While reading a scene file several parameters can change. The deferred init function should initialize all values which depend on these parameters.

Protected Attributes

FluidModel ***m_model**

Class PoissonDiskSampling

- Defined in file_SPlisHSPlasH_Utilities_PoissonDiskSampling.h

Nested Relationships

Nested Types

- *Struct PoissonDiskSampling::CellPosHasher*
- *Struct PoissonDiskSampling::HashEntry*
- *Struct PoissonDiskSampling::InitialPointInfo*

Class Documentation

class SPH::**PoissonDiskSampling**

This class implements a Poisson disk sampling for the surface of 3D models.

Public Functions

PoissonDiskSampling()

void **sampleMesh**(**const** unsigned int *numVertices*, **const** *Vector3r* **vertices*, **const** unsigned int *numFaces*, **const** unsigned int **faces*, **const** *Real minRadius*, **const** unsigned int *numTrials*, unsigned int *distanceNorm*, std::vector<*Vector3r*> &*samples*)

Performs the poisson sampling with the respective parameters. Compare http://graphics.cs.umass.edu/pubs/sa_2010.pdf

Parameters

- **mesh** – mesh data of sampled body
- **vertices** – vertex data of sampled data
- **sampledVertices** – sampled vertices that will be returned
- **minRadius** – minimal distance of sampled vertices
- **numTestpointsPerFace** – # of generated test points per face of body
- **distanceNorm** – 0: euclidean norm, 1: approx geodesic distance
- **numTrials** – # of iterations used to find samples

Public Static Functions

static inline FORCE_INLINE int floor (const Real v)

struct HashEntry

Struct to store the hash entry (spatial hashing)

Public Functions

inline HashEntry()

Public Members

std::vector<unsigned int> **samples**

unsigned int **startIndex**

struct InitialPointInfo

Struct to store the information of the initial points.

Public Members

CellPos **cP**

Vector3r **pos**

unsigned int **ID**

Class Poly6Kernel

- Defined in file_SPlisHSPlasH_SPHKernels.h

Class Documentation

class SPH::**Poly6Kernel**

Poly6 kernel.

Public Static Functions

static inline *Real* **getRadius**()

static inline void **setRadius**(*Real val*)

static inline *Real* **W**(**const** *Real r*)

W(r,h) = (315/(64 pi h^9))(h^2-|r|^2)^3 = (315/(64 pi h^9))(h^2-r*r)^3

static inline *Real* **W**(**const** *Vector3r &r*)

static inline *Vector3r* **gradW**(**const** *Vector3r &r*)

grad(W(r,h)) = r(-945/(32 pi h^9))(h^2-|r|^2)^2 = r(-945/(32 pi h^9))(h^2-r*r)^2

static inline *Real* **laplacianW**(**const** *Vector3r &r*)

laplacian(W(r,h)) = (-945/(32 pi h^9))(h^2-|r|^2)(-7|r|^2+3h^2) = (-945/(32 pi h^9))(h^2-r*r)(3 h^2-7 r*r)

static inline *Real* **W_zero**()

Protected Static Attributes

static *Real* **m_radius**

static *Real* **m_k**

static *Real* **m_l**

static *Real* **m_m**

static *Real* **m_W_zero**

Template Class PrecomputedKernel

- Defined in file_SPlisHSPlasH_SPHKernels.h

Class Documentation

template<typename **KernelType**, unsigned int **resolution** = 10000u>
class SPH::**PrecomputedKernel**

Precomputed kernel which is based on a lookup table as described by Bender and Koschier [BK15,BK17].

The lookup tables can be used in combination with any kernel.

References:

- [BK15] Jan Bender and Dan Koschier. Divergence-free smoothed particle hydrodynamics. In ACM SIGGRAPH / Eurographics Symposium on Computer Animation, SCA '15, 147-155. New York, NY, USA, 2015. ACM. URL: http://doi.acm.org/10.1145/2786784.2786796
- [BK17] Jan Bender and Dan Koschier. Divergence-free SPH for incompressible and viscous fluids. IEEE Transactions on Visualization and Computer Graphics, 23(3):1193-1206, 2017. URL: http://dx.doi.org/10.1109/TVCG.2016.2578335

Public Static Functions

static inline *Real* **getRadius**()

static inline void **setRadius**(*Real* *val*)

static inline *Real* **W**(**const** *Vector3r* &*r*)

static inline *Real* **W**(**const** *Real* *r*)

static inline *Vector3r* **gradW**(**const** *Vector3r* &*r*)

static inline *Real* **W_zero**()

Protected Static Attributes

static *Real* **m_W**[**resolution**]

static *Real* **m_gradW**[**resolution** + 1]

static *Real* **m_radius**

static *Real* **m_radius2**

static *Real* **m_invStepSize**

static *Real* **m_W_zero**

Class RegularSampling2D

- Defined in file_SPlisHSPlasH_Utilities_RegularSampling2D.h

Class Documentation

class SPH::**RegularSampling2D**

This class implements a per-triangle regular sampling for the surface of 3D models.

Public Functions

RegularSampling2D()

Public Static Functions

static void **sampleMesh**(**const** *Matrix3r* &*rotation*, **const** *Vector3r* &*translation*, **const** unsigned *numVertices*, **const** *Vector3r* **vertices*, **const** unsigned int *numFaces*, **const** unsigned int **faces*, **const** *Real* *maxDistance*, std::vector<*Vector3r*> &*samples*)

Performs the poisson sampling with the respective parameters. Compare http://graphics.cs.umass.edu/pubs/sa_2010.pdf

Parameters

- **rotation** – rotation of the mesh
- **translation** – translation of the mesh
- **numVertices** – number of mesh vertices
- **vertices** – vertex data of sampled data
- **numFaces** – number of faces in the mesh
- **faces** – face data of sampled mesh
- **maxDistance** – maximal distance of sampled vertices
- **samples** – vector to store the samples

Class RegularTriangleSampling

- Defined in file_SPlisHSPlasH_Utilities_RegularTriangleSampling.h

Class Documentation

class SPH::**RegularTriangleSampling**

This class implements a per-triangle regular sampling for the surface of 3D models.

Public Functions

RegularTriangleSampling()

Public Static Functions

static void **sampleMesh**(**const** unsigned int *numVertices*, **const** *Vector3r* **vertices*, **const** unsigned int *numFaces*, **const** unsigned int **faces*, **const** *Real* *maxDistance*, std::vector<*Vector3r*> &*samples*)

Performs the poisson sampling with the respective parameters. Compare http://graphics.cs.umass.edu/pubs/sa_2010.pdf

Parameters

- **numVertices** – number of mesh vertices
- **vertices** – vertex data of sampled data
- **numFaces** – number of faces in the mesh
- **faces** – face data of sampled mesh
- **maxDistance** – maximal distance of sampled vertices
- **samples** – vector to store the samples

Class RigidBodyObject

- Defined in file_SPlisHSPlasH_RigidBodyObject.h

Inheritance Relationships

Derived Type

- `public SPH::StaticRigidBody` (*Class StaticRigidBody*)

Class Documentation

class SPH::**RigidBodyObject**

Base class for rigid body objects.

Subclassed by *SPH::StaticRigidBody*

Public Functions

inline **RigidBodyObject**()

inline **virtual** **~RigidBodyObject**()

virtual bool **isDynamic**() **const** = 0

inline bool **isAnimated**() **const**

inline **virtual** void **setIsAnimated**(**const** bool *b*)

virtual *Real* **const** **getMass**() **const** = 0

virtual *Vector3r* **const** &**getPosition**() **const** = 0

virtual void **setPosition**(**const** *Vector3r* &*x*) = 0

virtual *Vector3r* **getWorldSpacePosition**() **const** = 0

virtual *Vector3r* **const** &**getVelocity**() **const** = 0

virtual void **setVelocity**(**const** *Vector3r* &*v*) = 0

virtual *Quaternionr* **const** &**getRotation**() **const** = 0

virtual void **setRotation**(**const** *Quaternionr* &*q*) = 0

virtual *Matrix3r* **getWorldSpaceRotation**() **const** = 0

virtual *Vector3r* **const** &**getAngularVelocity**() **const** = 0

virtual void **setAngularVelocity**(**const** *Vector3r* &*v*) = 0

virtual void **addForce**(**const** *Vector3r* &*f*) = 0

virtual void **addTorque**(**const** *Vector3r* &*t*) = 0

virtual void **updateMeshTransformation**() = 0

virtual const std::vector<*Vector3r*> &**getVertices**() **const** = 0

virtual const std::vector<*Vector3r*> &**getVertexNormals**() **const** = 0

virtual const std::vector<unsigned int> &**getFaces**() **const** = 0

Protected Attributes

bool **m_isAnimated**

Class SimpleQuadrature

- Defined in file_SPlisHSPlasH_Utilities_SimpleQuadrature.h

Class Documentation

class SPH::**SimpleQuadrature**

Public Types

using Integrand = std::function<double (Eigen::Vector3d **const**&)>

using Domain = Eigen::AlignedBox3d

Public Static Functions

static void **determineSamplePointsInSphere**(**const** double *radius*, unsigned int *p*)

static void **determineSamplePointsInCircle**(**const** double *radius*, unsigned int *p*)

static double **integrate**(*Integrand integrand*)

Public Static Attributes

static std::vector<Eigen::Vector3d> **m_samplePoints**

static double **m_volume** = 0.0

Class Simulation

- Defined in file_SPlisHSPlasH_Simulation.h

Nested Relationships

Nested Types

- *Struct Simulation::FluidInfo*
- *Struct Simulation::NonPressureForceMethod*

Inheritance Relationships

Base Type

- `public ParameterObject`

Class Documentation

class `SPH::`**Simulation** : **public** ParameterObject

Class to manage the current simulation time and the time step size. This class is a singleton.

Public Types

typedef *PrecomputedKernel*<*CubicKernel*, 10000> **PrecomputedCubicKernel**

Public Functions

Simulation()

Simulation(**const** *Simulation*&) = delete

Simulation &**operator=**(**const** *Simulation*&) = delete

~Simulation()

void **init**(**const** *Real particleRadius*, **const** bool *sim2D*)

void **deferredInit**()
This function is called after the simulation scene is loaded and all parameters are initialized. While reading a scene file several parameters can change. The deferred init function should initialize all values which depend on these parameters.

void **reset**()

void **addFluidModel**(**const** std::string *&id*, **const** unsigned int *nFluidParticles*, *Vector3r *fluidParticles*, *Vector3r *fluidVelocities*, unsigned int **fluidObjectIds*, **const** unsigned int *nMaxEmitterParticles*)

inline *FluidModel* ***getFluidModel**(**const** unsigned int *index*)

inline *FluidModel* ***getFluidModelFromPointSet**(**const** unsigned int *pointSetIndex*)

inline const unsigned int **numberOfFluidModels**() **const**

void **addBoundaryModel**(*BoundaryModel *bm*)

inline *BoundaryModel* ***getBoundaryModel**(**const** unsigned int *index*)

inline *BoundaryModel* ***getBoundaryModelFromPointSet**(**const** unsigned int *pointSetIndex*)

inline const unsigned int **numberOfBoundaryModels**() **const**

void **updateBoundaryVolume**()

inline void **addFluidInfo**(*FluidInfo &info*)

inline std::vector<*FluidInfo*> &**getFluidInfos**()

inline *FluidInfo* &**getFluidInfo**(**const** unsigned int *i*)

inline *AnimationFieldSystem* ***getAnimationFieldSystem**()

inline *BoundaryHandlingMethods* **getBoundaryHandlingMethod**() **const**

inline void **setBoundaryHandlingMethod**(*BoundaryHandlingMethods val*)

inline int **getKernel**() **const**

void **setKernel**(int *val*)

inline int **getGradKernel**() **const**

void **setGradKernel**(int *val*)

inline int **isSimulationInitialized**() **const**

void **setSimulationInitialized**(int *val*)

inline FORCE_INLINE Real W_zero () const

inline FORCE_INLINE Real W (const Vector3r &r) const

inline FORCE_INLINE Vector3r gradW (const Vector3r &r)

inline int **getSimulationMethod**() **const**

void **setSimulationMethod**(**const** int *val*)

void **setSimulationMethodChangedCallback**(std::function<void) > **const** &*callBackFct*

inline *TimeStep* ***getTimeStep**()

inline bool **is2DSimulation**()

inline bool **zSortEnabled**()

void **initKernels**()

void **setParticleRadius**(*Real val*)

inline *Real* **getParticleRadius**() **const**

inline *Real* **getSupportRadius**() **const**

void **updateTimeStepSize**()
Update time step size depending on the chosen method.

void **updateTimeStepSizeCFL**()
Update time step size by CFL condition.

virtual void **performNeighborhoodSearch**()
Perform the neighborhood search for all fluid particles.

void **performNeighborhoodSearchSort**()

void **computeNonPressureForces**()

void **animateParticles**()

void **emitParticles**()

virtual void **emittedParticles**(*FluidModel* **model*, **const** unsigned int *startIndex*)

inline *NeighborhoodSearch* ***getNeighborhoodSearch**()

inline void **setCachePath**(**const** std::string &*cachePath*)

inline const std::string &**getCachePath**() **const**

inline void **setUseCache**(**const** bool *useCache*)

inline const bool **getUseCache**() **const**

void **saveState**(*BinaryFileWriter* &*binWriter*)

void **loadState**(*BinaryFileReader* &*binReader*)

inline void **addDragMethod**(**const** std::string &*name*, **const** std::function<*NonPressureForceBase**) *FluidModel** > &*creator*

inline std::vector<*NonPressureForceMethod*> &**getDragMethods**()

inline void **addElasticityMethod**(**const** std::string &*name*, **const** std::function<*NonPressureForceBase**) *FluidModel** > &*creator*

inline std::vector<*NonPressureForceMethod*> &**getElasticityMethods**()

inline void **addSurfaceTensionMethod**(**const** std::string &*name*, **const** std::function<*NonPressureForceBase**) *FluidModel** > &*creator*

inline std::vector<*NonPressureForceMethod*> &**getSurfaceTensionMethods**()

inline void **addViscosityMethod**(**const** std::string &*name*, **const** std::function<*NonPressureForceBase**(*FluidModel**)> &*creator*

inline std::vector<*NonPressureForceMethod*> &**getViscosityMethods**()

inline void **addVorticityMethod**(**const** std::string &*name*, **const** std::function<*NonPressureForceBase**(*FluidModel**)> &*creator*

inline std::vector<*NonPressureForceMethod*> &**getVorticityMethods**()

inline FORCE_INLINE unsigned int numberOfPointSets () const

inline FORCE_INLINE unsigned int numberOfNeighbors (const unsigned int pointSetIndex,

inline FORCE_INLINE unsigned int getNeighbor (const unsigned int pointSetIndex, const

inline FORCE_INLINE const unsigned int * getNeighborList (const unsigned int pointSetI

Public Static Functions

static *Simulation* ***getCurrent**()

static void **setCurrent**(*Simulation* **tm*)

static bool **hasCurrent**()

Public Static Attributes

static int **SIM_2D** = -1

static int **PARTICLE_RADIUS** = -1

static int **GRAVITATION** = -1

static int **CFL_METHOD** = -1

static int **CFL_FACTOR** = -1

static int **CFL_MIN_TIMESTEPSIZE** = -1

static int **CFL_MAX_TIMESTEPSIZE** = -1

static int **ENABLE_Z_SORT** = -1

static int **KERNEL_METHOD** = -1

static int **GRAD_KERNEL_METHOD** = -1

static int **ENUM_KERNEL_CUBIC** = -1

static int **ENUM_KERNEL_WENDLANDQUINTICC2** = -1

static int **ENUM_KERNEL_POLY6** = -1

static int **ENUM_KERNEL_SPIKY** = -1

static int **ENUM_KERNEL_PRECOMPUTED_CUBIC** = -1

static int **ENUM_KERNEL_CUBIC_2D** = -1

static int **ENUM_KERNEL_WENDLANDQUINTICC2_2D** = -1

static int **ENUM_GRADKERNEL_CUBIC** = -1

static int **ENUM_GRADKERNEL_WENDLANDQUINTICC2** = -1

static int **ENUM_GRADKERNEL_POLY6** = -1

static int **ENUM_GRADKERNEL_SPIKY** = -1

static int **ENUM_GRADKERNEL_PRECOMPUTED_CUBIC** = -1

static int **ENUM_GRADKERNEL_CUBIC_2D** = -1

static int **ENUM_GRADKERNEL_WENDLANDQUINTICC2_2D** = -1

static int **SIMULATION_METHOD** = -1

static int **ENUM_CFL_NONE** = -1

static int **ENUM_CFL_STANDARD** = -1

static int **ENUM_CFL_ITER** = -1

static int **ENUM_SIMULATION_WCSPH** = -1

static int **ENUM_SIMULATION_PCISPH** = -1

static int **ENUM_SIMULATION_PBF** = -1

static int **ENUM_SIMULATION_IISPH** = -1

static int **ENUM_SIMULATION_DFSPH** = -1

static int **ENUM_SIMULATION_PF** = -1

static int **ENUM_SIMULATION_ICSPH** = -1

static int **BOUNDARY_HANDLING_METHOD** = -1

static int **ENUM_AKINCI2012** = -1

static int **ENUM_KOSCHIER2017** = -1

static int **ENUM_BENDER2019** = -1

Protected Functions

virtual void **initParameters** ( )

void **registerNonpressureForces** ( )

Protected Attributes

std::vector<*FluidModel**> **m_fluidModels**

std::vector<*BoundaryModel**> **m_boundaryModels**

std::vector<*FluidInfo*> **m_fluidInfos**

NeighborhoodSearch ***m_neighborhoodSearch**

AnimationFieldSystem ***m_animationFieldSystem**

int **m_cflMethod**

Real **m_cflFactor**

Real **m_cflMinTimeStepSize**

Real **m_cflMaxTimeStepSize**

int **m_kernelMethod**

int **m_gradKernelMethod**

Real **m_W_zero**

Real (***m_kernelFct**)(**const** *Vector3r*&)

Vector3r (***m_gradKernelFct**)(**const** *Vector3r* &r)

SimulationMethods **m_simulationMethod**

TimeStep ***m_timeStep**

Vector3r **m_gravitation**

Real **m_particleRadius**

Real **m_supportRadius**

bool **m_sim2D**

bool **m_enableZSort**

std::function<void ()> **m_simulationMethodChanged**

int **m_boundaryHandlingMethod**

std::string **m_cachePath**

bool **m_useCache**

std::vector<*NonPressureForceMethod*> **m_dragMethods**

std::vector<*NonPressureForceMethod*> **m_elasticityMethods**

std::vector<*NonPressureForceMethod*> **m_surfaceTensionMethods**

std::vector<*NonPressureForceMethod*> **m_vorticityMethods**

std::vector<*NonPressureForceMethod*> **m_viscoMethods**

bool **m_simulationIsInitialized**

struct FluidInfo

Fluid object information

Public Functions

inline bool **hasSameParticleSampling**(**const** *FluidInfo* &*other*)

Public Members

int **type**

int **numParticles**

AlignedBox3r **box**

std::string **id**

std::string **samplesFile**

std::string **visMeshFile**

Vector3r **translation**

Matrix3r **rotation**

Vector3r **scale**

Vector3r **initialVelocity**

Vector3r **initialAngularVelocity**

unsigned char **mode**

bool **invert**

std::array<unsigned int, 3> **resolutionSDF**

unsigned int **emitter_width**

unsigned int **emitter_height**

Real **emitter_velocity**

Real **emitter_emitStartTime**

Real **emitter_emitEndTime**

unsigned int **emitter_type**

struct NonPressureForceMethod

Public Members

std::string **m_name**

std::function<*NonPressureForceBase** (*FluidModel**)> **m_creator**

int **m_id**

Class SimulationDataDFSPH

- Defined in file_SPlisHSPlasH_DFSPH_SimulationDataDFSPH.h

Class Documentation

class SPH::**SimulationDataDFSPH**

Simulation data which is required by the method Divergence-free Smoothed Particle Hydrodynamics introduced by Bender and Koschier [BK15,BK17].

References:

- [BK15] Jan Bender and Dan Koschier. Divergence-free smoothed particle hydrodynamics. In ACM SIGGRAPH / Eurographics Symposium on Computer Animation, SCA '15, 147-155. New York, NY, USA, 2015. ACM. URL: http://doi.acm.org/10.1145/2786784.2786796
- [BK17] Jan Bender and Dan Koschier. Divergence-free SPH for incompressible and viscous fluids. IEEE Transactions on Visualization and Computer Graphics, 23(3):1193-1206, 2017. URL: http://dx.doi.org/10.1109/TVCG.2016.2578335

Public Functions

SimulationDataDFSPH()

virtual ~SimulationDataDFSPH()

virtual void **init**()
Initialize the arrays containing the particle data.

virtual void **cleanup**()
Release the arrays containing the particle data.

virtual void **reset**()
Reset the particle data.

void **performNeighborhoodSearchSort**()
Important: First call m_model->*performNeighborhoodSearchSort()* to call the z_sort of the neighborhood search.

void **emittedParticles**(*FluidModel* *model, **const** unsigned int *startIndex*)

inline FORCE_INLINE const Real getFactor (const unsigned int fluidIndex, const unsigne

inline FORCE_INLINE Real & getFactor (const unsigned int fluidIndex, const unsigned int

inline FORCE_INLINE void setFactor (const unsigned int fluidIndex, const unsigned int

inline FORCE_INLINE const Real getKappa (const unsigned int fluidIndex, const unsigned

inline FORCE_INLINE Real & getKappa (const unsigned int fluidIndex, const unsigned int

inline FORCE_INLINE void setKappa (const unsigned int fluidIndex, const unsigned int i

inline FORCE_INLINE const Real getKappaV (const unsigned int fluidIndex, const unsigne

inline FORCE_INLINE Real & getKappaV (const unsigned int fluidIndex, const unsigned int

inline FORCE_INLINE void setKappaV (const unsigned int fluidIndex, const unsigned int

inline FORCE_INLINE const Real getDensityAdv (const unsigned int fluidIndex, const uns

inline FORCE_INLINE Real & getDensityAdv (const unsigned int fluidIndex, const unsigne

inline FORCE_INLINE void setDensityAdv (const unsigned int fluidIndex, const unsigned

Protected Attributes

std::vector<std::vector<*Real*>> **m_factor**
factor α_i

std::vector<std::vector<*Real*>> **m_kappa**
stores κ value of last time step for a warm start of the pressure solver

std::vector<std::vector<*Real*>> **m_kappaV**
stores κ^v value of last time step for a warm start of the divergence solver

std::vector<std::vector<*Real*>> **m_density_adv**
advected density

Class SimulationDataICSPH

- Defined in file_SPlisHSPlasH_ICSPH_SimulationDataICSPH.h

Class Documentation

class SPH::**SimulationDataICSPH**

Simulation data which is required by the method Implicit Compressible SPH introduced by Gissler et al. [GHB+20].

References:

- [GHB+20] Christoph Gissler, Andreas Henne, Stefan Band, Andreas Peer and Matthias Teschner. An Implicit Compressible SPH Solver for Snow *Simulation*. ACM Transactions on Graphics, 39(4). URL: https://doi.org/10.1145/3386569.3392431

Public Functions

SimulationDataICSPH()

virtual ~SimulationDataICSPH()

virtual void **init**()
Initialize the arrays containing the particle data.

virtual void **cleanup**()
Release the arrays containing the particle data.

virtual void **reset**()
Reset the particle data.

void **performNeighborhoodSearchSort**()
Important: First call m_model->*performNeighborhoodSearchSort()* to call the z_sort of the neighborhood search.

void **emittedParticles**(*FluidModel* *model, **const** unsigned int *startIndex*)

inline FORCE_INLINE const Real getAii (const unsigned int fluidIndex, const unsigned i

inline FORCE_INLINE Real & getAii (const unsigned int fluidIndex, const unsigned int i

inline FORCE_INLINE void setAii (const unsigned int fluidIndex, const unsigned int i,

inline FORCE_INLINE const Real getDensityAdv (const unsigned int fluidIndex, const uns

inline FORCE_INLINE Real & getDensityAdv (const unsigned int fluidIndex, const unsigne

inline FORCE_INLINE void setDensityAdv (const unsigned int fluidIndex, const unsigned

inline FORCE_INLINE const Real getPressure (const unsigned int fluidIndex, const unsig

inline FORCE_INLINE Real & getPressure (const unsigned int fluidIndex, const unsigned

inline FORCE_INLINE void setPressure (const unsigned int fluidIndex, const unsigned in

inline FORCE_INLINE Vector3r & getPressureAccel (const unsigned int fluidIndex, const

inline FORCE_INLINE const Vector3r & getPressureAccel (const unsigned int fluidIndex,

inline FORCE_INLINE void setPressureAccel (const unsigned int fluidIndex, const unsign

inline FORCE_INLINE Vector3r & getPressureGradient (const unsigned int fluidIndex, con

inline FORCE_INLINE const Vector3r & getPressureGradient (const unsigned int fluidInde

inline FORCE_INLINE void setPressureGradient (const unsigned int fluidIndex, const uns

Protected Attributes

std::vector<std::vector<*Real*>> **m_aii**

std::vector<std::vector<*Real*>> **m_density_adv**

std::vector<std::vector<*Real*>> **m_pressure**

std::vector<std::vector<*Vector3r*>> **m_pressureGradient**

std::vector<std::vector<*Vector3r*>> **m_pressureAccel**

Class SimulationDataIISPH

- Defined in file_SPlisHSPlasH_IISPH_SimulationDataIISPH.h

Class Documentation

class SPH::**SimulationDataIISPH**

Simulation data which is required by the method Implicit Incompressible SPH introduced by Ihmsen et al. [ICS+14].

References:

- [ICS+14] Markus Ihmsen, Jens Cornelis, Barbara Solenthaler, Christopher Horvath, and Matthias Teschner. Implicit incompressible SPH. IEEE Transactions on Visualization and Computer Graphics, 20(3):426-435, March 2014. URL: http://dx.doi.org/10.1109/TVCG.2013.105

Public Functions

SimulationDataIISPH()

virtual ~SimulationDataIISPH()

virtual void **init**()
Initialize the arrays containing the particle data.

virtual void **cleanup**()
Release the arrays containing the particle data.

virtual void **reset**()
Reset the particle data.

void **performNeighborhoodSearchSort**()
Important: First call m_model->*performNeighborhoodSearchSort()* to call the z_sort of the neighborhood search.

void **emittedParticles**(*FluidModel* **model*, **const** unsigned int *startIndex*)

inline FORCE_INLINE const Real getAii (const unsigned int fluidIndex, const unsigned i

inline FORCE_INLINE Real & getAii (const unsigned int fluidIndex, const unsigned int i

inline FORCE_INLINE void setAii (const unsigned int fluidIndex, const unsigned int i,

inline FORCE_INLINE Vector3r & getDii (const unsigned int fluidIndex, const unsigned i
inline FORCE_INLINE const Vector3r & getDii (const unsigned int fluidIndex, const unsi
inline FORCE_INLINE void setDii (const unsigned int fluidIndex, const unsigned int i,
inline FORCE_INLINE Vector3r & getDij_pj (const unsigned int fluidIndex, const unsigne
inline FORCE_INLINE const Vector3r & getDij_pj (const unsigned int fluidIndex, const u
inline FORCE_INLINE void setDij_pj (const unsigned int fluidIndex, const unsigned int
inline FORCE_INLINE const Real getDensityAdv (const unsigned int fluidIndex, const uns
inline FORCE_INLINE Real & getDensityAdv (const unsigned int fluidIndex, const unsigne
inline FORCE_INLINE void setDensityAdv (const unsigned int fluidIndex, const unsigned
inline FORCE_INLINE const Real getPressure (const unsigned int fluidIndex, const unsig
inline FORCE_INLINE Real & getPressure (const unsigned int fluidIndex, const unsigned
inline FORCE_INLINE void setPressure (const unsigned int fluidIndex, const unsigned in
inline FORCE_INLINE const Real getLastPressure (const unsigned int fluidIndex, const u
inline FORCE_INLINE Real & getLastPressure (const unsigned int fluidIndex, const unsig
inline FORCE_INLINE void setLastPressure (const unsigned int fluidIndex, const unsigne
inline FORCE_INLINE Vector3r & getPressureAccel (const unsigned int fluidIndex, const
inline FORCE_INLINE const Vector3r & getPressureAccel (const unsigned int fluidIndex,
inline FORCE_INLINE void setPressureAccel (const unsigned int fluidIndex, const unsigne

Protected Attributes

std::vector<std::vector<*Real*>> **m_aii**

std::vector<std::vector<*Vector3r*>> **m_dii**

std::vector<std::vector<*Vector3r*>> **m_dij_pj**

std::vector<std::vector<*Real*>> **m_density_adv**

std::vector<std::vector<*Real*>> **m_pressure**

std::vector<std::vector<*Real*>> **m_lastPressure**

std::vector<std::vector<*Vector3r*>> **m_pressureAccel**

Class SimulationDataPBF

- Defined in file_SPlisHSPlasH_PBF_SimulationDataPBF.h

Class Documentation

class SPH::**SimulationDataPBF**

Simulation data which is required by the method Position-Based Fluids introduced by Macklin and Mueller [MM13,BMO+14,BMM15].

References:

- [MM13] Miles Macklin and Matthias Müller. Position based fluids. ACM Trans. Graph., 32(4):104:1-104:12, July 2013. URL: http://doi.acm.org/10.1145/2461912.2461984
- [BMO+14] Jan Bender, Matthias Müller, Miguel A. Otaduy, Matthias Teschner, and Miles Macklin. A survey on position-based simulation methods in computer graphics. Computer Graphics Forum, 33(6):228-251, 2014. URL: http://dx.doi.org/10.1111/cgf.12346
- [BMM15] Jan Bender, Matthias Müller, and Miles Macklin. Position-based simulation methods in computer graphics. In EUROGRAPHICS 2015 Tutorials. Eurographics Association, 2015. URL: http://dx.doi.org/10.2312/egt.20151045

Public Functions

SimulationDataPBF()

virtual ~SimulationDataPBF()

virtual void **init**()
Initialize the arrays containing the particle data.

virtual void **cleanup**()
Release the arrays containing the particle data.

virtual void **reset**()
Reset the particle data.

void **performNeighborhoodSearchSort**()
Important: First call m_model->*performNeighborhoodSearchSort()* to call the z_sort of the neighborhood search.

void **emittedParticles**(*FluidModel* *model, **const** unsigned int *startIndex*)

inline FORCE_INLINE const Real & getLambda (const unsigned int fluidIndex, const unsig

inline FORCE_INLINE Real & getLambda (const unsigned int fluidIndex, const unsigned in

inline FORCE_INLINE void setLambda (const unsigned int fluidIndex, const unsigned int

inline FORCE_INLINE Vector3r & getDeltaX (const unsigned int fluidIndex, const unsigne

inline FORCE_INLINE const Vector3r & getDeltaX (const unsigned int fluidIndex, const u

inline FORCE_INLINE void setDeltaX (const unsigned int fluidIndex, const unsigned int

inline FORCE_INLINE Vector3r & getLastPosition (const unsigned int fluidIndex, const u

inline FORCE_INLINE const Vector3r & getLastPosition (const unsigned int fluidIndex, c

inline FORCE_INLINE void setLastPosition (const unsigned int fluidIndex, const unsigne

inline FORCE_INLINE Vector3r & getOldPosition (const unsigned int fluidIndex, const un

inline FORCE_INLINE const Vector3r & getOldPosition (const unsigned int fluidIndex, co

inline FORCE_INLINE void setOldPosition (const unsigned int fluidIndex, const unsigned

Protected Attributes

std::vector<std::vector<*Real*>> **m_lambda**

std::vector<std::vector<*Vector3r*>> **m_deltaX**

std::vector<std::vector<*Vector3r*>> **m_oldX**

std::vector<std::vector<*Vector3r*>> **m_lastX**

Class SimulationDataPCISPH

- Defined in file_SPlisHSPlasH_PCISPH_SimulationDataPCISPH.h

Class Documentation

class SPH::**SimulationDataPCISPH**

Simulation data which is required by the method Predictive-corrective Incompressible SPH introduced by Solenthaler and Pajarola [SP09].

References:

- [SP09] B. Solenthaler and R. Pajarola. Predictive-corrective incompressible SPH. ACM Trans. Graph., 28(3):40:1-40:6, July 2009. URL: http://doi.acm.org/10.1145/1531326.1531346

Public Functions

SimulationDataPCISPH()

virtual **~SimulationDataPCISPH**()

virtual void **init**()
Initialize the arrays containing the particle data.

virtual void **cleanup**()
Release the arrays containing the particle data.

virtual void **reset**()
Reset the particle data.

void **performNeighborhoodSearchSort**()
Important: First call m_model->*performNeighborhoodSearchSort()* to call the z_sort of the neighborhood search.

inline *Real* **getPCISPH_ScalingFactor**(**const** unsigned int *fluidIndex*)

void **emittedParticles**(*FluidModel* **model*, **const** unsigned int *startIndex*)

inline FORCE_INLINE Vector3r & getPredictedPosition (const unsigned int fluidIndex, co

inline FORCE_INLINE const Vector3r & getPredictedPosition (const unsigned int fluidInd

inline FORCE_INLINE void setPredictedPosition (const unsigned int fluidIndex, const un

inline FORCE_INLINE Vector3r & getPredictedVelocity (const unsigned int fluidIndex, co

inline FORCE_INLINE const Vector3r & getPredictedVelocity (const unsigned int fluidInd

inline FORCE_INLINE void setPredictedVelocity (const unsigned int fluidIndex, const un

inline FORCE_INLINE const Real getDensityAdv (const unsigned int fluidIndex, const uns

inline FORCE_INLINE Real & getDensityAdv (const unsigned int fluidIndex, const unsigne

inline FORCE_INLINE void setDensityAdv (const unsigned int fluidIndex, const unsigned

inline FORCE_INLINE const Real getPressure (const unsigned int fluidIndex, const unsig

inline FORCE_INLINE Real & getPressure (const unsigned int fluidIndex, const unsigned

inline FORCE_INLINE void setPressure (const unsigned int fluidIndex, const unsigned int

inline FORCE_INLINE Vector3r & getPressureAccel (const unsigned int fluidIndex, const

inline FORCE_INLINE const Vector3r & getPressureAccel (const unsigned int fluidIndex,

inline FORCE_INLINE void setPressureAccel (const unsigned int fluidIndex, const unsigne

Protected Attributes

std::vector<*Real*> **m_pcisph_factor**

std::vector<std::vector<*Vector3r*>> **m_predX**

std::vector<std::vector<*Vector3r*>> **m_predV**

std::vector<std::vector<*Real*>> **m_densityAdv**

std::vector<std::vector<*Real*>> **m_pressure**

std::vector<std::vector<*Vector3r*>> **m_pressureAccel**

Class SimulationDataPF

- Defined in file_SPlisHSPlasH_PF_SimulationDataPF.h

Class Documentation

class SPH::**SimulationDataPF**

Simulation data which is required by the method Projective Fluids introduced by Weiler, Koschier and Bender [WKB16].

References:

- [WKB16] Marcel Weiler, Dan Koschier, and Jan Bender. Projective fluids. In Proceedings of the 9th International Conference on Motion in Games, MIG '16, 79-84. New York, NY, USA, 2016. ACM. URL: http://doi.acm.org/10.1145/2994258.2994282

Public Functions

SimulationDataPF()

virtual ~SimulationDataPF()

virtual void **init**()
Initialize the arrays containing the particle data.

virtual void **cleanup**()
Release the arrays containing the particle data.

virtual void **reset**()
Reset the particle data.

void **performNeighborhoodSearchSort** ()
Important: First call m_model->*performNeighborhoodSearchSort()* to call the z_sort of the neighborhood search.

void **emittedParticles** (*FluidModel* *model, **const** unsigned int *startIndex*)

inline FORCE_INLINE const Vector3r getOldPosition (const unsigned int fluidIndex, const

inline FORCE_INLINE Vector3r & getOldPosition (const unsigned int fluidIndex, const uns

inline FORCE_INLINE void setOldPosition (const unsigned int fluidIndex, const unsigned

inline FORCE_INLINE const unsigned int getNumFluidNeighbors (const unsigned int fluidIn

inline FORCE_INLINE unsigned int & getNumFluidNeighbors (const unsigned int fluidIndex

inline FORCE_INLINE void setNumFluidNeighbors (const unsigned int fluidIndex, const uns

inline FORCE_INLINE const Vector3r & getS (const unsigned int fluidIndex, const unsigne

inline FORCE_INLINE Vector3r & getS (const unsigned int fluidIndex, const unsigned int

inline FORCE_INLINE void setS (const unsigned int fluidIndex, const unsigned int i, con

inline FORCE_INLINE const Vector3r & getDiag (const unsigned int fluidIndex, const unsi

inline FORCE_INLINE Vector3r & getDiag (const unsigned int fluidIndex, const unsigned

inline FORCE_INLINE void setDiag (const unsigned int fluidIndex, const unsigned int i,

inline FORCE_INLINE const unsigned int & getParticleOffset (const unsigned int fluidInd

Protected Attributes

std::vector<std::vector<*Vector3r*>> **m_old_position**
particle position from last timestep

std::vector<std::vector<unsigned int>> **m_num_fluid_neighbors**
number of neighbors that are fluid particles

std::vector<std::vector<*Vector3r*>> **m_s**
positions predicted from momentum

std::vector<std::vector<*Vector3r*>> **m_mat_diag**
diagonal of system matrix, used by preconditioner

std::vector<unsigned int> **m_particleOffset**

Class SimulationDataWCSPH

- Defined in file_SPlisHSPlasH_WCSPH_SimulationDataWCSPH.h

Class Documentation

class SPH::**SimulationDataWCSPH**

Simulation data which is required by the method Weakly Compressible SPH for Free Surface Flows introduced by Becker and Teschner [BT07].

References:

- [BT07] Markus Becker and Matthias Teschner. Weakly compressible SPH for free surface flows. In ACM SIGGRAPH/Eurographics Symposium on Computer Animation, SCA '07, 209-217. Aire-la-Ville, Switzerland, Switzerland, 2007. Eurographics Association. URL: http://dl.acm.org/citation.cfm?id=1272690.1272719

Public Functions

SimulationDataWCSPH()

virtual ~SimulationDataWCSPH()

virtual void **init**()
Initialize the arrays containing the particle data.

virtual void **cleanup**()
Release the arrays containing the particle data.

virtual void **reset**()
Reset the particle data.

void **performNeighborhoodSearchSort**()
Important: First call m_model->*performNeighborhoodSearchSort()* to call the z_sort of the neighborhood search.

void **emittedParticles**(*FluidModel* *model, **const** unsigned int *startIndex*)

inline FORCE_INLINE const Real getPressure (const unsigned int fluidIndex, const unsig

inline FORCE_INLINE Real & getPressure (const unsigned int fluidIndex, const unsigned

inline FORCE_INLINE void setPressure (const unsigned int fluidIndex, const unsigned in

inline FORCE_INLINE Vector3r & getPressureAccel (const unsigned int fluidIndex, const

inline FORCE_INLINE const Vector3r & getPressureAccel (const unsigned int fluidIndex,

inline FORCE_INLINE void setPressureAccel (const unsigned int fluidIndex, const unsigne

Protected Attributes

std::vector<std::vector<*Real*>> **m_pressure**

std::vector<std::vector<*Vector3r*>> **m_pressureAccel**

Class SpikyKernel

- Defined in file_SPlisHSPlasH_SPHKernels.h

Class Documentation

class SPH::**SpikyKernel**

Spiky kernel.

Public Static Functions

static inline *Real* **getRadius**()

static inline void **setRadius**(*Real* *val*)

static inline *Real* **W**(**const** *Real* *r*)

W(r,h) = 15/(pi*h^6) * (h-r)^3

static inline *Real* **W**(**const** *Vector3r* &*r*)

static inline *Vector3r* **gradW**(**const** *Vector3r* &*r*)

grad(W(r,h)) = -r(45/(pi*h^6) * (h-r)^2)

static inline *Real* **W_zero**()

Protected Static Attributes

static *Real* **m_radius**

static *Real* **m_k**

static *Real* **m_l**

static *Real* **m_W_zero**

Class StaticRigidBody

- Defined in file_SPlisHSPlasH_StaticRigidBody.h

Inheritance Relationships

Base Type

- `public SPH::RigidBodyObject` (*Class RigidBodyObject*)

Class Documentation

class SPH::**StaticRigidBody** : **public** SPH::*RigidBodyObject*

This class stores the information of a static rigid body which is not part of a rigid body simulation.

Public Functions

inline **StaticRigidBody**()

inline **virtual** bool **isDynamic**() **const**

inline **virtual** *Real* **const** **getMass**() **const**

inline **virtual** *Vector3r* **const** &**getPosition**() **const**

inline **virtual** void **setPosition**(**const** *Vector3r* &*x*)

inline *Vector3r* **const** &**getPosition0**() **const**

inline void **setPosition0**(**const** *Vector3r* &*x*)

inline **virtual** *Vector3r* **getWorldSpacePosition**() **const**

inline **virtual** *Vector3r* **const** &**getVelocity**() **const**

inline **virtual** void **setVelocity**(**const** *Vector3r* &*v*)

inline **virtual** *Quaternionr* **const** &**getRotation**() **const**

inline **virtual** void **setRotation**(**const** *Quaternionr* &*q*)

inline *Quaternionr* **const** &**getRotation0**() **const**

inline void **setRotation0**(**const** *Quaternionr* &*q*)

inline **virtual** *Matrix3r* **getWorldSpaceRotation**() **const**

inline **virtual** *Vector3r* **const** &**getAngularVelocity**() **const**

inline **virtual** void **setAngularVelocity**(**const** *Vector3r* &*v*)

inline **virtual** void **addForce**(**const** *Vector3r* &*f*)

inline **virtual** void **addTorque**(**const** *Vector3r* &*t*)

inline void **animate**()

inline **virtual** **const** std::vector<*Vector3r*> &**getVertices**() **const**

inline **virtual** **const** std::vector<*Vector3r*> &**getVertexNormals**() **const**

inline **virtual** **const** std::vector<unsigned int> &**getFaces**() **const**

inline void **setWorldSpacePosition**(**const** *Vector3r* &*x*)

inline void **setWorldSpaceRotation**(**const** *Matrix3r* &*r*)

inline *TriangleMesh* &**getGeometry**()

inline **virtual** void **updateMeshTransformation**()

inline void **reset**()

Protected Attributes

Vector3r **m_x0**

Vector3r **m_x**

Quaternionr **m_q**

Quaternionr **m_q0**

Vector3r **m_velocity**

Vector3r **m_angularVelocity**

TriangleMesh **m_geometry**

Class SurfaceTension_Akinci2013

- Defined in file_SPlisHSPlasH_SurfaceTension_SurfaceTension_Akinci2013.h

Inheritance Relationships

Base Type

- `public SPH::SurfaceTensionBase` (*Class SurfaceTensionBase*)

Class Documentation

class `SPH::`**SurfaceTension_Akinci2013** : **public** SPH::*SurfaceTensionBase*

This class implements the surface tension method introduced by Akinci et al. [ATT13].

References:

- [AAT13] Nadir Akinci, Gizem Akinci, and Matthias Teschner. Versatile surface tension and adhesion for sph fluids. ACM Trans. Graph., 32(6):182:1-182:8, November 2013. URL: http://doi.acm.org/10.1145/2508363.2508395

Public Functions

SurfaceTension_Akinci2013(*FluidModel* **model*)

virtual ~SurfaceTension_Akinci2013(void)

virtual void **step**()

virtual void **reset**()

void **computeNormals**()

virtual void **performNeighborhoodSearchSort**()

inline FORCE_INLINE Vector3r & getNormal (const unsigned int i)

inline FORCE_INLINE const Vector3r & getNormal (const unsigned int i) const

inline FORCE_INLINE void setNormal (const unsigned int i, const Vector3r &val)

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* **model*)

Protected Attributes

std::vector<*Vector3r*> **m_normals**

Class SurfaceTension_Becker2007

- Defined in file_SPlisHSPlasH_SurfaceTension_SurfaceTension_Becker2007.h

Inheritance Relationships

Base Type

- `public SPH::SurfaceTensionBase` (*Class SurfaceTensionBase*)

Class Documentation

class `SPH::`**SurfaceTension_Becker2007** : **public** SPH::*SurfaceTensionBase*

This class implements the surface tension method introduced by Becker and Teschner [BT07].

References:

- [BT07] Markus Becker and Matthias Teschner. Weakly compressible SPH for free surface flows. In ACM SIGGRAPH/Eurographics Symposium on Computer Animation, SCA '07, 209-217. Aire-la-Ville, Switzerland, Switzerland, 2007. Eurographics Association. URL: http://dl.acm.org/citation.cfm?id=1272690.1272719

Public Functions

SurfaceTension_Becker2007 (*FluidModel* **model*)

virtual ~SurfaceTension_Becker2007 (void)

virtual void **step** ()

virtual void **reset** ()

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* **model*)

Class SurfaceTension_He2014

- Defined in file_SPlisHSPlasH_SurfaceTension_SurfaceTension_He2014.h

Inheritance Relationships

Base Type

- `public SPH::SurfaceTensionBase` (*Class SurfaceTensionBase*)

Class Documentation

class `SPH::`**SurfaceTension_He2014** : **public** SPH::*SurfaceTensionBase*

This class implements the surface tension method introduced by He et al. [HWZ+14].

References:

- [HWZ+14] Xiaowei He, Huamin Wang, Fengjun Zhang, Hongan Wang, Guoping Wang, and Kun Zhou. Robust simulation of sparsely sampled thin features in SPH-based free surface flows. ACM Trans. Graph., 34(1):7:1-7:9, December 2014. URL: http://doi.acm.org/10.1145/2682630

Public Functions

SurfaceTension_He2014 (*FluidModel* **model*)

virtual ~SurfaceTension_He2014 (void)

virtual void **step** ()

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

inline FORCE_INLINE const Real getColor (const unsigned int i) const

inline FORCE_INLINE Real & getColor (const unsigned int i)

inline FORCE_INLINE void setColor (const unsigned int i, const Real p)

inline FORCE_INLINE const Real getGradC2 (const unsigned int i) const

inline FORCE_INLINE Real & getGradC2 (const unsigned int i)

inline FORCE_INLINE void setGradC2 (const unsigned int i, const Real p)

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* **model*)

Protected Attributes

std::vector<*Real*> **m_color**

std::vector<*Real*> **m_gradC2**

Class SurfaceTension_ZorillaRitter2020

- Defined in file_SPlisHSPlasH_SurfaceTension_SurfaceTension_ZorillaRitter2020.h

Inheritance Relationships

Base Type

- `public SPH::SurfaceTensionBase` (*Class SurfaceTensionBase*)

Class Documentation

class `SPH::`**SurfaceTension_ZorillaRitter2020** : **public** SPH::*SurfaceTensionBase*

This class implements the surface tension method introduced by Zorilla, Ritter, Sappl, Rauch, Harders: extended version 2020: https://doi.org/10.3390/computers9020023 and original version 2019: https://diglib.eg.org/handle/10.2312/cgvc20191260

Public Functions

SurfaceTension_ZorillaRitter2020(*FluidModel* **model*)

virtual ~SurfaceTension_ZorillaRitter2020(void)

virtual void **performNeighborhoodSearchSort**() **override**

Public Static Functions

static inline *NonPressureForceBase* ***creator**(*FluidModel* **model*)

static bool **classifySurfaceParticle**(double *com*, int *non*, double *d_offset* = 0.0)

Linear classifier. Divides into surface or non-surface particle. The function is equivalent to the network classifier. Also, inspect lines 344 to 348 in the cpp file for how to compute the required input.

Parameters

- **com** – normalized center of mass / number of neighbors
- **non** – number of neighbors
- **d_offset** – constant parameter d

Returns true if surface, false otherwise

Class SurfaceTensionBase

- Defined in file_SPlisHSPlasH_SurfaceTension_SurfaceTensionBase.h

Inheritance Relationships

Base Type

- `public SPH::NonPressureForceBase` (*Class NonPressureForceBase*)

Derived Types

- `public SPH::SurfaceTension_Akinci2013` (*Class SurfaceTension_Akinci2013*)
- `public SPH::SurfaceTension_Becker2007` (*Class SurfaceTension_Becker2007*)
- `public SPH::SurfaceTension_He2014` (*Class SurfaceTension_He2014*)
- `public SPH::SurfaceTension_ZorillaRitter2020` (*Class SurfaceTension_ZorillaRitter2020*)

Class Documentation

class `SPH::`**SurfaceTensionBase** : **public** SPH::*NonPressureForceBase*

Base class for all surface tension methods.

Subclassed by *SPH::SurfaceTension_Akinci2013*, *SPH::SurfaceTension_Becker2007*, *SPH::SurfaceTension_He2014*, *SPH::SurfaceTension_ZorillaRitter2020*

Public Functions

SurfaceTensionBase(*FluidModel* **model*)

virtual ~SurfaceTensionBase(void)

Public Static Attributes

static int **SURFACE_TENSION** = -1

static int **SURFACE_TENSION_BOUNDARY** = -1

Protected Functions

virtual void **initParameters**()

Protected Attributes

Real **m_surfaceTension**

Real **m_surfaceTensionBoundary**

Class TimeIntegration

- Defined in file_SPlisHSPlasH_PBF_TimeIntegration.h

Class Documentation

class SPH::**TimeIntegration**

Class for the position-based fluids time integration.

Public Static Functions

static void **semiImplicitEuler**(**const** *Real h*, **const** *Real mass*, *Vector3r &position*, *Vector3r &velocity*, **const** *Vector3r &acceleration*)

Perform an integration step for a particle using the semi-implicit Euler (symplectic Euler) method:

$$\mathbf{v}(t+h) = \mathbf{v}(t) + \mathbf{a}(t)h$$
$$\mathbf{x}(t+h) = \mathbf{x}(t) + \mathbf{v}(t+h)h$$

Parameters

- **h** – time step size
- **mass** – mass of the particle
- **position** – position of the particle
- **velocity** – velocity of the particle
- **acceleration** – acceleration of the particle

static void **velocityUpdateFirstOrder**(**const** *Real h*, **const** *Real mass*, **const** *Vector3r &position*, **const** *Vector3r &oldPosition*, *Vector3r &velocity*)

Perform a velocity update (first order) for the linear velocity:

$$\mathbf{v}(t+h) = \frac{1}{h}(\mathbf{p}(t+h) - \mathbf{p}(t)$$

Parameters

- **h** – time step size
- **mass** – mass of the particle
- **position** – new position $\mathbf{p}(t+h)$ of the particle
- **oldPosition** – position $\mathbf{p}(t)$ of the particle before the time step
- **velocity** – resulting velocity of the particle

static void **velocityUpdateSecondOrder**(**const** *Real h*, **const** *Real mass*, **const** *Vector3r &position*, **const** *Vector3r &oldPosition*, **const** *Vector3r &positionOfLastStep*, *Vector3r &velocity*)

Class TimeManager

- Defined in file_SPlisHSPlasH_TimeManager.h

Class Documentation

class SPH::**TimeManager**

Class to manage the current simulation time and the time step size. This class is a singleton.

Public Functions

TimeManager()

~TimeManager()

Real **getTime**()

void **setTime**(*Real t*)

Real **getTimeStepSize**()

void **setTimeStepSize**(*Real tss*)

void **saveState**(*BinaryFileWriter &binWriter*)

void **loadState**(*BinaryFileReader &binReader*)

Public Static Functions

static *TimeManager* ***getCurrent**()

static void **setCurrent**(*TimeManager *tm*)

static bool **hasCurrent**()

Class TimeStep

- Defined in file_SPlisHSPlasH_TimeStep.h

Inheritance Relationships

Base Type

- public ParameterObject

Derived Types

- `public SPH::TimeStepDFSPH` (*Class TimeStepDFSPH*)
- `public SPH::TimeStepICSPH` (*Class TimeStepICSPH*)
- `public SPH::TimeStepIISPH` (*Class TimeStepIISPH*)
- `public SPH::TimeStepPBF` (*Class TimeStepPBF*)
- `public SPH::TimeStepPCISPH` (*Class TimeStepPCISPH*)
- `public SPH::TimeStepPF` (*Class TimeStepPF*)
- `public SPH::TimeStepWCSPH` (*Class TimeStepWCSPH*)

Class Documentation

class `SPH::`**TimeStep** : **public** ParameterObject

Base class for the simulation methods.

Subclassed by *SPH::TimeStepDFSPH*, *SPH::TimeStepICSPH*, *SPH::TimeStepIISPH*, *SPH::TimeStepPBF*, *SPH::TimeStepPCISPH*, *SPH::TimeStepPF*, *SPH::TimeStepWCSPH*

Public Functions

TimeStep()

virtual ~TimeStep(void)

void **computeDensities**(**const** unsigned int *fluidModelIndex*)

Determine densities of all fluid particles.

virtual void **step**() = 0

virtual void **reset**()

virtual void **init**()

virtual void **resize**() = 0

inline virtual void **emittedParticles**(*FluidModel* **model*, **const** unsigned int *startIndex*)

inline virtual void **saveState**(*BinaryFileWriter* &*binWriter*)

inline virtual void **loadState**(*BinaryFileReader* &*binReader*)

Public Static Attributes

static int **SOLVER_ITERATIONS** = -1

static int **MIN_ITERATIONS** = -1

static int **MAX_ITERATIONS** = -1

static int **MAX_ERROR** = -1

Protected Functions

void **clearAccelerations**(**const** unsigned int *fluidModelIndex*)
Clear accelerations and add gravitation.

virtual void **initParameters**()

void **approximateNormal**(Discregrid::DiscreteGrid **map*, **const** Eigen::Vector3d *&x*, Eigen::Vector3d *&n*, **const** unsigned int *dim*)

void **computeVolumeAndBoundaryX**(**const** unsigned int *fluidModelIndex*, **const** unsigned int *i*, **const** *Vector3r* *&xi*)

void **computeVolumeAndBoundaryX**()

void **computeDensityAndGradient**(**const** unsigned int *fluidModelIndex*, **const** unsigned int *i*, **const** *Vector3r* *&xi*)

void **computeDensityAndGradient**()

Protected Attributes

unsigned int **m_iterations**

Real **m_maxError**

unsigned int **m_minIterations**

unsigned int **m_maxIterations**

Class TimeStepDFSPH

- Defined in file_SPlisHSPlasH_DFSPH_TimeStepDFSPH.h

Inheritance Relationships

Base Type

- `public SPH::TimeStep` (*Class TimeStep*)

Class Documentation

class `SPH::`**TimeStepDFSPH** : **public** SPH::*TimeStep*
This class implements the Divergence-free Smoothed Particle Hydrodynamics approach introduced by Bender and Koschier [BK15,BK17,KBST19].

References:

- [BK15] Jan Bender and Dan Koschier. Divergence-free smoothed particle hydrodynamics. In ACM SIGGRAPH / Eurographics Symposium on Computer Animation, SCA '15, 147-155. New York, NY, USA, 2015. ACM. URL: http://doi.acm.org/10.1145/2786784.2786796
- [BK17] Jan Bender and Dan Koschier. Divergence-free SPH for incompressible and viscous fluids. IEEE Transactions on Visualization and Computer Graphics, 23(3):1193-1206, 2017. URL: http://dx.doi.org/10.1109/TVCG.2016.2578335

- [KBST19] Dan Koschier, Jan Bender, Barbara Solenthaler, and Matthias Teschner. Smoothed particle hydrodynamics for physically-based simulation of fluids and solids. In Eurographics 2019 - Tutorials. Eurographics Association, 2019. URL: https://interactivecomputergraphics.github.io/SPH-Tutorial

Public Functions

TimeStepDFSPH()

virtual ~TimeStepDFSPH(void)

virtual void **step**()

virtual void **reset**()

virtual void **resize**()

Public Static Attributes

static int **SOLVER_ITERATIONS_V** = -1

static int **MAX_ITERATIONS_V** = -1

static int **MAX_ERROR_V** = -1

static int **USE_DIVERGENCE_SOLVER** = -1

Protected Functions

void **computeDFSPHFactor**(**const** unsigned int *fluidModelIndex*)

void **pressureSolve**()

void **pressureSolveIteration**(**const** unsigned int *fluidModelIndex*, *Real* &*avg_density_err*)

void **divergenceSolve**()

void **divergenceSolveIteration**(**const** unsigned int *fluidModelIndex*, *Real* &*avg_density_err*)

void **computeDensityAdv**(**const** unsigned int *fluidModelIndex*, **const** unsigned int *index*, **const** int *numParticles*, **const** *Real h*, **const** *Real density0*)

void **computeDensityChange**(**const** unsigned int *fluidModelIndex*, **const** unsigned int *index*, **const** *Real h*)

void **warmstartDivergenceSolve**(**const** unsigned int *fluidModelIndex*)

void **warmstartPressureSolve**(**const** unsigned int *fluidModelIndex*)

void **performNeighborhoodSearch**()
Perform the neighborhood search for all fluid particles.

virtual void **emittedParticles**(*FluidModel* **model*, **const** unsigned int *startIndex*)

virtual void **initParameters**()

Protected Attributes

SimulationDataDFSPH **m_simulationData**

unsigned int **m_counter**

const *Real* **m_eps** = static_cast<*Real*>(1.0e-5)

bool **m_enableDivergenceSolver**

unsigned int **m_iterationsV**

Real **m_maxErrorV**

unsigned int **m_maxIterationsV**

Class TimeStepICSPH

- Defined in file_SPlisHSPlasH_ICSPH_TimeStepICSPH.h

Inheritance Relationships

Base Type

- `public SPH::TimeStep` (*Class TimeStep*)

Class Documentation

class `SPH::`**TimeStepICSPH** : **public** SPH::*TimeStep*

This class implements the Implicit Compressible SPH approach introduced by Gissler et al. [GHB+20].

References:

- [GHB+20] Christoph Gissler, Andreas Henne, Stefan Band, Andreas Peer and Matthias Teschner. An Implicit Compressible SPH Solver for Snow *Simulation*. ACM Transactions on Graphics, 39(4). URL: https://doi.org/10.1145/3386569.3392431

Public Functions

TimeStepICSPH()

virtual ~TimeStepICSPH(void)

virtual void **step**()

virtual void **reset**()

virtual void **resize**()

inline const *SimulationDataICSPH* &**getSimulationData**()

Public Static Attributes

static int **LAMBDA** = -1

static int **PRESSURE_CLAMPING** = -1

Protected Functions

void **computeDensityAdv**(**const** unsigned int *fluidModelIndex*)
Compute rho_adv, i ^ (0) (see equation(6) in[GHB + 20]) using the velocities after the non-pressure forces were applied.

void **compute_aii**(**const** unsigned int *fluidModelIndex*)

void **pressureSolve**()

void **pressureSolveIteration**(**const** unsigned int *fluidModelIndex*, *Real* &*avg_density_err*)

void **integration**(**const** unsigned int *fluidModelIndex*)

void **computePressureAccels**(**const** unsigned int *fluidModelIndex*)
Determine the pressure accelerations when the pressure is already known.

void **performNeighborhoodSearch**()
Perform the neighborhood search for all fluid particles.

virtual void **initParameters**()

virtual void **emittedParticles**(*FluidModel* *model, **const** unsigned int *startIndex*)

Protected Attributes

SimulationDataICSPH **m_simulationData**

Real **m_lambda**

bool **m_clamping**

const *Real* **m_psi** = 1.5

unsigned int **m_counter**

Class TimeStepIISPH

- Defined in file_SPlisHSPlasH_IISPH_TimeStepIISPH.h

Inheritance Relationships

Base Type

- `public SPH::TimeStep` (*Class TimeStep*)

Class Documentation

class SPH::**TimeStepIISPH** : **public** SPH::*TimeStep*

This class implements the Implicit Incompressible SPH approach introduced by Ihmsen et al. [ICS+14].

References:

- [ICS+14] Markus Ihmsen, Jens Cornelis, Barbara Solenthaler, Christopher Horvath, and Matthias Teschner. Implicit incompressible SPH. IEEE Transactions on Visualization and Computer Graphics, 20(3):426-435, March 2014. URL: http://dx.doi.org/10.1109/TVCG.2013.105

Public Functions

TimeStepIISPH()

virtual **~TimeStepIISPH**(void)

virtual void **step**()

virtual void **reset**()

virtual void **resize**()

inline **const** *SimulationDataIISPH* &**getSimulationData**()

Protected Functions

void **predictAdvection**(**const** unsigned int *fluidModelIndex*)

void **pressureSolve**()

void **pressureSolveIteration**(**const** unsigned int *fluidModelIndex*, *Real* &*avg_density_err*)

void **integration**(**const** unsigned int *fluidModelIndex*)

void **computePressureAccels**(**const** unsigned int *fluidModelIndex*)
Determine the pressure accelerations when the pressure is already known.

void **performNeighborhoodSearch**()
Perform the neighborhood search for all fluid particles.

virtual void **emittedParticles**(*FluidModel* *model, **const** unsigned int *startIndex*)

Protected Attributes

SimulationDataIISPH **m_simulationData**

unsigned int **m_counter**

Class TimeStepPBF

- Defined in file_SPlisHSPlasH_PBF_TimeStepPBF.h

Inheritance Relationships

Base Type

- `public SPH::TimeStep` (*Class TimeStep*)

Class Documentation

class `SPH::`**TimeStepPBF** : **public** SPH::*TimeStep*

This class implements the position-based fluids approach introduced by Macklin and Mueller [MM13,BMO+14,BMM15].

References:

- [MM13] Miles Macklin and Matthias Müller. Position based fluids. ACM Trans. Graph., 32(4):104:1-104:12, July 2013. URL: http://doi.acm.org/10.1145/2461912.2461984
- [BMO+14] Jan Bender, Matthias Müller, Miguel A. Otaduy, Matthias Teschner, and Miles Macklin. A survey on position-based simulation methods in computer graphics. Computer Graphics Forum, 33(6):228-251, 2014. URL: http://dx.doi.org/10.1111/cgf.12346
- [BMM15] Jan Bender, Matthias Müller, and Miles Macklin. Position-based simulation methods in computer graphics. In EUROGRAPHICS 2015 Tutorials. Eurographics Association, 2015. URL: http://dx.doi.org/10.2312/egt.20151045

Public Functions

TimeStepPBF()

Initialize the simulation data required for this method.

virtual ~TimeStepPBF(void)

virtual void **step**()

Perform a simulation step.

virtual void **reset**()

Reset the simulation method.

virtual void **resize**()

Public Static Attributes

static int **VELOCITY_UPDATE_METHOD** = -1

static int **ENUM_PBF_FIRST_ORDER** = -1

static int **ENUM_PBF_SECOND_ORDER** = -1

Protected Functions

void **pressureSolve**()
Perform a position-based correction step for the following density constraint:$C(\mathbf{x}) = \left(\frac{\rho_i}{\rho_0} - 1\right) = 0$

void **pressureSolveIteration**(**const** unsigned int *fluidModelIndex*, *Real* &*avg_density_err*)

void **performNeighborhoodSearch**()
Perform the neighborhood search for all fluid particles.

virtual void **emittedParticles**(*FluidModel* *model, **const** unsigned int *startIndex*)

virtual void **initParameters**()

Protected Attributes

SimulationDataPBF **m_simulationData**

unsigned int **m_counter**

int **m_velocityUpdateMethod**

Class TimeStepPCISPH

- Defined in file_SPlisHSPlasH_PCISPH_TimeStepPCISPH.h

Inheritance Relationships

Base Type

- `public SPH::TimeStep` (*Class TimeStep*)

Class Documentation

class `SPH::`**TimeStepPCISPH** : **public** SPH::*TimeStep*
This class implements the Predictive-corrective Incompressible SPH approach introduced by Solenthaler and Pajarola [SP09].

References:

- [SP09] B. Solenthaler and R. Pajarola. Predictive-corrective incompressible SPH. ACM Trans. Graph., 28(3):40:1-40:6, July 2009. URL: http://doi.acm.org/10.1145/1531326.1531346

Public Functions

TimeStepPCISPH()

virtual **~TimeStepPCISPH**(void)

virtual void **step**()

virtual void **reset**()

virtual void **resize**()

Protected Functions

void **pressureSolve**()

void **pressureSolveIteration**(**const** unsigned int *fluidModelIndex*, *Real* &*avg_density_err*)

void **performNeighborhoodSearch**()
Perform the neighborhood search for all fluid particles.

virtual void **emittedParticles**(*FluidModel* *model, **const** unsigned int *startIndex*)

Protected Attributes

SimulationDataPCISPH **m_simulationData**

unsigned int **m_counter**

Class TimeStepPF

- Defined in file_SPlisHSPlasH_PF_TimeStepPF.h

Inheritance Relationships

Base Type

- `public SPH::TimeStep` (*Class TimeStep*)

Class Documentation

class `SPH::`**TimeStepPF** : **public** SPH::*TimeStep*
This class implements the Projective Fluids approach introduced by Weiler, Koschier and Bender [WKB16].

References:

- [WKB16] Marcel Weiler, Dan Koschier, and Jan Bender. Projective fluids. In Proceedings of the 9th International Conference on Motion in Games, MIG '16, 79-84. New York, NY, USA, 2016. ACM. URL: http://doi.acm.org/10.1145/2994258.2994282

Public Functions

TimeStepPF()

virtual **~TimeStepPF**(void)

virtual void **step**() **override**

virtual void **reset**() **override**

virtual void **resize**() **override**

Public Static Functions

static void **matrixVecProd**(**const** *Real* *vec, *Real* *result, void *userData)

Public Static Attributes

static int **STIFFNESS** = -1

Protected Types

using VectorXr = Eigen::Matrix<*Real*, -1, 1>

using VectorXrMap = Eigen::Map<*VectorXr*>

using Solver = Eigen::ConjugateGradient<*MatrixReplacement*, Eigen::Lower | Eigen::Upper, *JacobiPreconditioner3D*>

Protected Functions

void **preparePreconditioner**()

void **initialGuessForPositions**(**const** unsigned int *fluidModelIndex*)

void **solvePDConstraints**()

void **updatePositionsAndVelocity**(**const** *VectorXr* &*x*)

void **addAccellerationToVelocity**()

void **matrixFreeRHS**(**const** *VectorXr* &*x*, *VectorXr* &*result*)
compute the right hand side of the system in a matrix-free fashion and store the result in result

void **performNeighborhoodSearch**()
Perform the neighborhood search for all fluid particles.

virtual void **emittedParticles**(*FluidModel* *model, **const** unsigned int *startIndex*) **override**

virtual void **initParameters**() **override**

Protected Attributes

SimulationDataPF **m_simulationData**

Solver **m_solver**

Real **m_stiffness**

unsigned int **m_counter**

unsigned int **m_numActiveParticlesTotal**

Protected Static Functions

static FORCE_INLINE void diagonalMatrixElement (const unsigned int row, Vector3r &resu

Class TimeStepWCSPH

- Defined in file_SPlisHSPlasH_WCSPH_TimeStepWCSPH.h

Inheritance Relationships

Base Type

- `public SPH::TimeStep` (*Class TimeStep*)

Class Documentation

class `SPH::`**TimeStepWCSPH** : **public** SPH::*TimeStep*

This class implements the Weakly Compressible SPH for Free Surface Flows approach introduced by Becker and Teschner [BT07].

References:

- [BT07] Markus Becker and Matthias Teschner. Weakly compressible SPH for free surface flows. In ACM SIGGRAPH/Eurographics Symposium on Computer Animation, SCA '07, 209-217. Aire-la-Ville, Switzerland, Switzerland, 2007. Eurographics Association. URL: http://dl.acm.org/citation.cfm?id=1272690.1272719

Public Functions

TimeStepWCSPH()

virtual ~TimeStepWCSPH(void)

virtual void **step**()

virtual void **reset**()

virtual void **resize**()

Public Static Attributes

static int **STIFFNESS** = -1

static int **EXPONENT** = -1

Protected Functions

void **computePressureAccels**(**const** unsigned int *fluidModelIndex*)
Determine the pressure accelerations when the pressure is already known.

void **performNeighborhoodSearch**()
Perform the neighborhood search for all fluid particles.

virtual void **emittedParticles**(*FluidModel* *model, **const** unsigned int *startIndex*)

virtual void **initParameters**()

Protected Attributes

Real **m_stiffness**

Real **m_exponent**

SimulationDataWCSPH **m_simulationData**

unsigned int **m_counter**

Class TriangleMesh

- Defined in file_SPlisHSPlasH_TriangleMesh.h

Class Documentation

class SPH::**TriangleMesh**
Data structure for a triangle mesh with normals and vertex normals.

Public Types

typedef std::vector<unsigned int> **Faces**

typedef std::vector<*Vector3r*> **Normals**

typedef std::vector<*Vector3r*> **Vertices**

Public Functions

TriangleMesh()

~TriangleMesh()

void **release**()

void **initMesh**(**const** unsigned int *nPoints*, **const** unsigned int *nFaces*)

void **addFace**(**const** unsigned int ***const** *indices*)
Add a new face.

void **addFace**(**const** int ***const** *indices*)
Add a new face.

void **addVertex**(**const** *Vector3r* &*vertex*)
Add new vertex.

inline const *Faces* &**getFaces**() **const**

inline *Faces* &**getFaces**()

inline const *Normals* &**getFaceNormals**() **const**

inline *Normals* &**getFaceNormals**()

inline const *Normals* &**getVertexNormals**() **const**

inline *Normals* &**getVertexNormals**()

inline const *Vertices* &**getVertices**() **const**

inline *Vertices* &**getVertices**()

inline const *Vertices* &**getVertices0**() **const**

inline *Vertices* &**getVertices0**()

inline unsigned int **numVertices**() **const**

inline unsigned int **numFaces**() **const**

void **updateMeshTransformation**(**const** *Vector3r* &*x*, **const** *Matrix3r* &*R*)

void **updateNormals**()

void **updateVertexNormals**()

Protected Attributes

Vertices **m_x0**

Vertices **m_x**

Faces **m_indices**

Normals **m_normals**

Normals **m_vertexNormals**

Class Viscosity_Bender2017

- Defined in file_SPlisHSPlasH_Viscosity_Viscosity_Bender2017.h

Inheritance Relationships

Base Type

- `public SPH::ViscosityBase` (*Class ViscosityBase*)

Class Documentation

class SPH::**Viscosity_Bender2017** : **public** SPH::*ViscosityBase*

This class implements the implicit simulation method for viscous fluids introduced by Bender and Koschier [BK17].

References:

- [BK17] Jan Bender and Dan Koschier. Divergence-free SPH for incompressible and viscous fluids. IEEE Transactions on Visualization and Computer Graphics, 23(3):1193-1206, 2017. URL: http://dx.doi.org/10.1109/TVCG.2016.2578335

Public Functions

Viscosity_Bender2017 (*FluidModel* *model)

virtual ~Viscosity_Bender2017 (void)

virtual void **step** ()

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

void **computeTargetStrainRate** ()

void **computeViscosityFactor** ()

inline FORCE_INLINE void viscoGradientMultTransposeRightOpt (const Eigen::Matrix< Real

Matrix product

inline FORCE_INLINE const Vector6r & getTargetStrainRate (const unsigned int i) const

inline FORCE_INLINE Vector6r & getTargetStrainRate (const unsigned int i)

inline FORCE_INLINE void setTargetStrainRate (const unsigned int i, const Vector6r &va

inline FORCE_INLINE const Matrix6r & getViscosityFactor (const unsigned int i) const

inline FORCE_INLINE Matrix6r & getViscosityFactor (const unsigned int i)

inline FORCE_INLINE void setViscosityFactor (const unsigned int i, const Matrix6r &val

inline FORCE_INLINE const Vector6r & getViscosityLambda (const unsigned int i) const

inline FORCE_INLINE Vector6r & getViscosityLambda (const unsigned int i)

inline FORCE_INLINE void setViscosityLambda (const unsigned int i, const Vector6r &val

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* *model)

Public Static Attributes

static int **ITERATIONS** = -1

static int **MAX_ITERATIONS** = -1

static int **MAX_ERROR** = -1

Protected Functions

virtual void **initParameters** ( )

Protected Attributes

std::vector<*Vector6r*> **m_targetStrainRate**

std::vector<*Matrix6r*> **m_viscosityFactor**

std::vector<*Vector6r*> **m_viscosityLambda**

unsigned int **m_iterations**

unsigned int **m_maxIter**

Real **m_maxError**

Class Viscosity_Peer2015

- Defined in file_SPlisHSPlasH_Viscosity_Viscosity_Peer2015.h

Inheritance Relationships

Base Type

- `public SPH::ViscosityBase` (*Class ViscosityBase*)

Class Documentation

class `SPH::`**Viscosity_Peer2015** : **public** SPH::*ViscosityBase*

This class implements the implicit simulation method for viscous fluids introduced by Peer et al. [PICT15].

References:

- [PICT15] A. Peer, M. Ihmsen, J. Cornelis, and M. Teschner. An Implicit Viscosity Formulation for SPH Fluids. ACM Trans. Graph., 34(4):1-10, 2015. URL: http://doi.acm.org/10.1145/2766925

Public Functions

Viscosity_Peer2015 (*FluidModel* *model)

virtual ~Viscosity_Peer2015 (void)

virtual void **step** ()

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

inline FORCE_INLINE const Matrix3r & getTargetNablaV (const unsigned int i) const

inline FORCE_INLINE Matrix3r & getTargetNablaV (const unsigned int i)

inline FORCE_INLINE void setTargetNablaV (const unsigned int i, const Matrix3r &val)

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* *model)

static void **matrixVecProd** (**const** *Real* *vec, *Real* *result, void *userData)

static FORCE_INLINE void diagonalMatrixElement (const unsigned int row, Real &result,

Public Static Attributes

static int **ITERATIONS** = -1

static int **MAX_ITERATIONS** = -1

static int **MAX_ERROR** = -1

Protected Types

typedef Eigen::ConjugateGradient<*MatrixReplacement*, Eigen::Lower | Eigen::Upper, *JacobiPreconditioner1D*> **Solver**

Protected Functions

virtual void **initParameters** ()

void **computeDensities** ()

Protected Attributes

std::vector<*Real*> **m_density**

std::vector<*Matrix3r*> **m_targetNablaV**

Solver **m_solver**

unsigned int **m_iterations**

unsigned int **m_maxIter**

Real **m_maxError**

Class Viscosity_Peer2016

- Defined in file_SPlisHSPlasH_Viscosity_Viscosity_Peer2016.h

Inheritance Relationships

Base Type

- `public SPH::ViscosityBase` (*Class ViscosityBase*)

Class Documentation

class `SPH::`**Viscosity_Peer2016** : **public** SPH::*ViscosityBase*

This class implements the implicit simulation method for viscous fluids introduced by Peer and Teschner [PGBT17].

References:

- [PGBT17] Andreas Peer, Christoph Gissler, Stefan Band, and Matthias Teschner. An implicit SPH formulation for incompressible linearly elastic solids. Computer Graphics Forum, 2017. URL: http://dx.doi.org/10.1111/cgf.13317

Public Functions

Viscosity_Peer2016 (*FluidModel* *model)

virtual ~Viscosity_Peer2016 (void)

virtual void **step** ()

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

inline FORCE_INLINE const Matrix3r & getTargetNablaV (const unsigned int i) const

inline FORCE_INLINE Matrix3r & getTargetNablaV (const unsigned int i)

inline FORCE_INLINE void setTargetNablaV (const unsigned int i, const Matrix3r &val)

inline FORCE_INLINE const Vector3r & getOmega (const unsigned int i) const

inline FORCE_INLINE Vector3r & getOmega (const unsigned int i)

inline FORCE_INLINE void setOmega (const unsigned int i, const Vector3r &val)

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* *model)

static void **matrixVecProdV** (**const** *Real* *vec, *Real* *result, void *userData)

static FORCE_INLINE void diagonalMatrixElementV (const unsigned int row, Real &result,

static void **matrixVecProdOmega** (**const** *Real* *vec, *Real* *result, void *userData)

static FORCE_INLINE void diagonalMatrixElementOmega (const unsigned int row, Real &res

Public Static Attributes

static int **ITERATIONS_V** = -1

static int **ITERATIONS_OMEGA** = -1

static int **MAX_ITERATIONS_V** = -1

static int **MAX_ERROR_V** = -1

static int **MAX_ITERATIONS_OMEGA** = -1

static int **MAX_ERROR_OMEGA** = -1

Protected Types

typedef Eigen::ConjugateGradient<*MatrixReplacement*, Eigen::Lower | Eigen::Upper, *JacobiPreconditioner1D*> **Solver**

Protected Functions

virtual void **initParameters** ( )

void **computeDensities** ( )

Protected Attributes

std::vector<*Real*> **m_density**

std::vector<*Matrix3r*> **m_targetNablaV**

std::vector<*Vector3r*> **m_omega**

Solver **m_solverV**

Solver **m_solverOmega**

unsigned int **m_iterationsV**

unsigned int **m_iterationsOmega**

unsigned int **m_maxIterV**

Real **m_maxErrorV**

unsigned int **m_maxIterOmega**

Real **m_maxErrorOmega**

Class Viscosity_Standard

- Defined in file_SPlisHSPlasH_Viscosity_Viscosity_Standard.h

Inheritance Relationships

Base Type

- `public SPH::ViscosityBase` (*Class ViscosityBase*)

Class Documentation

class `SPH::`**Viscosity_Standard** : **public** SPH::*ViscosityBase*

This class implements the standard method for viscosity descibed e.g. by Ihmsen et al. [IOS+14].

The method evaluates the term $\nu\nabla^2\mathbf{v}$ and uses an approximation of the kernel Laplacian to improve the stability. This approximation is given in [IOS+14].

References:

- [IOS+14] Markus Ihmsen, Jens Orthmann, Barbara Solenthaler, Andreas Kolb, and Matthias Teschner. SPH Fluids in Computer Graphics. In Sylvain Lefebvre and Michela Spagnuolo, editors, Eurographics 2014 - State of the Art Reports. The Eurographics Association, 2014. URL: http://dx.doi.org/10.2312/egst.20141034

Public Functions

Viscosity_Standard(*FluidModel* *model)

virtual ~Viscosity_Standard(void)

virtual void **step**()

virtual void **reset**()

Public Static Functions

static inline *NonPressureForceBase* ***creator**(*FluidModel* *model)

Public Static Attributes

static int **VISCOSITY_COEFFICIENT_BOUNDARY** = -1

Protected Functions

virtual void **initParameters**()

Protected Attributes

Real **m_boundaryViscosity**

Class Viscosity_Takahashi2015

- Defined in file_SPlisHSPlasH_Viscosity_Viscosity_Takahashi2015.h

Inheritance Relationships

Base Type

- `public SPH::ViscosityBase` (*Class ViscosityBase*)

Class Documentation

class `SPH::`**Viscosity_Takahashi2015** : **public** SPH::*ViscosityBase*

This class implements a variant of the implicit simulation method for viscous fluids introduced by Takahashi et al. [TDF+15]. In the original work of Takahashi et al. the second-ring neighbors are required to create the matrix of the linear system. In contrast we use a meshless conjugate gradient solver which performs the required matrix-vector multiplication in two sequential loops. In this way only the one-ring neighbors are required in each loop which increases the performance significantly.

Thanks to Anreas Peer who helped us with the implementation.

References:

- [TDF+15] T. Takahashi, Y. Dobashi, I. Fujishiro, T. Nishita, and M.C. Lin. Implicit Formulation for SPH-based Viscous Fluids. Computer Graphics Forum, 34(2):493-502, 2015. URL: http://dx.doi.org/10.1111/cgf.12578

Public Functions

Viscosity_Takahashi2015 (*FluidModel* **model*)

virtual ~Viscosity_Takahashi2015 (void)

virtual void **step** ()

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

inline FORCE_INLINE const Matrix3r & getViscousStress (const unsigned int i) const

inline FORCE_INLINE Matrix3r & getViscousStress (const unsigned int i)

inline FORCE_INLINE void setViscousStress (const unsigned int i, const Matrix3r &val)

inline FORCE_INLINE const Vector3r & getAccel (const unsigned int i) const

inline FORCE_INLINE Vector3r & getAccel (const unsigned int i)

inline FORCE_INLINE void setAccel (const unsigned int i, const Vector3r &val)

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* *model*)

static void **matrixVecProd** (**const** *Real* *vec, *Real* *result, void *userData*)

static FORCE_INLINE void diagonalMatrixElement (const unsigned int row, Real &result,

Public Static Attributes

static int **ITERATIONS** = -1

static int **MAX_ITERATIONS** = -1

static int **MAX_ERROR** = -1

Protected Types

typedef Eigen::ConjugateGradient<*MatrixReplacement*, Eigen::Lower | Eigen::Upper, Eigen::IdentityPreconditioner> **Solve**

Protected Functions

virtual void **initParameters** ()

Protected Attributes

std::vector<*Vector3r*> **m_accel**

std::vector<*Matrix3r*> **m_viscousStress**

Solver **m_solver**

unsigned int **m_iterations**

unsigned int **m_maxIter**

Real **m_maxError**

Protected Static Functions

static void **computeViscosityAcceleration** (*Viscosity_Takahashi2015* *visco, **const** *Real* *v)

Class Viscosity_Weiler2018

- Defined in file_SPlisHSPlasH_Viscosity_Viscosity_Weiler2018.h

Inheritance Relationships

Base Type

- `public SPH::ViscosityBase` (*Class ViscosityBase*)

Class Documentation

class `SPH::`**Viscosity_Weiler2018** : **public** SPH::*ViscosityBase*

This class implements the implicit Laplace viscosity method introduced by Weiler et al. 2018 [WKBB18].

References:

- [WKBB18] Marcel Weiler, Dan Koschier, Magnus Brand, and Jan Bender. A physically consistent implicit viscosity solver for SPH fluids. Computer Graphics Forum (Eurographics), 2018. URL: https://doi.org/10.1111/cgf.13349

Public Functions

Viscosity_Weiler2018 (*FluidModel *model*)

virtual ~Viscosity_Weiler2018 (void)

virtual void **step** ()

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

inline FORCE_INLINE const Vector3r & getVDiff (const unsigned int i) const

inline FORCE_INLINE Vector3r & getVDiff (const unsigned int i)

inline FORCE_INLINE void setVDiff (const unsigned int i, const Vector3r &val)

void **computeRHS** (VectorXr &*b*, VectorXr &*g*)

void **applyForces** (**const** VectorXr &*x*)

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel *model*)

static void **matrixVecProd** (**const** *Real *vec*, *Real *result*, void **userData*)

Public Static Attributes

static int **ITERATIONS** = -1

static int **MAX_ITERATIONS** = -1

static int **MAX_ERROR** = -1

static int **VISCOSITY_COEFFICIENT_BOUNDARY** = -1

Protected Types

typedef Eigen::ConjugateGradient<*MatrixReplacement*, Eigen::Lower | Eigen::Upper, *BlockJacobiPreconditioner3D*> **Solv**

Protected Functions

virtual void **initParameters**()

Protected Attributes

Real **m_boundaryViscosity**

unsigned int **m_maxIter**

Real **m_maxError**

unsigned int **m_iterations**

std::vector<*Vector3r*> **m_vDiff**

Real **m_tangentialDistanceFactor**

Solver **m_solver**

Protected Static Functions

static FORCE_INLINE void diagonalMatrixElement (const unsigned int row, Matrix3r &resu

Class Viscosity_XSPH

- Defined in file_SPlisHSPlasH_Viscosity_Viscosity_XSPH.h

Inheritance Relationships

Base Type

- `public SPH::ViscosityBase` (*Class ViscosityBase*)

Class Documentation

class `SPH::`**Viscosity_XSPH** : **public** SPH::*ViscosityBase*

This class implements the XSPH method descibed by Schechter and Bridson [SB12].

References:

- [SB12] Hagit Schechter and Robert Bridson. Ghost sph for animating water. ACM Trans. Graph., 31(4):61:1-61:8, July 2012. URL: http://doi.acm.org/10.1145/2185520.2185557

Public Functions

Viscosity_XSPH(*FluidModel* *model)

virtual ~Viscosity_XSPH(void)

virtual void **step**()

virtual void **reset**()

Public Static Functions

static inline *NonPressureForceBase* ***creator**(*FluidModel* *model)

Public Static Attributes

static int **VISCOSITY_COEFFICIENT_BOUNDARY** = -1

Protected Functions

virtual void **initParameters**()

Protected Attributes

Real **m_boundaryViscosity**

Class ViscosityBase

- Defined in file_SPlisHSPlasH_Viscosity_ViscosityBase.h

Inheritance Relationships

Base Type

- `public SPH::NonPressureForceBase` (*Class NonPressureForceBase*)

Derived Types

- `public SPH::Viscosity_Bender2017` (*Class Viscosity_Bender2017*)
- `public SPH::Viscosity_Peer2015` (*Class Viscosity_Peer2015*)
- `public SPH::Viscosity_Peer2016` (*Class Viscosity_Peer2016*)
- `public SPH::Viscosity_Standard` (*Class Viscosity_Standard*)
- `public SPH::Viscosity_Takahashi2015` (*Class Viscosity_Takahashi2015*)
- `public SPH::Viscosity_Weiler2018` (*Class Viscosity_Weiler2018*)
- `public SPH::Viscosity_XSPH` (*Class Viscosity_XSPH*)

Class Documentation

class SPH::**ViscosityBase** : **public** SPH::*NonPressureForceBase*

Base class for all viscosity methods.

Subclassed by *SPH::Viscosity_Bender2017*, *SPH::Viscosity_Peer2015*, *SPH::Viscosity_Peer2016*, *SPH::Viscosity_Standard*, *SPH::Viscosity_Takahashi2015*, *SPH::Viscosity_Weiler2018*, *SPH::Viscosity_XSPH*

Public Functions

ViscosityBase(*FluidModel* **model*)

virtual ~ViscosityBase(void)

Public Static Attributes

static int **VISCOSITY_COEFFICIENT** = -1

Protected Functions

virtual void **initParameters**()

Protected Attributes

Real **m_viscosity**

Class VorticityBase

- Defined in file_SPlisHSPlasH_Vorticity_VorticityBase.h

Inheritance Relationships

Base Type

- `public SPH::NonPressureForceBase` (*Class NonPressureForceBase*)

Derived Types

- `public SPH::MicropolarModel_Bender2017` (*Class MicropolarModel_Bender2017*)
- `public SPH::VorticityConfinement` (*Class VorticityConfinement*)

Class Documentation

class SPH::**VorticityBase** : **public** SPH::*NonPressureForceBase*

Base class for all vorticity methods.

Subclassed by *SPH::MicropolarModel_Bender2017*, *SPH::VorticityConfinement*

Public Functions

VorticityBase(*FluidModel* **model*)

virtual **~VorticityBase**(void)

Public Static Attributes

static int **VORTICITY_COEFFICIENT** = -1

Protected Functions

virtual void **initParameters**()

Protected Attributes

Real **m_vorticityCoeff**

Class VorticityConfinement

- Defined in file_SPlisHSPlasH_Vorticity_VorticityConfinement.h

Inheritance Relationships

Base Type

- public SPH::VorticityBase (*Class VorticityBase*)

Class Documentation

class SPH::**VorticityConfinement** : **public** SPH::*VorticityBase*

This class implements the vorticity confinement method introduced by Macklin and Mueller [MM13].

References:

- [MM13] Miles Macklin and Matthias Müller. Position based fluids. ACM Trans. Graph., 32(4):104:1-104:12, July 2013. URL: http://doi.acm.org/10.1145/2461912.2461984

Public Functions

VorticityConfinement (*FluidModel* *model)

virtual ~VorticityConfinement (void)

virtual void **step** ()

virtual void **reset** ()

virtual void **performNeighborhoodSearchSort** ()

inline FORCE_INLINE const Vector3r & getAngularVelocity (const unsigned int i) const

inline FORCE_INLINE Vector3r & getAngularVelocity (const unsigned int i)

inline FORCE_INLINE void setAngularVelocity (const unsigned int i, const Vector3r &val

Public Static Functions

static inline *NonPressureForceBase* ***creator** (*FluidModel* *model)

Protected Attributes

std::vector<*Vector3r*> **m_omega**

std::vector<*Real*> **m_normOmega**

Class WendlandQuinticC2Kernel

- Defined in file_SPlisHSPlasH_SPHKernels.h

Class Documentation

class SPH::**WendlandQuinticC2Kernel**

quintic Wendland C2 kernel.

Public Static Functions

static inline *Real* **getRadius** ()

static inline void **setRadius** (*Real* *val*)

static inline *Real* **W**(**const** *Real* *r*)

static inline *Real* **W**(**const** *Vector3r* &*r*)

static inline *Vector3r* **gradW**(**const** *Vector3r* &*r*)

static inline *Real* **W_zero** ()

Protected Static Attributes

static *Real* **m_radius**

static *Real* **m_k**

static *Real* **m_l**

static *Real* **m_W_zero**

Class WendlandQuinticC2Kernel2D

- Defined in file_SPlisHSPlasH_SPHKernels.h

Class Documentation

class SPH::**WendlandQuinticC2Kernel2D**
Wendland Quintic C2 spline kernel (2D).

Public Static Functions

static inline *Real* **getRadius**()

static inline void **setRadius**(*Real val*)

static inline *Real* **W**(**const** *Real r*)

static inline *Real* **W**(**const** *Vector3r &r*)

static inline *Vector3r* **gradW**(**const** *Vector3r &r*)

static inline *Real* **W_zero**()

Protected Static Attributes

static *Real* **m_radius**

static *Real* **m_k**

static *Real* **m_l**

static *Real* **m_W_zero**

Class ConsoleSink

- Defined in file_Utilities_Logger.h

Inheritance Relationships

Base Type

- `public Utilities::LogSink` (*Class LogSink*)

Class Documentation

class `Utilities::`**ConsoleSink** : **public** Utilities::*LogSink*

Public Functions

inline **ConsoleSink**(**const** *LogLevel minLevel*)

inline **virtual** void **write**(**const** *LogLevel level*, **const** std::string &*str*)

Class Counting

- Defined in file_Utilities_Counting.h

Class Documentation

class `Utilities::`**Counting**

Public Static Functions

static **inline** void **reset**()

static inline FORCE_INLINE void increaseCounter (const std::string &name, const Real i

static inline FORCE_INLINE void printAverageCounts ()

static inline FORCE_INLINE void printCounterSums ()

Public Static Attributes

static std::unordered_map<std::string, *AverageCount*> **m_averageCounts**

Class FileSink

- Defined in file_Utilities_Logger.h

Inheritance Relationships

Base Type

- `public Utilities::LogSink` (*Class LogSink*)

Class Documentation

class `Utilities::`**FileSink** : **public** Utilities::*LogSink*

Public Functions

inline **FileSink**(**const** *LogLevel* *minLevel*, **const** std::string &*fileName*)

inline **virtual** **~FileSink**()

inline **virtual** void **write**(**const** *LogLevel* *level*, **const** std::string &*str*)

Protected Attributes

std::ofstream **m_file**

Class FileSystem

- Defined in file_Utilities_FileSystem.h

Class Documentation

class `Utilities::`**FileSystem**

This class implements different file system functions.

Public Static Functions

static **inline** std::string **getFilePath**(**const** std::string &*path*)

static **inline** std::string **getFileName**(**const** std::string &*path*)

static **inline** std::string **getFileNameWithExt**(**const** std::string &*path*)

static **inline** std::string **getFileExt**(**const** std::string &*path*)

static **inline** bool **isRelativePath**(**const** std::string &*path*)

static **inline** int **makeDir**(**const** std::string &*path*)

static **inline** int **makeDirs**(**const** std::string &*path*)

Make all subdirectories.

static **inline** std::string **normalizePath**(**const** std::string &*path*)

static **inline** bool **fileExists**(**const** std::string &*fileName*)

static **inline** std::string **getProgramPath**()

static inline bool **copyFile**(**const** std::string &*source*, **const** std::string &*dest*)

static inline bool **isFile**(**const** std::string &*path*)

static inline bool **isDirectory**(**const** std::string &*path*)

static inline bool **getFilesInDirectory**(**const** std::string &*path*, std::vector<std::string> &*res*)

static inline std::string **getFileMD5**(**const** std::string &*filename*)
Compute the MD5 hash of a file.

static inline bool **writeMD5File**(**const** std::string &*fileName*, **const** std::string &*md5File*)
Write the MD5 hash of a file to the md5File.

static inline bool **checkMD5**(**const** std::string &*md5Hash*, **const** std::string &*md5File*)
Compare an MD5 hash with the hash stored in an MD5 file.

Class IDFactory

- Defined in file_Utilities_Timing.h

Class Documentation

class Utilities::**IDFactory**
Factory for unique ids.

Public Static Functions

static inline int **getId**()

Class Logger

- Defined in file_Utilities_Logger.h

Class Documentation

class Utilities::**Logger**

Public Functions

inline **Logger**()

inline **~Logger**()

inline void **addSink**(std::unique_ptr<*LogSink*> *sink*)

inline void **write**(**const** *LogLevel* *level*, **const** std::string &*str*)

inline void **activate**(**const** bool *b*)

Protected Attributes

std::vector<std::unique_ptr<*LogSink*>> **m_sinks**

bool **m_active**

Class LogSink

- Defined in file_Utilities_Logger.h

Inheritance Relationships

Derived Types

- `public Utilities::ConsoleSink` (*Class ConsoleSink*)
- `public Utilities::FileSink` (*Class FileSink*)

Class Documentation

class `Utilities::`**LogSink**
Subclassed by *Utilities::ConsoleSink*, *Utilities::FileSink*

Public Functions

inline **LogSink**(**const** *LogLevel minLevel*)

inline **virtual** **~LogSink**()

virtual void **write**(**const** *LogLevel level*, **const** std::string &*str*) = 0

Protected Attributes

LogLevel **m_minLevel**

Class LogStream

- Defined in file_Utilities_Logger.h

Class Documentation

class `Utilities::`**LogStream**

Public Functions

inline LogStream(*Logger* *logger, **const** *LogLevel* level)

template<typename **T**>
inline *LogStream* &**operator<<**(*T* **const** &value)

inline ~LogStream()

Protected Attributes

LogLevel **m_level**

Logger ***m_logger**

std::ostringstream **m_buffer**

Class OBJLoader

- Defined in file_Utilities_OBJLoader.h

Class Documentation

class Utilities::**OBJLoader**
Read for OBJ files.

Public Types

using Vec3f = std::array<float, 3>

using Vec2f = std::array<float, 2>

Public Static Functions

static inline void **loadObj**(**const** std::string &*filename*, std::vector<*Vec3f*> *x, std::vector<*MeshFaceIndices*> *faces, std::vector<*Vec3f*> *normals, std::vector<*Vec2f*> *texcoords, **const** *Vec3f* &*scale*)
This function loads an OBJ file. Only triangulated meshes are supported.

Class PartioReaderWriter

- Defined in file_Utilities_PartioReaderWriter.h

Class Documentation

class Utilities::**PartioReaderWriter**
Class for reading and writing partio files.

Public Static Functions

static bool **readParticles**(**const** std::string &*fileName*, **const** *Vector3r* &*translation*, **const** *Matrix3r* &*rotation*, **const** *Real* *scale*, std::vector<*Vector3r*> &*pos*, std::vector<*Vector3r*> &*vel*)

static bool **readParticles**(**const** std::string &*fileName*, **const** *Vector3r* &*translation*, **const** *Matrix3r* &*rotation*, **const** *Real* *scale*, std::vector<*Vector3r*> &*positions*, std::vector<*Vector3r*> &*velocities*, *Real* &*particleRadius*)

static bool **readParticles**(**const** std::string &*fileName*, **const** *Vector3r* &*translation*, **const** *Matrix3r* &*rotation*, **const** *Real* *scale*, std::vector<*Vector3r*> &*pos*)

static void **writeParticles**(**const** std::string &*fileName*, **const** unsigned int *numParticles*, **const** *Vector3r* **particlePositions*, **const** *Vector3r* **particleVelocities*, **const** *Real* *particleRadius*)

Class SceneLoader

- Defined in file_SPlisHSPlasH_Utilities_SceneLoader.h

Nested Relationships

Nested Types

- *Struct SceneLoader::AnimationFieldData*
- *Struct SceneLoader::BoundaryData*
- *Struct SceneLoader::Box*
- *Struct SceneLoader::EmitterData*
- *Struct SceneLoader::FluidBlock*
- *Struct SceneLoader::FluidData*
- *Struct SceneLoader::MaterialData*
- *Struct SceneLoader::Scene*

Class Documentation

class Utilities::**SceneLoader**
Importer of SPlisHSPlasH scene files.

Public Functions

void **readScene**(**const** char *_fileName_, _Scene_ &_scene_)

template<typename **T**>
inline bool **readValue**(**const** nlohmann::json &_j_, _T_ &_v_)

template<typename **T**, int **size**>
inline bool **readVector**(**const** nlohmann::json &_j_, Eigen::Matrix<_T_, _size_, 1, Eigen::DontAlign> &_vec_)

template<typename **T**>
inline bool **readValue**(**const** std::string &_section_, **const** std::string &_key_, _T_ &_v_)

inline bool **hasValue**(**const** std::string &_section_, **const** std::string &_key_)

template<typename **T**, int **size**>
inline bool **readVector**(**const** std::string &_section_, **const** std::string &_key_, Eigen::Matrix<_T_, _size_, 1, Eigen::DontAlign> &_vec_)

void **readMaterialParameterObject**(**const** std::string &_key_, GenParam::ParameterObject *_paramObj_)

void **readParameterObject**(**const** std::string &_key_, GenParam::ParameterObject *_paramObj_)

template<>
bool **readValue**(**const** nlohmann::json &_j_, bool &_v_)

template<>
bool **readValue**(**const** nlohmann::json &_j_, bool &_v_)

Protected Functions

void **readParameterObject**(nlohmann::json &_config_, GenParam::ParameterObject *_paramObj_)

Protected Attributes

nlohmann::json **m_jsonData**

struct AnimationFieldData
Struct to store an animation field object.

Public Members

std::string **particleFieldName**

std::string **expression**[3]

unsigned int **shapeType**

Vector3r **x**

Matrix3r **rotation**

Vector3r **scale**

Real **startTime**

Real **endTime**

struct BoundaryData
Struct to store a boundary object.

Public Members

std::string **samplesFile**

std::string **meshFile**

Vector3r **translation**

Matrix3r **rotation**

Vector3r **scale**

Real **density**

bool **dynamic**

bool **isWall**

Eigen::Matrix<float, 4, 1, Eigen::DontAlign> **color**

void ***rigidBody**

std::string **mapFile**

bool **mapInvert**

Real **mapThickness**

Eigen::Matrix<unsigned int, 3, 1, Eigen::DontAlign> **mapResolution**

unsigned int **samplingMode**

bool **isAnimated**

struct Box

Struct for an AABB.

Public Members

Vector3r **m_minX**

Vector3r **m_maxX**

struct EmitterData

Struct to store an emitter object.

Public Members

std::string **id**

unsigned int **width**

unsigned int **height**

Vector3r **x**

Real **velocity**

Matrix3r **rotation**

Real **emitStartTime**

Real **emitEndTime**

unsigned int **type**

struct FluidBlock
Struct to store a fluid block.

Public Members

std::string **id**

std::string **visMeshFile**

Box **box**

unsigned char **mode**

Vector3r **initialVelocity**

Vector3r **initialAngularVelocity**

struct FluidData
Struct to store a fluid object.

Public Members

std::string **id**

std::string **samplesFile**

std::string **visMeshFile**

Vector3r **translation**

Matrix3r **rotation**

Vector3r **scale**

Vector3r **initialVelocity**

Vector3r **initialAngularVelocity**

unsigned char **mode**

bool **invert**

std::array<unsigned int, 3> **resolutionSDF**

struct MaterialData
Struct to store particle coloring information.

Public Members

std::string **id**

std::string **colorField**

unsigned int **colorMapType**

Real **minVal**

Real **maxVal**

unsigned int **maxEmitterParticles**

bool **emitterReuseParticles**

Vector3r **emitterBoxMin**

Vector3r **emitterBoxMax**

struct Scene

Struct to store scene information.

Public Members

std::vector<*BoundaryData**> **boundaryModels**

std::vector<*FluidData**> **fluidModels**

std::vector<*FluidBlock**> **fluidBlocks**

std::vector<*EmitterData**> **emitters**

std::vector<*AnimationFieldData**> **animatedFields**

std::vector<*MaterialData**> **materials**

Real **particleRadius**

bool **sim2D**

Real **timeStepSize**

Vector3r **camPosition**

Vector3r **camLookat**

Class SDFFunctions

- Defined in file_SPlisHSPlasH_Utilities_SDFFunctions.h

Class Documentation

class Utilities::**SDFFunctions**

Functions for generating and querying an SDF.

Public Static Functions

static Discregrid::CubicLagrangeDiscreteGrid ***generateSDF**(**const** unsigned int *numVertices*, **const** *Vector3r* **vertices*, **const** unsigned int *numFaces*, **const** unsigned int **faces*, **const** *AlignedBox3r* &*bbox*, **const** std::array<unsigned int, 3> &*resolution*, **const** bool *invert* = false)

Generate SDF from mesh.

static *AlignedBox3r* **computeBoundingBox**(**const** unsigned int *numVertices*, **const** *Vector3r* **vertices*)

Compute the bounding box of a mesh.

static double **distance**(Discregrid::CubicLagrangeDiscreteGrid **sdf*, **const** *Vector3r* &*x*, **const** *Real thickness*, *Vector3r* &*normal*, *Vector3r* &*nextSurfacePoint*)

Determine distance of a point x to the surface represented by the SDF and corresponding surface normal and next point on the surface.

static double **distance**(Discregrid::CubicLagrangeDiscreteGrid **sdf*, **const** *Vector3r* &*x*, **const** *Real thickness*)
Determine distance of a point x to the surface represented by the SDF.

Class StringTools

- Defined in file_Utilities_StringTools.h

Class Documentation

class Utilities::**StringTools**
Tools to handle std::string objects.

Public Static Functions

static inline void **tokenize**(**const** std::string &*str*, std::vector<std::string> &*tokens*, **const** std::string &*delimiters* = " ")

template<typename **T**>
static inline std::string **real2String**(**const** *T r*)
converts a double or a float to a string

static inline std::string **to_upper**(**const** std::string &*str*)

Class SystemInfo

- Defined in file_Utilities_SystemInfo.h

Class Documentation

class Utilities::**SystemInfo**

Public Static Functions

static inline std::string **getHostName**()

Class Timing

- Defined in file_Utilities_Timing.h

Class Documentation

class Utilities::**Timing**

Class for time measurements.

Public Static Functions

static inline void **reset** ()

static inline FORCE_INLINE void startTiming (const std::string &name=std::string(""))

static inline FORCE_INLINE double stopTiming (bool print=true)

static inline FORCE_INLINE double stopTiming (bool print, int &id)

static inline FORCE_INLINE void printAverageTimes ()

static inline FORCE_INLINE void printTimeSums ()

Public Static Attributes

static bool **m_dontPrintTimes**

static unsigned int **m_startCounter**

static unsigned int **m_stopCounter**

static std::stack<*TimingHelper*> **m_timingStack**

static std::unordered_map<int, *AverageTime*> **m_averageTimes**

Class VolumeSampling

- Defined in file_SPlisHSPlasH_Utilities_VolumeSampling.h

Class Documentation

class Utilities::**VolumeSampling**

This class implements a volume sampling of 3D models.

Public Static Functions

static void **sampleMesh**(**const** unsigned int *numVertices*, **const** *Vector3r* **vertices*, **const** unsigned int *numFaces*, **const** unsigned int **faces*, **const** *Real* *radius*, **const** *AlignedBox3r* **region*, **const** std::array<unsigned int, 3> &*resolution*, **const** bool *invert*, **const** unsigned int *sampleMode*, std::vector<*Vector3r*> &*samples*)

Performs the volume sampling with the respective parameters.

Parameters

- **numVertices** – number of vertices
- **vertices** – vertex data
- **numFaces** – number of faces

- **faces** – index list of faces
- **radius** – radius of sampled particles
- **region** – defines a subregion of the mesh to be sampled (nullptr if not used)
- **resolution** – resolution of the used SDF
- **invert** – defines if the mesh should be inverted and the outside is sampled
- **sampleMode** – 0=regular, 1=almost dense, 2=dense
- **samples** – sampled vertices that will be returned

Class WindingNumbers

- Defined in file_SPlisHSPlasH_Utilities_WindingNumbers.h

Class Documentation

class Utilities::**WindingNumbers**

Public Static Functions

static *Real* **computeGeneralizedWindingNumber**(**const** *Vector3r* &*p*, **const** *Vector3r* &*a*, **const** *Vector3r* &*b*, **const** *Vector3r* &*c*)

Determine the winding number for a point p and a triangle abc.

static *Real* **computeGeneralizedWindingNumber**(**const** *Vector3r* &*p*, **const** SPH::*TriangleMesh* &*mesh*)

Determine the winding number of a point p in a triangle mesh.

Class Vector3f8

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Class Documentation

class Vector3f8

Public Functions

inline Vector3f8()

inline Vector3f8(**const** bool)

inline Vector3f8(**const** *Scalarf8* &*x*, **const** *Scalarf8* &*y*, **const** *Scalarf8* &*z*)

inline Vector3f8(**const** *Scalarf8* &*x*)

inline Vector3f8(**const** *Vector3f* &*x*)

inline Vector3f8(**const** *Vector3f* &*v0*, **const** *Vector3f* &*v1*, **const** *Vector3f* &*v2*, **const** *Vector3f* &*v3*, **const** *Vector3f* &*v4*, **const** *Vector3f* &*v5*, **const** *Vector3f* &*v6*, **const** *Vector3f* &*v7*)

inline **Vector3f8**(*Vector3f* **const** **x*)

inline void **setZero**()

inline *Scalarf8* &**operator[]**(int *i*)

inline **const** *Scalarf8* &**operator[]**(int *i*) **const**

inline *Scalarf8* &**x**()

inline *Scalarf8* &**y**()

inline *Scalarf8* &**z**()

inline **const** *Scalarf8* &**x**() **const**

inline **const** *Scalarf8* &**y**() **const**

inline **const** *Scalarf8* &**z**() **const**

inline *Scalarf8* **dot**(**const** *Vector3f8* &*a*) **const**

inline *Scalarf8* **operator***(**const** *Vector3f8* &*a*) **const**

inline void **cross**(**const** *Vector3f8* &*a*, **const** *Vector3f8* &*b*)

inline **const** *Vector3f8* **operator%**(**const** *Vector3f8* &*a*) **const**

inline *Vector3f8* &**operator*=**(**const** *Scalarf8* &*s*)

inline **const** *Vector3f8* **operator/**(**const** *Scalarf8* &*s*) **const**

inline *Vector3f8* &**operator/=**(**const** *Scalarf8* &*s*)

inline **const** *Vector3f8* **operator-**() **const**

inline *Scalarf8* **squaredNorm**() **const**

inline *Scalarf8* **norm**() **const**

inline void **normalize**()

inline void **store**(std::vector<*Vector3r*> &*Vf*) **const**

inline void **store**(*Vector3r* **Vf*) **const**

inline *Vector3r* **reduce**() **const**

Public Members

Scalarf8 **v**[3]

Public Static Functions

static **inline** *Vector3f8* **blend**(*Scalarf8* **const** &*c*, *Vector3f8* **const** &*a*, *Vector3f8* **const** &*b*)

24.1.3 Enums

Enum BoundaryHandlingMethods

- Defined in file_SPlisHSPlasH_Simulation.h

Enum Documentation

enum SPH::**BoundaryHandlingMethods**

Values:

enumerator Akinci2012

enumerator Koschier2017

enumerator Bender2019

enumerator NumSimulationMethods

Enum FieldType

- Defined in file_SPlisHSPlasH_FluidModel.h

Enum Documentation

enum SPH::**FieldType**

Values:

enumerator Scalar

enumerator Vector3

enumerator Vector6

enumerator Matrix3

enumerator Matrix6

enumerator UInt

Enum ParticleState

- Defined in file_SPlisHSPlasH_FluidModel.h

Enum Documentation

enum SPH::**ParticleState**

Values:

enumerator Active

enumerator AnimatedByEmitter

enumerator Fixed

Enum SimulationMethods

- Defined in file_SPlisHSPlasH_Simulation.h

Enum Documentation

enum SPH::**SimulationMethods**
Values:

enumerator WCSPH

enumerator PCISPH

enumerator PBF

enumerator IISPH

enumerator DFSPH

enumerator PF

enumerator ICSPH

enumerator NumSimulationMethods

Enum SurfaceSamplingMode

- Defined in file_SPlisHSPlasH_Utilities_SurfaceSampling.h

Enum Documentation

enum SPH::**SurfaceSamplingMode**
Values:

enumerator PoissonDisk

enumerator RegularTriangle

enumerator Regular2D

Enum LogLevel

- Defined in file_Utilities_Logger.h

Enum Documentation

enum Utilities::**LogLevel**
Values:

enumerator DEBUG

enumerator INFO

enumerator WARN

enumerator ERR

24.1.4 Functions

Function abs

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **abs**(*Scalarf8* **const** &*a*)

Function blend

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **blend**(*Scalarf8* **const** &*c*, *Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Template Function constant8f

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

template<int **i0**, int **i1**, int **i2**, int **i3**, int **i4**, int **i5**, int **i6**, int **i7**>
static inline __m256 **constant8f**()

Function convert_one

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **convert_one**(**const** unsigned int **idx*, **const** *Real* **x*, **const** unsigned char *count* = 8u)

Function convert_zero(const unsigned int *, const Real *, const unsigned char)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **convert_zero**(**const** unsigned int *idx, **const** *Real* *x, **const** unsigned char *count* = 8u)

Function convert_zero(const Real, const unsigned char)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **convert_zero**(**const** *Real* x, **const** unsigned char *count* = 8u)

Function convertMat_zero

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Matrix3f8* **convertMat_zero**(**const** unsigned int *idx, **const** *Matrix3r* *v, **const** unsigned char *count* = 8u)

Function convertVec_zero(const unsigned int *, const Real *, const unsigned char)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

inline *Vector3f8* **convertVec_zero**(**const** unsigned int *idx, **const** *Real* *v, **const** unsigned char *count* = 8u)

Function convertVec_zero(const unsigned int *, const Vector3r *, const unsigned char)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Vector3f8* **convertVec_zero**(**const** unsigned int *idx, **const** *Vector3r* *v, **const** unsigned char *count* = 8u)

Function dyadicProduct

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

inline void **dyadicProduct**(**const** *Vector3f8* &*a*, **const** *Vector3f8* &*b*, *Matrix3f8* &*res*)

Function getTime

- Defined in file_SPlisHSPlasH_AnimationField.cpp

Function Documentation

Real SPH::*TimeManager*::**getTime**()

Function max

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **max**(*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Function multiplyAndAdd

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **multiplyAndAdd**(**const** *Scalarf8* &*a*, **const** *Scalarf8* &*b*, **const** *Scalarf8* &*c*)

Function multiplyAndSubtract

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **multiplyAndSubtract**(**const** *Scalarf8* &*a*, **const** *Scalarf8* &*b*, **const** *Scalarf8* &*c*)

Function operator!=

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **operator!=** (*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Function operator*(Scalarf8 const&, Scalarf8 const&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **operator*** (*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Function operator*(Vector3f8 const&, const Scalarf8&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

inline *Vector3f8* **operator*** (*Vector3f8* **const** &*a*, **const** *Scalarf8* &*s*)

Function operator*=

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* &**operator*=** (*Scalarf8* &*a*, *Scalarf8* **const** &*b*)

Function operator+(Scalarf8 const&, Scalarf8 const&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **operator+** (*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Function operator+(Vector3f8 const&, Vector3f8 const&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

inline *Vector3f8* **operator+** (*Vector3f8* **const** &*a*, *Vector3f8* **const** &*b*)

Function operator+=(Scalarf8&, Scalarf8 const&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* &**operator+=** (*Scalarf8* &*a*, *Scalarf8* **const** &*b*)

Function operator+=(Vector3f8&, Vector3f8 const&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

inline *Vector3f8* &**operator+=** (*Vector3f8* &*a*, *Vector3f8* **const** &*b*)

Function operator-(Scalarf8&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

inline *Scalarf8* **operator-** (*Scalarf8* &*a*)

Function operator-(Scalarf8 const&, Scalarf8 const&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **operator-** (*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Function operator-(Vector3f8 const&, Vector3f8 const&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

inline *Vector3f8* **operator-** (*Vector3f8* **const** &*a*, *Vector3f8* **const** &*b*)

Function operator-=(Scalarf8&, Scalarf8 const&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* &**operator-=** (*Scalarf8* &*a*, *Scalarf8* **const** &*b*)

Function operator-=(Vector3f8&, Vector3f8 const&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

inline *Vector3f8* &**operator-=** (*Vector3f8* &*a*, *Vector3f8* **const** &*b*)

Function operator-=(Matrix3f8&, Matrix3f8 const&)

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

inline *Matrix3f8* &**operator-=** (*Matrix3f8* &*a*, *Matrix3f8* **const** &*b*)

Function operator/

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **operator/** (*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Function operator/=

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* &**operator/=**(*Scalarf8* &*a*, *Scalarf8* **const** &*b*)

Function operator<

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **operator<**(*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Function operator<=

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **operator<=**(*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Function operator==

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **operator==**(*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Function operator>

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **operator>**(*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

Function operator>=

- Defined in file_SPlisHSPlasH_Utilities_AVX_math.h

Function Documentation

static inline *Scalarf8* **operator>=** (*Scalarf8* **const** &*a*, *Scalarf8* **const** &*b*)

24.1.5 Variables

Variable haltonVec323

- Defined in file_SPlisHSPlasH_SurfaceTension_SurfaceTension_ZorillaRitter2020_haltonVec323.h

Variable Documentation

std::vector<float> **haltonVec323**

Variable SPH::gaussian_abscissae_1

- Defined in file_SPlisHSPlasH_Utilities_GaussQuadrature.cpp

Variable Documentation

double **const** SPH::**gaussian_abscissae_1**[101][51]

Variable SPH::gaussian_n_1

- Defined in file_SPlisHSPlasH_Utilities_GaussQuadrature.cpp

Variable Documentation

unsigned int **const** SPH::**gaussian_n_1**[101]

Variable SPH::gaussian_weights_1

- Defined in file_SPlisHSPlasH_Utilities_GaussQuadrature.cpp

Variable Documentation

double **const** SPH::**gaussian_weights_1**[101][51]

Variable Utilities::logger

- Defined in file_Utilities_Logger.h

Variable Documentation

Utilities::*Logger* Utilities::**logger**

24.1.6 Defines

Define _USE_MATH_DEFINES

- Defined in file_SPlisHSPlasH_Drag_DragForce_Gissler2017.cpp

Define Documentation

_USE_MATH_DEFINES

Define _USE_MATH_DEFINES

- Defined in file_SPlisHSPlasH_SPHKernels.h

Define Documentation

_USE_MATH_DEFINES

Define _USE_MATH_DEFINES

- Defined in file_SPlisHSPlasH_Utilities_PoissonDiskSampling.cpp

Define Documentation

_USE_MATH_DEFINES

Define _USE_MATH_DEFINES

- Defined in file_SPlisHSPlasH_Utilities_WindingNumbers.cpp

Define Documentation

_USE_MATH_DEFINES

Define compute_Vj

- Defined in file_SPlisHSPlasH_FluidModel.h

Define Documentation

compute_Vj(*fm_neighbor*)

Define compute_Vj_gradW

- Defined in file_SPlisHSPlasH_FluidModel.h

Define Documentation

compute_Vj_gradW()

Define compute_Vj_gradW_samephase

- Defined in file_SPlisHSPlasH_FluidModel.h

Define Documentation

compute_Vj_gradW_samephase()

Define compute_xj

- Defined in file_SPlisHSPlasH_FluidModel.h

Define Documentation

compute_xj(*fm_neighbor*, *pid*)

Define forall_boundary_neighbors

- Defined in file_SPlisHSPlasH_Simulation.h

Define Documentation

forall_boundary_neighbors(*code*)
Loop over the boundary neighbors of all fluid phases. Simulation *sim and unsigned int fluidModelIndex must be defined.

Define forall_density_maps

- Defined in file_SPlisHSPlasH_Simulation.h

Define Documentation

forall_density_maps(*code*)
Loop over the boundary density maps. Simulation *sim, unsigned int nBoundaries and unsigned int fluidModelIndex must be defined.

Define forall_fluid_neighbors

- Defined in file_SPlisHSPlasH_Simulation.h

Define Documentation

forall_fluid_neighbors(*code*)
Loop over the fluid neighbors of all fluid phases. Simulation *sim and unsigned int fluidModelIndex must be defined.

Define forall_fluid_neighbors_in_same_phase

- Defined in file_SPlisHSPlasH_Simulation.h

Define Documentation

forall_fluid_neighbors_in_same_phase(*code*)
Loop over the fluid neighbors of the same fluid phase. Simulation *sim, unsigned int fluidModelIndex and FluidModel* model must be defined.

Define forall_volume_maps

- Defined in file_SPlisHSPlasH_Simulation.h

Define Documentation

forall_volume_maps(*code*)
Loop over the boundary volume maps. Simulation *sim, unsigned int nBoundaries and unsigned int fluidModelIndex must be defined.

Define FORCE_INLINE

- Defined in file_SPlisHSPlasH_Common.h

Define Documentation

FORCE_INLINE

Define INCREASE_COUNTER

- Defined in file_Utilities_Counting.h

Define Documentation

INCREASE_COUNTER(*counterName*, *increaseBy*)

Define INIT_COUNTING

- Defined in file_Utilities_Counting.h

Define Documentation

INIT_COUNTING

Define INIT_LOGGING

- Defined in file_Utilities_Logger.h

Define Documentation

INIT_LOGGING

Define INIT_TIMING

- Defined in file_Utilities_Timing.h

Define Documentation

INIT_TIMING

Define LOG_DEBUG

- Defined in file_Utilities_Logger.h

Define Documentation

LOG_DEBUG

Define LOG_ERR

- Defined in file_Utilities_Logger.h

Define Documentation

LOG_ERR

Define LOG_INFO

- Defined in file_Utilities_Logger.h

Define Documentation

LOG_INFO

Define LOG_WARN

- Defined in file_Utilities_Logger.h

Define Documentation

LOG_WARN

Define PD_USE_DIAGONAL_PRECONDITIONER

- Defined in file_SPlisHSPlasH_PF_TimeStepPF.h

Define Documentation

PD_USE_DIAGONAL_PRECONDITIONER

Define REAL_MAX

- Defined in file_SPlisHSPlasH_Common.h

Define Documentation

REAL_MAX

Define REAL_MIN

- Defined in file_SPlisHSPlasH_Common.h

Define Documentation

REAL_MIN

Define RealParameter

- Defined in file_SPlisHSPlasH_Common.h

Define Documentation

RealParameter

Define RealParameterType

- Defined in file_SPlisHSPlasH_Common.h

Define Documentation

RealParameterType

Define RealVectorParameter

- Defined in file_SPlisHSPlasH_Common.h

Define Documentation

RealVectorParameter

Define RealVectorParameterType

- Defined in file_SPlisHSPlasH_Common.h

Define Documentation

RealVectorParameterType

Define REPORT_MEMORY_LEAKS

- Defined in file_SPlisHSPlasH_Common.h

Define Documentation

REPORT_MEMORY_LEAKS

Define S_ISDIR

- Defined in file_Utilities_FileSystem.h

Define Documentation

S_ISDIR(*mode*)

Define S_ISREG

- Defined in file_Utilities_FileSystem.h

Define Documentation

S_ISREG(*mode*)

Define START_TIMING

- Defined in file_Utilities_Timing.h

Define Documentation

START_TIMING(*timerName*)

Define STOP_TIMING

- Defined in file_Utilities_Timing.h

Define Documentation

STOP_TIMING

Define STOP_TIMING_AVG

- Defined in file_Utilities_Timing.h

Define Documentation

STOP_TIMING_AVG

Define STOP_TIMING_AVG_PRINT

- Defined in file_Utilities_Timing.h

Define Documentation

STOP_TIMING_AVG_PRINT

Define STOP_TIMING_PRINT

- Defined in file_Utilities_Timing.h

Define Documentation

STOP_TIMING_PRINT

Define USE_BLOCKDIAGONAL_PRECONDITIONER

- Defined in file_SPlisHSPlasH_Viscosity_Viscosity_Weiler2018.h

Define Documentation

USE_BLOCKDIAGONAL_PRECONDITIONER

Define USE_WARMSTART

- Defined in file_SPlisHSPlasH_DFSPH_TimeStepDFSPH.h

Define Documentation

USE_WARMSTART

Define USE_WARMSTART_V

- Defined in file_SPlisHSPlasH_DFSPH_TimeStepDFSPH.h

Define Documentation

USE_WARMSTART_V

Define Vec3Block

- Defined in file_SPlisHSPlasH_PF_TimeStepPF.cpp

Define Documentation

Warning: doxygendefine: Cannot find define "Vec3Block" in doxygen xml output for project "SPlisHSPlasH" from directory: ./doxyoutput/xml

24.1.7 Typedefs

Typedef AlignedBox2r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using AlignedBox2r = Eigen::AlignedBox<*Real*, 2>

Typedef AlignedBox3r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using AlignedBox3r = Eigen::AlignedBox<*Real*, 3>

Typedef AngleAxisr

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using AngleAxisr = Eigen::AngleAxis<*Real*>

Typedef AtomicRealVec

- Defined in file_SPlisHSPlasH_PF_TimeStepPF.cpp

Typedef Documentation

Warning: doxygentypedef: Cannot find typedef "AtomicRealVec" in doxygen xml output for project "SPlisHSPlasH" from directory: ./doxyoutput/xml

Typedef Matrix2r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Matrix2r = Eigen::Matrix<*Real*, 2, 2, Eigen::DontAlign>

Typedef Matrix3f

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Matrix3f = Eigen::Matrix<float, 3, 3, Eigen::DontAlign>

Typedef Matrix3r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Matrix3r = Eigen::Matrix<*Real*, 3, 3, Eigen::DontAlign>

Typedef Matrix4r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Matrix4r = Eigen::Matrix<*Real*, 4, 4, Eigen::DontAlign>

Typedef Matrix5r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Matrix5r = Eigen::Matrix<*Real*, 5, 5, Eigen::DontAlign>

Typedef Matrix6r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Matrix6r = Eigen::Matrix<*Real*, 6, 6, Eigen::DontAlign>

Typedef MatrixXr

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using MatrixXr = Eigen::Matrix<*Real*, -1, -1, 0, -1, -1>

Typedef NeighborhoodSearch

- Defined in file_SPlisHSPlasH_NeighborhoodSearch.h

Typedef Documentation

typedef CompactNSearch::NeighborhoodSearch **NeighborhoodSearch**

Typedef Quaternionr

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Quaternionr = Eigen::Quaternion<*Real*, Eigen::DontAlign>

Typedef Real

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

typedef float **Real**

Typedef SystemMatrixType

- Defined in file_SPlisHSPlasH_Utilities_MatrixFreeSolver.h

Typedef Documentation

using SystemMatrixType = Eigen::SparseMatrix<*Real*>

Typedef Vector2i

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Vector2i = Eigen::Matrix<int, 2, 1, Eigen::DontAlign>

Typedef Vector2r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Vector2r = Eigen::Matrix<*Real*, 2, 1, Eigen::DontAlign>

Typedef Vector3f

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Vector3f = Eigen::Matrix<float, 3, 1, Eigen::DontAlign>

Typedef Vector3r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Vector3r = Eigen::Matrix<*Real*, 3, 1, Eigen::DontAlign>

Typedef Vector4f

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Vector4f = Eigen::Matrix<float, 4, 1, Eigen::DontAlign>

Typedef Vector4r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Vector4r = Eigen::Matrix<*Real*, 4, 1, Eigen::DontAlign>

Typedef Vector5r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Vector5r = Eigen::Matrix<*Real*, 5, 1, Eigen::DontAlign>

Typedef Vector6r

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using Vector6r = Eigen::Matrix<*Real*, 6, 1, Eigen::DontAlign>

Typedef VectorXr

- Defined in file_SPlisHSPlasH_Common.h

Typedef Documentation

using SPH::*TimeStepPF*::**VectorXr** = Eigen::Matrix<*Real*, -1, 1>

CHAPTER

TWENTYFIVE

REFERENCES

CHAPTER

TWENTYSIX

INDICES AND TABLES

- genindex
- search

BIBLIOGRAPHY

[AAT13] Nadir Akinci, Gizem Akinci, and Matthias Teschner. Versatile surface tension and adhesion for sph fluids. *ACM Trans. Graph.*, 32(6):182:1–182:8, November 2013. URL: http://doi.acm.org/10.1145/2508363.2508395, doi:10.1145/2508363.2508395.

[AIA+12] Nadir Akinci, Markus Ihmsen, Gizem Akinci, Barbara Solenthaler, and Matthias Teschner. Versatile rigid-fluid coupling for incompressible sph. *ACM Trans. Graph.*, 31(4):62:1–62:8, July 2012. URL: http://doi.acm.org/10.1145/2185520.2185558, doi:10.1145/2185520.2185558.

[BIT09] Markus Becker, Markus Ihmsen, and Matthias Teschner. Corotated SPH for deformable solids. In *Proceedings of Eurographics Conference on Natural Phenomena*, 27–34. 2009. URL: http://dx.doi.org/10.2312EG/DL/conf/EG2009/nph/027-034, doi:10.2312EG/DL/conf/EG2009/nph/027-034.

[BT07] Markus Becker and Matthias Teschner. Weakly compressible sph for free surface flows. In *ACM SIGGRAPH/Eurographics Symposium on Computer Animation*, SCA '07, 209–217. Aire-la-Ville, Switzerland, Switzerland, 2007. Eurographics Association. URL: http://dl.acm.org/citation.cfm?id=1272690.1272719.

[BK15] Jan Bender and Dan Koschier. Divergence-free smoothed particle hydrodynamics. In *ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, SCA '15, 147–155. New York, NY, USA, 2015. ACM. URL: http://doi.acm.org/10.1145/2786784.2786796, doi:10.1145/2786784.2786796.

[BK17] Jan Bender and Dan Koschier. Divergence-free sph for incompressible and viscous fluids. *IEEE Transactions on Visualization and Computer Graphics*, 23(3):1193–1206, 2017. URL: http://dx.doi.org/10.1109/TVCG.2016.2578335, doi:10.1109/TVCG.2016.2578335.

[BKKW17] Jan Bender, Dan Koschier, Tassilo Kugelstadt, and Marcel Weiler. A micropolar material model for turbulent sph fluids. In *ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, SCA '17. ACM, 2017. URL: http://doi.acm.org/10.1145/3099564.3099578, doi:10.1145/3099564.3099578.

[BKWK19] Jan Bender, Tassilo Kugelstadt, Marcel Weiler, and Dan Koschier. Volume maps: an implicit boundary representation for sph. In *Proceedings of ACM SIGGRAPH Conference on Motion, Interaction and Games*, MIG '19. ACM, 2019. URL: https://dl.acm.org/doi/10.1145/3359566.3360077, doi:10.1145/3359566.3360077.

[BMullerM15] Jan Bender, Matthias Müller, and Miles Macklin. Position-based simulation methods in computer graphics. In *EUROGRAPHICS 2015 Tutorials*. Eurographics Association, 2015. URL: http://dx.doi.org/10.2312/egt.20151045, doi:10.2312/egt.20151045.

[BMullerO+14] Jan Bender, Matthias Müller, Miguel A. Otaduy, Matthias Teschner, and Miles Macklin. A survey on position-based simulation methods in computer graphics. *Computer Graphics Forum*, 33(6):228–251, 2014. URL: http://dx.doi.org/10.1111/cgf.12346, doi:10.1111/cgf.12346.

[DCB14] Crispin Deul, Patrick Charrier, and Jan Bender. Position-based rigid body dynamics. *Computer Animation and Virtual Worlds*, 2014. URL: http://dx.doi.org/10.1002/cav.1614, doi:10.1002/cav.1614.

[GBP+17] Christoph Gissler, Stefan Band, Andreas Peer, Markus Ihmsen, and Matthias Teschner. Approximate air-fluid interactions for sph. In *Virtual Reality Interactions and Physical Simulations*, 1–10. April 2017. URL: http://dx.doi.org/10.2312/vriphys.20171081, doi:10.2312/vriphys.20171081.

[HWZ+14] Xiaowei He, Huamin Wang, Fengjun Zhang, Hongan Wang, Guoping Wang, and Kun Zhou. Robust simulation of sparsely sampled thin features in sph-based free surface flows. *ACM Trans. Graph.*, 34(1):7:1–7:9, December 2014. URL: http://doi.acm.org/10.1145/2682630, doi:10.1145/2682630.

[ICS+14] Markus Ihmsen, Jens Cornelis, Barbara Solenthaler, Christopher Horvath, and Matthias Teschner. Implicit incompressible sph. *IEEE Transactions on Visualization and Computer Graphics*, 20(3):426–435, March 2014. URL: http://dx.doi.org/10.1109/TVCG.2013.105, doi:10.1109/TVCG.2013.105.

[IOS+14] Markus Ihmsen, Jens Orthmann, Barbara Solenthaler, Andreas Kolb, and Matthias Teschner. SPH Fluids in Computer Graphics. In Sylvain Lefebvre and Michela Spagnuolo, editors, *Eurographics 2014 - State of the Art Reports*. The Eurographics Association, 2014. URL: http://dx.doi.org/10.2312/egst.20141034, doi:10.2312/egst.20141034.

[JZW+15] Min Jiang, Yahan Zhou, Rui Wang, Richard Southern, and Jian Jun Zhang. Blue noise sampling using an sph-based method. *ACM Transactions on Graphics (TOG)*, 34(6):1–11, 2015.

[KB17] Dan Koschier and Jan Bender. Density maps for improved sph boundary handling. In *ACM SIGGRAPH/Eurographics Symposium on Computer Animation*, 1–10. July 2017. URL: http://dx.doi.org/10.1145/3099564.3099565, doi:10.1145/3099564.3099565.

[KBST19] Dan Koschier, Jan Bender, Barbara Solenthaler, and Matthias Teschner. Smoothed particle hydrodynamics for physically-based simulation of fluids and solids. In *Eurographics 2019 - Tutorials*. Eurographics Association, 2019. URL: https://interactivecomputergraphics.github.io/SPH-Tutorial, doi:10.2312/egt.20191035.

[KBFernandezFernandez+21] Tassilo Kugelstadt, Jan Bender, José Antonio Fernández-Fernández, Stefan Rhys Jeske, Fabian Löschner, and Andreas Longva. Fast corotated elastic sph solids with implicit zero-energy mode control. *Proc. ACM Comput. Graph. Interact. Tech.*, 2021.

[MMuller13] Miles Macklin and Matthias Müller. Position based fluids. *ACM Trans. Graph.*, 32(4):104:1–104:12, July 2013. URL: http://doi.acm.org/10.1145/2461912.2461984, doi:10.1145/2461912.2461984.

[MMullerCK14] Miles Macklin, Matthias Müller, Nuttapong Chentanez, and Tae-Yong Kim. Unified Particle Physics for Real-Time Applications. *ACM Trans. Graph.*, 33(4):1–12, 2014. URL: http://doi.acm.org/10.1145/2601097.2601152, doi:10.1145/2601097.2601152.

[PICT15] A. Peer, M. Ihmsen, J. Cornelis, and M. Teschner. An Implicit Viscosity Formulation for SPH Fluids. *ACM Trans. Graph.*, 34(4):1–10, 2015. URL: http://doi.acm.org/10.1145/2766925, doi:10.1145/2766925.

[PGBT17] Andreas Peer, Christoph Gissler, Stefan Band, and Matthias Teschner. An implicit sph formulation for incompressible linearly elastic solids. *Computer Graphics Forum*, 2017. URL: http://dx.doi.org/10.1111/cgf.13317, doi:10.1111/cgf.13317.

[PT16] Andreas Peer and Matthias Teschner. Prescribed velocity gradients for highly viscous SPH fluids with vorticity diffusion. *IEEE Transactions on Visualization and Computer Graphics*, pages 1–9, 2016. URL: http://dx.doi.org/10.1109/tvcg.2016.2636144, doi:10.1109/tvcg.2016.2636144.

[SB12] Hagit Schechter and Robert Bridson. Ghost sph for animating water. *ACM Trans. Graph.*, 31(4):61:1–61:8, July 2012. URL: http://doi.acm.org/10.1145/2185520.2185557, doi:10.1145/2185520.2185557.

[SP09] B. Solenthaler and R. Pajarola. Predictive-corrective incompressible sph. *ACM Trans. Graph.*, 28(3):40:1–40:6, July 2009. URL: http://doi.acm.org/10.1145/1531326.1531346, doi:10.1145/1531326.1531346.

[TDF+15] T. Takahashi, Y. Dobashi, I. Fujishiro, T. Nishita, and M.C. Lin. Implicit Formulation for SPH-based Viscous Fluids. *Computer Graphics Forum*, 34(2):493–502, 2015. URL: http://dx.doi.org/10.1111/cgf.12578, doi:10.1111/cgf.12578.

[WKB16] Marcel Weiler, Dan Koschier, and Jan Bender. Projective fluids. In *Proceedings of the 9th International Conference on Motion in Games*, MIG '16, 79–84. New York, NY, USA, 2016. ACM. URL: http://doi.acm.org/10.1145/2994258.2994282, doi:10.1145/2994258.2994282.

[WKBB18] Marcel Weiler, Dan Koschier, Magnus Brand, and Jan Bender. A physically consistent implicit viscosity solver for sph fluids. *Computer Graphics Forum (Eurographics)*, 2018. URL: https://doi.org/10.1111/cgf.13349, doi:10.1111/cgf.13349.

INDEX

Symbols

A

B

C

D

E

F

U

V