Simulating Guidewires in Blood Vessels using Cosserat Rod Theory

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Chapter 1

Requirements Traceability

Member GuidewireSim.ConstraintSolvingStep.CorrectBendTwistPredictions (int cylinderIndex, BSM.Quaternion[] cylinderOrientationPredictions)

The relevant entries of `cylinderOrientationPredictions` should be unit quaternions, i.e. have length approximately equal to one.

After the quaternion predictions got corrected, they should again be unit quaternions, i.e. have length approximately equal to one.

Member GuidewireSim.ConstraintSolvingStep.CorrectStretchPredictions (int sphereIndex, Vector3[] spherePositionPredictions, BSM.Quaternion[] cylinderOrientationPredictions)

The relevant entries of `cylinderOrientationPredictions` should be unit quaternions, i.e. have length approximately equal to one.

After the quaternion prediction got corrected, it should again be a unit quaternions, i.e. have length approximately equal to one.

Member GuidewireSim.ConstraintSolvingStep.SolveBendTwistConstraint (BSM.Quaternion orientationOne, BSM.Quaternion orientationTwo, Vector3 discreteRestDarbouxVector, float rodElementLength, out BSM.Quaternion deltaOrientationOne, out BSM.Quaternion deltaOrientationTwo, float inertiaWeightOne=1f, float inertiaWeightTwo=1f)

`orientationOne` and `orientationTwo` should be unit quaternions, i.e. have length approximately equal to one.

`rodElementLength` should be positive.

`inertiaWeightOne` and `inertiaWeightTwo` should be values between 0 and 1.

Member GuidewireSim.ConstraintSolvingStep.SolveBendTwistConstraints (BSM.Quaternion[] cylinderOrientationPredictions, int cylinderCount, Vector3[] discreteRestDarbouxVectors, float rodElementLength)

`cylinderCount` should be at least one.

`rodElementLength` should be positive.

Executes the constraint solving step in bilateral interleaving order if executeInBilateralOrder and otherwise in naive order.

Member GuidewireSim.ConstraintSolvingStep.SolveBendTwistConstraintsInBilateralOrder (BSM.Quaternion[] cylinderOrientationPredictions, int cylinderCount, Vector3[] discreteRestDarbouxVectors, float rodElementLength)

`cylinderCount` should be at least one.

`rodElementLength` should be positive.

Member GuidewireSim.ConstraintSolvingStep.SolveBendTwistConstraintsInNaiveOrder (BSM.Quaternion[] cylinderOrientationPredictions, int cylinderCount, Vector3[] discreteRestDarbouxVectors, float rodElementLength)

`cylinderCount` should be at least one.

`rodElementLength` should be positive.

Member GuidewireSim.ConstraintSolvingStep.SolveStretchConstraint (Vector3 particlePositionOne, Vector3 particlePositionTwo, BSM.Quaternion orientation, BSM.Quaternion e_3, float rodElementLength, out Vector3 deltaPositionOne, out Vector3 deltaPositionTwo, out BSM.Quaternion deltaOrientation, float inverseMassOne=1f, float inverseMassTwo=1f, float inertiaWeight=1f)

`orientation` should be a unit quaternions, i.e. have length approximately equal to one.

`e_3` should be a unit quaternions, i.e. have length approximately equal to one.

`rodElementLength` should be positive.

`inverseMassOne`, `inverseMassTwo` and `inertiaWeight` should be values between 0 and 1.

Member GuidewireSim.ConstraintSolvingStep.SolveStretchConstraints (Vector3[] spherePosition↩ Predictions, BSM.Quaternion[] cylinderOrientationPredictions, int spheresCount, BSM.Quaternion[] worldSpaceBasis, float rodElementLength)

`spheresCount` should be at least one.

`rodElementLength` should be positive.

Executes the constraint solving step in bilateral interleaving order if executeInBilateralOrder and otherwise in naive order.

Member GuidewireSim.ConstraintSolvingStep.SolveStretchConstraintsInBilateralOrder (Vector3[] sphere↩ PositionPredictions, BSM.Quaternion[] cylinderOrientationPredictions, int spheresCount, float rod↩ ElementLength, BSM.Quaternion e_3)

`spheresCount` should be at least one.

`rodElementLength` should be positive.

Member GuidewireSim.ConstraintSolvingStep.SolveStretchConstraintsInNaiveOrder (Vector3[] sphere↩ PositionPredictions, BSM.Quaternion[] cylinderOrientationPredictions, int spheresCount, float rod↩ ElementLength, BSM.Quaternion e_3)

`spheresCount` should be at least one.

`rodElementLength` should be positive.

Member GuidewireSim.DirectorsDrawer.CalculateArrowHeadPositions (Vector3 startPosition, Vector3 endPosition)

`arrowHeadPositions` has a length of 4.

Member GuidewireSim.DirectorsDrawer.DrawArrowHeadLines (int directorIndex, Vector3 endPosition, Vector3[] arrowHeadPositions)

`arrowHeadPositions` has a length of 4.

Member GuidewireSim.InitializationStep.InitDiscreteRestDarbouxVectors (int cylinderCount, BSM.↩ Quaternion[] cylinderOrientations, out Vector3[] discreteRestDarbouxVectors, float rodElementLength)

`cylinderCount` should be at least one.

`rodElementLength` should be positive.

Member GuidewireSim.InitializationStep.InitSpherePositions (GameObject[] spheres, int spheresCount, out Vector3[] spherePositions)

`spheresCount` should be at least one.

Member GuidewireSim.MathHelper.ColumnVectorMatrixMultiplication (Vector3 columnVector, float[,] matrix)

`matrix` must be a 3×3 matrix.

Member GuidewireSim.MathHelper.MatrixVectorMultiplication (float[,] matrix, Vector3 vector)

`matrix` must be a 3×3 matrix.

Member GuidewireSim.MathHelper.RandomUnitQuaternion ()

The length of the drawn quaternion is approximately equal to one.

Member GuidewireSim.SimulationLoop.AdaptCalculations ()

Sets the positions of the GameObjects spheres to spherePositions.

Calculates cylinderPositions based on spherePositions.

Sets the positions of the GameObjects cylinders to cylinderPositions.

Sets the rotations of the GameObjects cylinders to cylinderOrientations.

Member GuidewireSim.SimulationLoop.FixedUpdate ()

Execute the simulation loop if and only if ExecuteSingleLoopTest is false.

Member GuidewireSim.SimulationLoop.PerformConstraintSolvingStep ()

Performs the constraint solving of every constraint #solverStep many times.

Solve stretch constraints, if and only if solveStretchConstraints is true.

Solve bend twist constraints, if and only if solveBendTwistConstraints is true.

If solveStretchConstraints, then SpheresCount is at least two.

If solveStretchConstraints, then CylinderCount is at least one.

If solveBendTwistConstraints, then SpheresCount is at least three.

If solveBendTwistConstraints, then CylinderCount is at least two.

If solveStretchConstraints, after the step is complete the deviation between the actual rod element length and the default (rest state) rodElementLength should be close to zero.

If solveStretchConstraints, after the step is complete the deviation of the stretch constraint to zero should be close to zero.

If solveCollisionConstraints, after this step is complete clear the list `registeredCollisions`, since these collisions are now resolved.

Member GuidewireSim.SimulationLoop.PerformInitializationStep ()

Set SpheresCount to the length of spheres.

Set CylinderCount to the length of cylinders.

Call every init method of initializationStep.

Member GuidewireSim.SimulationLoop.PerformPredictionStep ()

Predict the sphereVelocities.

Predict the spherePositionPredictions.

Predict the cylinderAngularVelocities.

Predict the cylinderOrientationPredictions.

Member GuidewireSim.SimulationLoop.PerformUpdateStep ()

Upate sphereVelocities.

Upate spherePositions.

Upate cylinderAngularVelocities.

Upate cylinderOrientations.

Upate directors.

Member GuidewireSim.StressTestPerformer.PerformStressTestOne (float applyForceTime=1f)

Output a log message when no further forces are applied to the guidewire.

Member GuidewireSim.TorqueTestPerformer.PerformTorqueTestThree (Vector3 pullTorque, float applyTorqueTime=10f)

Output a log message when no further torques are applied to the guidewire.

Member GuidewireSim.TorqueTestPerformer.PerformTorqueTestTwo (Vector3 pullTorque, float applyTorqueTime=1f)

Output a log message when no further torques are applied to the guidewire.

Member UnitTest_SolveBendTwistConstraint.Test_SolveBendTwistConstraint (int iterations, BSM.Quaternion orientationOne, BSM.Quaternion orientationTwo, float rodElementLength, Vector3 discreteRestDarbouxVector, GuidewireSim.MathHelper mathHelper, GuidewireSim.ConstraintSolvingStep constraintSolvingStep)

`orientationOne` and orientationTwo are still unit quaternions at the end of the test.

The deviation between the bend twist constraint and zero is lower than a reasonable tolerance, i.e. close to zero., which means that the algorithm of SolveBendTwistConstraint() converges towards the fulfillment of the bend twist constraint.

Member UnitTest_SolveStretchConstraint.PickRandomPositions (out Vector3 particlePositionOne, out Vector3 particlePositionTwo)

Picks the first particle position uniformly distributed so that $x, y, z \in [-5, 5]$.

Picks a distance between the two particles that is uniformly distributed in the interval $[rodElementLength - maximalDistanceOffset, rodElementLength + maximalDistanceOffset]$.

Picks the second particle position uniformly distributed on the surface of the sphere with center `particlePositionOne` and radius `startDistance`.

Member UnitTest_SolveStretchConstraint.Test_SolveStretchConstraint (int iterations, Vector3 particlePositionOne, Vector3 particlePositionTwo, BSM.Quaternion orientation, GuidewireSim.MathHelper mathHelper, GuidewireSim.ConstraintSolvingStep constraintSolvingStep)

`orientation` is still a unit quaternion at the end of the test.

The deviation between the stretch constraint and zero is lower than the tolerance 0.1, which means that the algorithm of SolveStretchConstraint() converges towards the fulfillment of the stretch constraint.

The deviation between the actual distance of `particlePositionOne` and `particlePositionTwo` and the rest rod element length is lower than a reasonable tolerance, i.e. close to zero.

Chapter 2

Namespace Index

2.1 Package List

Here are the packages with brief descriptions (if available):

Chapter 3

Hierarchical Index

3.1 Class Hierarchy

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

Chapter 4

Class Index

4.1 Class List

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

Chapter 5

File Index

5.1 File List

Here is a list of all files with brief descriptions:

Chapter 6

Namespace Documentation

6.1 GuidewireSim Namespace Reference

Classes

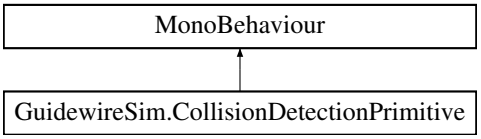
- class CollisionDetectionPrimitive
- class CollisionDetectionVessel
- class CollisionHandler
- struct CollisionPair
- class CollisionSolvingStep
- class CollisionTestPerformer
- class ConstraintSolvingStep
- class DirectorsDrawer
- class ForceTestPerformer
- class InitializationStep
- class MathHelper
- class ObjectSetter
- class PredictionStep
- class SimulationLoop
- class StressTestPerformer
- class TorqueTestPerformer
- class UpdateStep

Chapter 7

Class Documentation

7.1 GuidewireSim.CollisionDetectionPrimitive Class Reference

Inheritance diagram for GuidewireSim.CollisionDetectionPrimitive:



Public Attributes

- int sphereID

Private Member Functions

- void Awake ()
- void Start ()
- void AssignSphereID ()
- void OnCollisionEnter (Collision other)
- void OnCollisionStay (Collision other)

Private Attributes

- SimulationLoop simulationLoop

  The SimulationLoop component in the Simulation GameObject.
- CollisionHandler collisionHandler

  The CollisionHandler component in the Simulation GameObject.

7.1.1 Detailed Description

This class is responsible for tracking collisions of the object it is attached to. Attach this component only to sphere objects of the guidewire.

7.1.2 Member Function Documentation

7.1.2.1 AssignSphereID()

```
void GuidewireSim.CollisionDetectionPrimitive.AssignSphereID ( )  [private]
```

Assigns the unique ID of the object sphere it is attached to to sphereID.

7.1.2.2 Awake()

```
void GuidewireSim.CollisionDetectionPrimitive.Awake ( )  [private]
```

7.1.2.3 OnCollisionEnter()

```
void GuidewireSim.CollisionDetectionPrimitive.OnCollisionEnter (
            Collision other )  [private]
```

Registers a collision that Unity's collision detection detected.

7.1.2.4 OnCollisionStay()

```
void GuidewireSim.CollisionDetectionPrimitive.OnCollisionStay (
            Collision other )  [private]
```

Registers a collision that Unity's collision detection detected.

7.1.2.5 Start()

```
void GuidewireSim.CollisionDetectionPrimitive.Start ( )  [private]
```

7.1.3 Member Data Documentation

7.1.3.1 collisionHandler

```
CollisionHandler GuidewireSim.CollisionDetectionPrimitive.collisionHandler  [private]
```

The CollisionHandler component in the Simulation GameObject.

7.1.3.2 simulationLoop

```
SimulationLoop GuidewireSim.CollisionDetectionPrimitive.simulationLoop  [private]
```

The SimulationLoop component in the Simulation GameObject.

7.1.3.3 sphereID

```
int GuidewireSim.CollisionDetectionPrimitive.sphereID
```

The unique ID of the sphere that this component is attached to. Matches the position in `spheres` in #Simulation↩ Loop.

Note

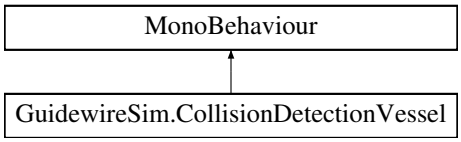
Should also match the position in `spherePositions`, `sphereVelocities`, `sphereExternal↩ Forces`, `spherePositionPredictions` in #SimulationLoop.

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

- CollisionDetectionPrimitive.cs

7.2 GuidewireSim.CollisionDetectionVessel Class Reference

Inheritance diagram for GuidewireSim.CollisionDetectionVessel:



Private Member Functions

- void Awake ()
- int YieldSphereID (Transform sphereTransform)

Private Attributes

- SimulationLoop simulationLoop

  The SimulationLoop component in the Simulation GameObject.
- CollisionHandler collisionHandler

  The CollisionHandler component in the Simulation GameObject.

7.2.1 Detailed Description

Similarly to CollisionDetectionPrimitive, this class is responsible for tracking collisions of the object it is attached to. Attach this component only to blood vessel objects.

7.2.2 Member Function Documentation

7.2.2.1 Awake()

```
void GuidewireSim.CollisionDetectionVessel.Awake ( )  [private]
```

7.2.2.2 YieldSphereID()

```
int GuidewireSim.CollisionDetectionVessel.YieldSphereID (
            Transform sphereTransform )  [private]
```

7.2.3 Member Data Documentation

7.2.3.1 collisionHandler

```
CollisionHandler GuidewireSim.CollisionDetectionVessel.collisionHandler  [private]
```

The CollisionHandler component in the Simulation GameObject.

7.2.3.2 simulationLoop

```
SimulationLoop GuidewireSim.CollisionDetectionVessel.simulationLoop  [private]
```

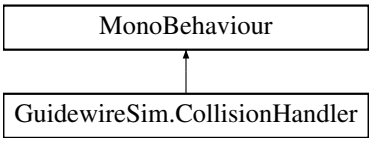
The SimulationLoop component in the Simulation GameObject.

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

- CollisionDetectionVessel.cs

7.3 GuidewireSim.CollisionHandler Class Reference

Inheritance diagram for GuidewireSim.CollisionHandler:



Public Member Functions

- void RegisterCollision (Transform sphere, int sphereID, Vector3 contactPoint, Vector3 collisionNormal)
- void ResetRegisteredCollisions ()
- void SetCollidersToPredictions (int spheresCount, Vector3[ ] spherePositionPredictions, Vector3[ ] sphere↩ Positions)

Public Attributes

- List< CollisionPair > registeredCollisions

  All collisions that occured between the last and the current frame in OnTriggerEnter.
- SphereCollider[ ] sphereColliders

Private Member Functions

- void Start ()

Private Attributes

- float sphereRadius = 5f

  The radius of the sphere elements of the guidewire.

7.3.1 Detailed Description

This class manages all collisions that should be resolved, i.e. the collisions of the last frame.

7.3.2 Member Function Documentation

7.3.2.1 RegisterCollision()

```
void GuidewireSim.CollisionHandler.RegisterCollision (
            Transform sphere,
            int sphereID,
            Vector3 contactPoint,
            Vector3 collisionNormal )
```

Registers a collision by adding it to registeredCollisions.

Parameters

sphere	The sphere of the guidewire that collided.
sphereID	The unique ID of `sphere`.
contactPoint	The contact point of the collision.
collisionNormal	The normal of the collision.

7.3.2.2 ResetRegisteredCollisions()

```
void GuidewireSim.CollisionHandler.ResetRegisteredCollisions ( )
```

Clears the list of all registered collisions.

7.3.2.3 SetCollidersToPredictions()

```
void GuidewireSim.CollisionHandler.SetCollidersToPredictions (
            int spheresCount,
            Vector3[] spherePositionPredictions,
            Vector3[] spherePositions )
```

Sets the position of the collider of each sphere to the sphere's position prediction.

Note

The position of the collider is implicitly set by setting the colliders center argument.

Parameters

spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
spherePositionPredictions	The prediction of the position at the current frame of each sphere (in this case of the last frame).
spherePositions	The position at the current frame of each sphere.

7.3.2.4 Start()

```
void GuidewireSim.CollisionHandler.Start ( )  [private]
```

7.3.3 Member Data Documentation

7.3.3.1 registeredCollisions

```
List<CollisionPair> GuidewireSim.CollisionHandler.registeredCollisions
```

All collisions that occured between the last and the current frame in OnTriggerEnter.

7.3.3.2 sphereColliders

```
SphereCollider [] GuidewireSim.CollisionHandler.sphereColliders
```

Each element stores a reference to the SpherCollider of the respective element in `spheres` in SimulationLoop.

Example

The second element in this list is the SphereCollider corresponding to the sphere GameObject that is referenced in the second element of `spheres` in SimulationLoop.

7.3.3.3 sphereRadius

```
float GuidewireSim.CollisionHandler.sphereRadius = 5f  [private]
```

The radius of the sphere elements of the guidewire.

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

- CollisionHandler.cs

7.4 GuidewireSim.CollisionPair Struct Reference

Public Member Functions

- CollisionPair (Transform sphere, int sphereID, Vector3 contactPoint, Vector3 collisionNormal)

Public Attributes

- Transform sphere

  The sphere object of the guidewire that was part of the collision.
- Vector3 contactPoint

  The contact point of the collision.
- Vector3 collisionNormal

  The normal of the collision.
- int sphereID

  The ID of the sphere object of the guidewire that was part of the collision.

7.4.1 Detailed Description

Carries all information of a collision that occured.

7.4.2 Constructor & Destructor Documentation

7.4.2.1 CollisionPair()

```
GuidewireSim.CollisionPair.CollisionPair (
            Transform sphere,
            int sphereID,
            Vector3 contactPoint,
            Vector3 collisionNormal )
```

7.4.3 Member Data Documentation

7.4.3.1 collisionNormal

```
Vector3 GuidewireSim.CollisionPair.collisionNormal
```

The normal of the collision.

7.4.3.2 contactPoint

```
Vector3 GuidewireSim.CollisionPair.contactPoint
```

The contact point of the collision.

7.4.3.3 sphere

```
Transform GuidewireSim.CollisionPair.sphere
```

The sphere object of the guidewire that was part of the collision.

7.4.3.4 sphereID

```
int GuidewireSim.CollisionPair.sphereID
```

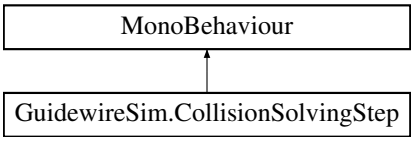
The ID of the sphere object of the guidewire that was part of the collision.

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

- CollisionPair.cs

7.5 GuidewireSim.CollisionSolvingStep Class Reference

Inheritance diagram for GuidewireSim.CollisionSolvingStep:



Public Member Functions

- void SolveCollisionConstraints (Vector3[] spherePositionPredictions, int solverStep, int constraintSolverSteps)

Private Member Functions

- void Awake ()
- void SolveCollisionConstraint (Vector3 spherePositionPrediction, Vector3 contactPoint, Vector3 collisionNormal, int solverStep, out Vector3 deltaPosition)
- void DrawCollisionInformation (Vector3 spherePositionPrediction, Vector3 contactPoint, Vector3 collisionNormal)
- Vector3 CalculateDeltaPosition (Vector3 spherePositionPrediction, Vector3 closestSurfacePoint, Vector3 normalVector)
- void CorrectCollisionPredictions (int sphereIndex, Vector3[] spherePositionPredictions, int solverStep, int constraintSolverSteps)

Private Attributes

- MathHelper mathHelper

  The component MathHelper that provides math related helper functions.
- CollisionHandler collisionHandler

  The component CollisionHandler that tracks all collisions.
- Vector3 deltaPosition = new Vector3()

  The correction of `spherePositionPrediction` in method SolveCollisionConstraint().
- Vector3 initialPositionPrediction = new Vector3()
- float sphereRadius = 5f

  The radius of a sphere of the guidewire.
- float collisionMargin = 0.1f
- float collisionStiffness = 0.001f

  The collision constraint stiffness parameter.

7.5.1 Detailed Description

This class implements the collision solving that is part of the constraint solving step.

7.5.2 Member Function Documentation

7.5.2.1 Awake()

```
void GuidewireSim.CollisionSolvingStep.Awake ( )  [private]
```

7.5.2.2 CalculateDeltaPosition()

```
Vector3 GuidewireSim.CollisionSolvingStep.CalculateDeltaPosition (
            Vector3 spherePositionPrediction,
            Vector3 closestSurfacePoint,
            Vector3 normalVector )  [private]
```

Calculates the displacement of the collision constraint.

Parameters

spherePositionPredictions	The prediction of the position at the current frame of each sphere (in this case of the last frame).
closestSurfacePoint	The contact point of the collision.
normalVector	The collision normal.

Returns

The delta position, i.e. the calculated displacement.

7.5.2.3 CorrectCollisionPredictions()

```
void GuidewireSim.CollisionSolvingStep.CorrectCollisionPredictions (
            int sphereIndex,
            Vector3[] spherePositionPredictions,
            int solverStep,
            int constraintSolverSteps )  [private]
```

Corrects the position prediction of the sphere of `sphereIndex` with the calculated displacement.

Parameters

sphereIndex	The sphere ID of the colliding sphere.
spherePositionPredictions	The prediction of the position at the current frame of each sphere (in this case of the last frame).
solverStep	The current iteration of the constraint solving step.
constraintSolverSteps	The total number of solver steps of the constraint solving step.

7.5.2.4 DrawCollisionInformation()

```
void GuidewireSim.CollisionSolvingStep.DrawCollisionInformation (
            Vector3 spherePositionPrediction,
            Vector3 contactPoint,
            Vector3 collisionNormal )  [private]
```

Draws the contact point, collision normal, and displacement corrections into the scene of the collision that occured.

Parameters

spherePositionPrediction	The position prediction of the sphere that collided.
contactPoint	The contact point of the collision.
collisionNormal	The normal of the collision.

7.5.2.5 SolveCollisionConstraint()

```
void GuidewireSim.CollisionSolvingStep.SolveCollisionConstraint (
            Vector3 spherePositionPrediction,
            Vector3 contactPoint,
            Vector3 collisionNormal,
            int solverStep,
            out Vector3 deltaPosition )  [private]
```

Solves the collision constraint for one collision that occured this frame.

Parameters

spherePositionPredictions	The prediction of the position at the current frame of each sphere (in this case of the last frame).
contactPoint	The contact point of the collision.
collisionNormal	The normal of the collision.
solverStep	The current iteration of the constraint solving step.

Attention

Current calculation of the normal only works for spheres.

7.5.2.6 SolveCollisionConstraints()

```
void GuidewireSim.CollisionSolvingStep.SolveCollisionConstraints (
            Vector3[] spherePositionPredictions,
            int solverStep,
            int constraintSolverSteps )
```

Is responsible for executing one iteration of the constraint solving step for the collision constraint of each collision of this frame.

Parameters

spherePositionPredictions	The prediction of the position at the current frame of each sphere (in this case of the last frame).
solverStep	The current iteration of the constraint solving step.
constraintSolverSteps	The total number of solver steps of the constraint solving step.

7.5.3 Member Data Documentation

7.5.3.1 collisionHandler

```
CollisionHandler GuidewireSim.CollisionSolvingStep.collisionHandler  [private]
```

The component CollisionHandler that tracks all collisions.

7.5.3.2 collisionMargin

```
float GuidewireSim.CollisionSolvingStep.collisionMargin = 0.1f  [private]
```

A margin by which a colliding element of the guidewire is set away from the object colliding with in the direction of the normal.

Note

Without this margin, the colliding element of the guidewire (e.g. a sphere) is corrected such that its surface exactly touches the object colliding with, which results in the guidewire still penetrating the object.

7.5.3.3 collisionStiffness

```
float GuidewireSim.CollisionSolvingStep.collisionStiffness = 0.001f  [private]
```

The collision constraint stiffness parameter.

7.5.3.4 deltaPosition

```
Vector3 GuidewireSim.CollisionSolvingStep.deltaPosition = new Vector3()  [private]
```

The correction of `spherePositionPrediction` in method SolveCollisionConstraint().

7.5.3.5 initialPositionPrediction

```
Vector3 GuidewireSim.CollisionSolvingStep.initialPositionPrediction = new Vector3()  [private]
```

7.5.3.6 mathHelper

```
MathHelper GuidewireSim.CollisionSolvingStep.mathHelper  [private]
```

The component MathHelper that provides math related helper functions.

7.5.3.7 sphereRadius

```
float GuidewireSim.CollisionSolvingStep.sphereRadius = 5f  [private]
```

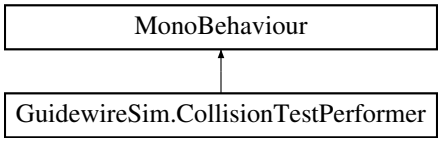
The radius of a sphere of the guidewire.

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

- CollisionSolvingStep.cs

7.6 GuidewireSim.CollisionTestPerformer Class Reference

Inheritance diagram for GuidewireSim.CollisionTestPerformer:



Private Member Functions

- void Awake ()
- void Start ()
- void PerformCollisionTests ()
- void PerformCollisionTestOne ()
- IEnumerator PerformCollisionTestTwo (float applyForceTime=1.5f)
- IEnumerator PerformCollisionTestThree (float exitVelocity=4f)
- IEnumerator PerformCollisionTestFour (float pullForceFactor=0.3f)

Private Attributes

- SimulationLoop simulationLoop

  The SimulationLoop component that executes all steps of the simulation loop.
- Vector3 pullForce = new Vector3(0f, 0f, 5f)

  External force that is applied in Force Test Three.
- bool doCollisionTestOne = false
- bool doCollisionTestTwo = false
- bool doCollisionTestThree = false
- bool doCollisionTestFour = false
- float startTime = 0f

7.6.1 Member Function Documentation

7.6.1.1 Awake()

```
void GuidewireSim.CollisionTestPerformer.Awake ( )  [private]
```

7.6.1.2 PerformCollisionTestFour()

```
IEnumerator GuidewireSim.CollisionTestPerformer.PerformCollisionTestFour (
            float pullForceFactor = 0.3f )  [private]
```

7.6.1.3 PerformCollisionTestOne()

```
void GuidewireSim.CollisionTestPerformer.PerformCollisionTestOne ( )  [private]
```

Performs torque test one. This test applies an external force to one end of the guidewire.

7.6.1.4 PerformCollisionTests()

```
void GuidewireSim.CollisionTestPerformer.PerformCollisionTests ( )  [private]
```

Performs each Torque Test whose respective serialized boolean is set to true in the Unity inspector.

7.6.1.5 PerformCollisionTestThree()

```
IEnumerator GuidewireSim.CollisionTestPerformer.PerformCollisionTestThree (
            float exitVelocity = 4f )  [private]
```

7.6.1.6 PerformCollisionTestTwo()

```
IEnumerator GuidewireSim.CollisionTestPerformer.PerformCollisionTestTwo (
            float applyForceTime = 1.5f )  [private]
```

7.6.1.7 Start()

```
void GuidewireSim.CollisionTestPerformer.Start ( )  [private]
```

7.6.2 Member Data Documentation

7.6.2.1 doCollisionTestFour

```
bool GuidewireSim.CollisionTestPerformer.doCollisionTestFour = false  [private]
```

7.6.2.2 doCollisionTestOne

```
bool GuidewireSim.CollisionTestPerformer.doCollisionTestOne = false  [private]
```

7.6.2.3 doCollisionTestThree

```
bool GuidewireSim.CollisionTestPerformer.doCollisionTestThree = false  [private]
```

7.6.2.4 doCollisionTestTwo

```
bool GuidewireSim.CollisionTestPerformer.doCollisionTestTwo = false  [private]
```

7.6.2.5 pullForce

```
Vector3 GuidewireSim.CollisionTestPerformer.pullForce = new Vector3(0f, 0f, 5f)  [private]
```

External force that is applied in Force Test Three.

7.6.2.6 simulationLoop

```
SimulationLoop GuidewireSim.CollisionTestPerformer.simulationLoop  [private]
```

The SimulationLoop component that executes all steps of the simulation loop.

7.6.2.7 startTime

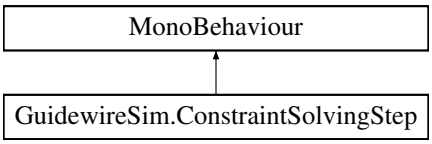
```
float GuidewireSim.CollisionTestPerformer.startTime = 0f  [private]
```

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

- CollisionTestPerformer.cs

7.7 GuidewireSim.ConstraintSolvingStep Class Reference

Inheritance diagram for GuidewireSim.ConstraintSolvingStep:



Public Member Functions

- void SolveStretchConstraints (Vector3[ ] spherePositionPredictions, BSM.Quaternion[ ] cylinderOrientation↩ Predictions, int spheresCount, BSM.Quaternion[ ] worldSpaceBasis, float rodElementLength)
- void SolveBendTwistConstraints (BSM.Quaternion[ ] cylinderOrientationPredictions, int cylinderCount, Vector3[ ] discreteRestDarbouxVectors, float rodElementLength)
- void SolveStretchConstraint (Vector3 particlePositionOne, Vector3 particlePositionTwo, BSM.Quaternion orientation, BSM.Quaternion e_3, float rodElementLength, out Vector3 deltaPositionOne, out Vector3 deltaPositionTwo, out BSM.Quaternion deltaOrientation, float inverseMassOne=1f, float inverseMassTwo=1f, float inertiaWeight=1f)
- void SolveBendTwistConstraint (BSM.Quaternion orientationOne, BSM.Quaternion orientationTwo, Vector3 discreteRestDarbouxVector, float rodElementLength, out BSM.Quaternion deltaOrientationOne, out BSM.↩ Quaternion deltaOrientationTwo, float inertiaWeightOne=1f, float inertiaWeightTwo=1f)

Private Member Functions

- void Awake ()
- void SolveStretchConstraintsInBilateralOrder (Vector3[ ] spherePositionPredictions, BSM.Quaternion[ ] cylinderOrientationPredictions, int spheresCount, float rodElementLength, BSM.Quaternion e_3)
- void SolveStretchConstraintsInNaiveOrder (Vector3[ ] spherePositionPredictions, BSM.Quaternion[ ] cylinderOrientationPredictions, int spheresCount, float rodElementLength, BSM.Quaternion e_3)
- void SolveBendTwistConstraintsInBilateralOrder (BSM.Quaternion[ ] cylinderOrientationPredictions, int cylinderCount, Vector3[ ] discreteRestDarbouxVectors, float rodElementLength)
- void SolveBendTwistConstraintsInNaiveOrder (BSM.Quaternion[ ] cylinderOrientationPredictions, int cylinderCount, Vector3[ ] discreteRestDarbouxVectors, float rodElementLength)
- void CorrectStretchPredictions (int sphereIndex, Vector3[ ] spherePositionPredictions, BSM.Quaternion[ ] cylinderOrientationPredictions)
- void CorrectBendTwistPredictions (int cylinderIndex, BSM.Quaternion[ ] cylinderOrientationPredictions)

Private Attributes

- MathHelper mathHelper

  The component MathHelper that provides math related helper functions.
- Vector3 deltaPositionOne = new Vector3()

  The correction of `particlePositionOne` in method SolveStretchConstraint().
- Vector3 deltaPositionTwo = new Vector3()

  The correction of `particlePositionTwo` in method SolveStretchConstraint().
- BSM.Quaternion deltaOrientation = new BSM.Quaternion()

  The correction of `orientation` in method SolveStretchConstraint().
- BSM.Quaternion deltaOrientationOne = new BSM.Quaternion()

  The correction of `orientationOne` in method SolveBendTwistConstraint().
- BSM.Quaternion deltaOrientationTwo = new BSM.Quaternion()

  The correction of `orientationTwo` in method SolveBendTwistConstraint().
- float stretchStiffness = 0.1f
- float bendStiffness = 0.1f
- bool executeInBilateralOrder = false

  Whether to solve both constraints in bilateral interleaving order. Naive order is used when false.

7.7.1 Detailed Description

This class executes and implements various algorithms of the constraint solving step of the algorithm and manages all coherent data.

7.7.2 Member Function Documentation

7.7.2.1 Awake()

```
void GuidewireSim.ConstraintSolvingStep.Awake ( )  [private]
```

7.7.2.2 CorrectBendTwistPredictions()

```
void GuidewireSim.ConstraintSolvingStep.CorrectBendTwistPredictions (
            int cylinderIndex,
            BSM.Quaternion[] cylinderOrientationPredictions )  [private]
```

Corrects the predictions of the bend twist constraint by adding `deltaOrientationOne` and `deltaOrientationTwo`.

Note

Note that `deltaOrientationOne` and `deltaOrientationTwo` may have a length unequal one by definition.

Parameters

cylinderIndex	The index of the first element of `cylinderOrientationPredictions` that gets corrected.
cylinderOrientationPredictions	The array of orientation predictions of which two quaternions get corrected in this method.

Requirements The relevant entries of `cylinderOrientationPredictions` should be unit quaternions, i.e. have length approximately equal to one.

After the quaternion predictions got corrected, they should again be unit quaternions, i.e. have length approximately equal to one.

7.7.2.3 CorrectStretchPredictions()

```
void GuidewireSim.ConstraintSolvingStep.CorrectStretchPredictions (
            int sphereIndex,
            Vector3[] spherePositionPredictions,
            BSM.Quaternion[] cylinderOrientationPredictions )  [private]
```

Corrects the predictions of the stretch constraint by adding `deltaPositionOne`, `deltaPositionTwo` and `deltaOrientation`.

Note

Note that `deltaOrientation` may has a length unequal one by definition.

Parameters

sphereIndex	The index of the first element of `spherePositionPredictions` that gets corrected.
spherePositionPredictions	The array of position predictions of which two positions get corrected in this method.
cylinderOrientationPredictions	The array of orientation predictions of which one quaternions gets corrected in this method.

Requirements The relevant entries of `cylinderOrientationPredictions` should be unit quaternions, i.e. have length approximately equal to one.

After the quaternion prediction got corrected, it should again be a unit quaternions, i.e. have length approximately equal to one.

7.7.2.4 SolveBendTwistConstraint()

```
void GuidewireSim.ConstraintSolvingStep.SolveBendTwistConstraint (
            BSM.Quaternion orientationOne,
            BSM.Quaternion orientationTwo,
            Vector3 discreteRestDarbouxVector,
            float rodElementLength,
            out BSM.Quaternion deltaOrientationOne,
            out BSM.Quaternion deltaOrientationTwo,
            float inertiaWeightOne = 1f,
            float inertiaWeightTwo = 1f )
```

Solves the bend twist constraint by calculating the corrections `deltaOrientationOne` and `deltaOrientationTwo`.

Note

To be more precise, the bend twist constraint is not solved but minimized, i.e. the constraint will after correcting with the corrections be closer to zero.

Parameters

	orientationOne	The first orientation quaternion prediction of the orientation element to be corrected.
	orientationTwo	The second orientation quaternion prediction of the orientation element to be corrected.
	discreteRestDarbouxVector	The discrete Darboux Vector at the rest configuration, i.e. at frame 0.
	rodElementLength	The distance between two spheres, also the distance between two orientations.
out	*deltaOrientationOne*	The correction of `orientationOne`.
out	*deltaOrientationTwo*	The correction of `orientationTwo`.
	inertiaWeightOne	The inertia weight scalar for `orientationOne`. Use a value of 1 for a moving orientation and 0 for a fixed orientation.
	inertiaWeightTwo	The inertia weight scalar for `orientationTwo`. Use a value of 1 for a moving orientation and 0 for a fixed orientation.

Requirements `orientationOne` and `orientationTwo` should be unit quaternions, i.e. have length approximately equal to one.

`rodElementLength` should be positive.

`inertiaWeightOne` and `inertiaWeightTwo` should be values between 0 and 1.

7.7.2.5 SolveBendTwistConstraints()

```
void GuidewireSim.ConstraintSolvingStep.SolveBendTwistConstraints (
            BSM.Quaternion[] cylinderOrientationPredictions,
            int cylinderCount,
            Vector3[] discreteRestDarbouxVectors,
            float rodElementLength )
```

Is responsible for executing one iteration of the constraint solving step for the bend twist constraint, i.e. corrects each orientation prediction one time.

Note

Can be executed in naive order or bilateral interleaving order.

Parameters

cylinderOrientationPredictions	The array of orientation predictions that get corrected in this step.
cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
discreteRestDarbouxVectors	The array of all discrete Darboux Vectors at the rest configuration, i.e. at frame 0. Has (n-1) elements, if n is the number of orientations of the guidewire, because the darboux vector is taken of two adjacent orientations.
rodElementLength	The distance between two spheres, also the distance between two orientations.

Requirements `cylinderCount` should be at least one.

`rodElementLength` should be positive.

Executes the constraint solving step in bilateral interleaving order if executeInBilateralOrder and otherwise in naive order.

7.7.2.6 SolveBendTwistConstraintsInBilateralOrder()

```
void GuidewireSim.ConstraintSolvingStep.SolveBendTwistConstraintsInBilateralOrder (
            BSM.Quaternion[] cylinderOrientationPredictions,
            int cylinderCount,
            Vector3[] discreteRestDarbouxVectors,
            float rodElementLength )  [private]
```

Is responsible for executing one iteration of the constraint solving step for the bend twist constraint in bilateral order, i.e. corrects each orientation prediction one time.

Note

You can read more about bilateral order in the 2016 paper "Position and Orientation Based Cosserat Rods".

Attention

The index shifting of this algorithm is not easy to understand, but got deeply tested.

Parameters

cylinderOrientationPredictions	The array of orientation predictions that get corrected in this step.
cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
discreteRestDarbouxVectors	The array of all discrete Darboux Vectors at the rest configuration, i.e. at frame 0. Has (n-1) elements, if n is the number of orientations of the guidewire, because the darboux vector is taken of two adjacent orientations.
rodElementLength	The distance between two spheres, also the distance between two orientations.

Requirements `cylinderCount` should be at least one.

`rodElementLength` should be positive.

7.7.2.7 SolveBendTwistConstraintsInNaiveOrder()

```
void GuidewireSim.ConstraintSolvingStep.SolveBendTwistConstraintsInNaiveOrder (
            BSM.Quaternion[] cylinderOrientationPredictions,
            int cylinderCount,
            Vector3[] discreteRestDarbouxVectors,
            float rodElementLength )  [private]
```

Is responsible for executing one iteration of the constraint solving step for the bend twist constraint in naive order, i.e. corrects each orientation prediction one time.

Note

Naive order means the predictions are updated beginning from one end of the guidewire to the other end of the guidewire.

Parameters

cylinderOrientationPredictions	The array of orientation predictions that get corrected in this step.
cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
discreteRestDarbouxVectors	The array of all discrete Darboux Vectors at the rest configuration, i.e. at frame 0. Has (n-1) elements, if n is the number of orientations of the guidewire, because the darboux vector is taken of two adjacent orientations.
rodElementLength	The distance between two spheres, also the distance between two orientations.

Requirements `cylinderCount` should be at least one.

`rodElementLength` should be positive.

7.7.2.8 SolveStretchConstraint()

```
void GuidewireSim.ConstraintSolvingStep.SolveStretchConstraint (
            Vector3 particlePositionOne,
            Vector3 particlePositionTwo,
            BSM.Quaternion orientation,
            BSM.Quaternion e_3,
            float rodElementLength,
            out Vector3 deltaPositionOne,
            out Vector3 deltaPositionTwo,
            out BSM.Quaternion deltaOrientation,
            float inverseMassOne = 1f,
            float inverseMassTwo = 1f,
            float inertiaWeight = 1f )
```

Solves the stretch constraint by calculating the corrections `deltaPositionOne` and `deltaPositionTwo`, `deltaOrientation`.

Note

To be more precise, the stretch constraint is not solved but minimized, i.e. the constraint will after correcting with the corrections be closer to zero.

Parameters

	particlePositionOne	The first particle position prediction of the centerline element to be corrected.
	particlePositionTwo	The second particle position prediction of the centerline element to be corrected.
	orientation	The orientation quaternion prediction of the orientation element between the particle positions to be corrected.
	e_3	The third basis vector of the world space coordinates embedded as a quaternion with scalar part 0.
	rodElementLength	The distance between two spheres, also the distance between two orientations.
`out`	*deltaPositionOne*	The correction of `particlePositionOne`.
`out`	*deltaPositionTwo*	The correction of `particlePositionTwo`.
`out`	*deltaOrientation*	The correction of `orientation`.
	inverseMassOne	The inverse mass scalar for `particlePositionOne`. Use a value of 1 for a moving particle and 0 for a fixed particle.
	inverseMassTwo	The inverse mass scalar for `particlePositionTwo`. Use a value of 1 for a moving particle and 0 for a fixed particle.
	inertiaWeight	The inertia weight scalar for `orientation`. Use a value of 1 for a moving orientation and 0 for a fixed orientation.

Requirements `orientation` should be a unit quaternions, i.e. have length approximately equal to one.

`e_3` should be a unit quaternions, i.e. have length approximately equal to one.

`rodElementLength` should be positive.

`inverseMassOne`, `inverseMassTwo` and `inertiaWeight` should be values between 0 and 1.

7.7.2.9 SolveStretchConstraints()

```
void GuidewireSim.ConstraintSolvingStep.SolveStretchConstraints (
            Vector3[] spherePositionPredictions,
            BSM.Quaternion[] cylinderOrientationPredictions,
            int spheresCount,
            BSM.Quaternion[] worldSpaceBasis,
            float rodElementLength )
```

Is responsible for executing one iteration of the constraint solving step for the stretch constraint, i.e. corrects each particle position prediction one time and also each orientation prediction one time.

Note

Can be executed in naive order or bilateral interleaving order.

Parameters

spherePositionPredictions	The array of position predictions that get corrected in this step.
cylinderOrientationPredictions	The array of orientation predictions that get corrected in this step.
spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
worldSpaceBasis	The three basis vectors of the world coordinate system as embedded quaternions with scalar part 0.
rodElementLength	The distance between two spheres, also the distance between two orientations.

Requirements `spheresCount` should be at least one.

`rodElementLength` should be positive.

Executes the constraint solving step in bilateral interleaving order if executeInBilateralOrder and otherwise in naive order.

7.7.2.10 SolveStretchConstraintsInBilateralOrder()

```
void GuidewireSim.ConstraintSolvingStep.SolveStretchConstraintsInBilateralOrder (
            Vector3[] spherePositionPredictions,
            BSM.Quaternion[] cylinderOrientationPredictions,
            int spheresCount,
            float rodElementLength,
            BSM.Quaternion e_3 )  [private]
```

Executes one iteration of the constraint solving step for the stretch constraint in bilateral order, i.e. corrects each particle position prediction one time and also each orientation prediction one time.

Note

You can read more about bilateral order in the 2016 paper "Position and Orientation Based Cosserat Rods".

Attention

The index shifting of this algorithm is not easy to understand, but got deeply tested.

Parameters

spherePositionPredictions	The array of position predictions that get corrected in this step.
cylinderOrientationPredictions	The array of orientation predictions that get corrected in this step.
spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
rodElementLength	The distance between two spheres, also the distance between two orientations.
e_3	The third basis vector of the world coordinate system as embedded quaternions with scalar part 0.

Requirements `spheresCount` should be at least one.

`rodElementLength` should be positive.

7.7.2.11 SolveStretchConstraintsInNaiveOrder()

```
void GuidewireSim.ConstraintSolvingStep.SolveStretchConstraintsInNaiveOrder (
            Vector3[] spherePositionPredictions,
            BSM.Quaternion[] cylinderOrientationPredictions,
            int spheresCount,
            float rodElementLength,
            BSM.Quaternion e_3 )  [private]
```

Executes one iteration of the constraint solving step for the stretch constraint in naive order, i.e. corrects each particle position prediction one time and also each orientation prediction one time.

Note

Naive order means the predictions are updated beginning from one end of the guidewire to the other end of the guidewire.

Parameters

spherePositionPredictions	The array of position predictions that get corrected in this step.
cylinderOrientationPredictions	The array of orientation predictions that get corrected in this step.
spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
rodElementLength	The distance between two spheres, also the distance between two orientations.
e_3	The third basis vector of the world coordinate system as embedded quaternions with scalar part 0.

Requirements `spheresCount` should be at least one.

`rodElementLength` should be positive.

7.7.3 Member Data Documentation

7.7.3.1 bendStiffness

```
float GuidewireSim.ConstraintSolvingStep.bendStiffness = 0.1f  [private]
```

7.7.3.2 deltaOrientation

```
BSM.Quaternion GuidewireSim.ConstraintSolvingStep.deltaOrientation = new BSM.Quaternion()
[private]
```

The correction of `orientation` in method SolveStretchConstraint().

7.7.3.3 deltaOrientationOne

```
BSM.Quaternion GuidewireSim.ConstraintSolvingStep.deltaOrientationOne = new BSM.Quaternion()
[private]
```

The correction of `orientationOne` in method SolveBendTwistConstraint().

7.7.3.4 deltaOrientationTwo

```
BSM.Quaternion GuidewireSim.ConstraintSolvingStep.deltaOrientationTwo = new BSM.Quaternion()
[private]
```

The correction of `orientationTwo` in method SolveBendTwistConstraint().

7.7.3.5 deltaPositionOne

```
Vector3 GuidewireSim.ConstraintSolvingStep.deltaPositionOne = new Vector3()  [private]
```

The correction of `particlePositionOne` in method SolveStretchConstraint().

7.7.3.6 deltaPositionTwo

```
Vector3 GuidewireSim.ConstraintSolvingStep.deltaPositionTwo = new Vector3()  [private]
```

The correction of `particlePositionTwo` in method SolveStretchConstraint().

7.7.3.7 executeInBilateralOrder

```
bool GuidewireSim.ConstraintSolvingStep.executeInBilateralOrder = false  [private]
```

Whether to solve both constraints in bilateral interleaving order. Naive order is used when false.

7.7.3.8 mathHelper

```
MathHelper GuidewireSim.ConstraintSolvingStep.mathHelper  [private]
```

The component MathHelper that provides math related helper functions.

7.7.3.9 stretchStiffness

```
float GuidewireSim.ConstraintSolvingStep.stretchStiffness = 0.1f  [private]
```

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

- ConstraintSolvingStep.cs

7.8 DebugExtension Class Reference

Debug Extension

Static Public Member Functions

- static void DebugPoint (Vector3 position, Color color, float scale=1.0f, float duration=0, bool depthTest=true)
- static void DebugPoint (Vector3 position, float scale=1.0f, float duration=0, bool depthTest=true)
- static void DebugBounds (Bounds bounds, Color color, float duration=0, bool depthTest=true)
- static void DebugBounds (Bounds bounds, float duration=0, bool depthTest=true)
- static void DebugLocalCube (Transform transform, Vector3 size, Color color, Vector3 center=default(Vector3), float duration=0, bool depthTest=true)
- static void DebugLocalCube (Transform transform, Vector3 size, Vector3 center=default(Vector3), float duration=0, bool depthTest=true)
- static void DebugLocalCube (Matrix4x4 space, Vector3 size, Color color, Vector3 center=default(Vector3), float duration=0, bool depthTest=true)
- static void DebugLocalCube (Matrix4x4 space, Vector3 size, Vector3 center=default(Vector3), float duration=0, bool depthTest=true)
- static void DebugCircle (Vector3 position, Vector3 up, Color color, float radius=1.0f, float duration=0, bool depthTest=true)
- static void DebugCircle (Vector3 position, Color color, float radius=1.0f, float duration=0, bool depthTest=true)
- static void DebugCircle (Vector3 position, Vector3 up, float radius=1.0f, float duration=0, bool depthTest=true)
- static void DebugCircle (Vector3 position, float radius=1.0f, float duration=0, bool depthTest=true)
- static void DebugWireSphere (Vector3 position, Color color, float radius=1.0f, float duration=0, bool depthTest=true)
- static void DebugWireSphere (Vector3 position, float radius=1.0f, float duration=0, bool depthTest=true)
- static void DebugCylinder (Vector3 start, Vector3 end, Color color, float radius=1, float duration=0, bool depthTest=true)
- static void DebugCylinder (Vector3 start, Vector3 end, float radius=1, float duration=0, bool depthTest=true)
- static void DebugCone (Vector3 position, Vector3 direction, Color color, float angle=45, float duration=0, bool depthTest=true)
- static void DebugCone (Vector3 position, Vector3 direction, float angle=45, float duration=0, bool depthTest=true)
- static void DebugCone (Vector3 position, Color color, float angle=45, float duration=0, bool depthTest=true)
- static void DebugCone (Vector3 position, float angle=45, float duration=0, bool depthTest=true)
- static void DebugArrow (Vector3 position, Vector3 direction, Color color, float duration=0, bool depthTest=true)
- static void DebugArrow (Vector3 position, Vector3 direction, float duration=0, bool depthTest=true)
- static void DebugCapsule (Vector3 start, Vector3 end, Color color, float radius=1, float duration=0, bool depthTest=true)
- static void DebugCapsule (Vector3 start, Vector3 end, float radius=1, float duration=0, bool depthTest=true)
- static void DrawPoint (Vector3 position, Color color, float duration=2f, float scale=1.0f)
- static void DrawPoint (Vector3 position, float scale=1.0f)
- static void DrawBounds (Bounds bounds, Color color)
- static void DrawBounds (Bounds bounds)
- static void DrawLocalCube (Transform transform, Vector3 size, Color color, Vector3 center=default(Vector3))
- static void DrawLocalCube (Transform transform, Vector3 size, Vector3 center=default(Vector3))
- static void DrawLocalCube (Matrix4x4 space, Vector3 size, Color color, Vector3 center=default(Vector3))
- static void DrawLocalCube (Matrix4x4 space, Vector3 size, Vector3 center=default(Vector3))
- static void DrawCircle (Vector3 position, Vector3 up, Color color, float radius=1.0f)
- static void DrawCircle (Vector3 position, Color color, float radius=1.0f)
- static void DrawCircle (Vector3 position, Vector3 up, float radius=1.0f)
- static void DrawCircle (Vector3 position, float radius=1.0f)
- static void DrawCylinder (Vector3 start, Vector3 end, Color color, float radius=1.0f)
- static void DrawCylinder (Vector3 start, Vector3 end, float radius=1.0f)
- static void DrawCone (Vector3 position, Vector3 direction, Color color, float angle=45)
- static void DrawCone (Vector3 position, Vector3 direction, float angle=45)
- static void DrawCone (Vector3 position, Color color, float angle=45)
- static void DrawCone (Vector3 position, float angle=45)
- static void DrawArrow (Vector3 position, Vector3 direction, Color color)

- static void DrawArrow (Vector3 position, Vector3 direction)
- static void DrawCapsule (Vector3 start, Vector3 end, Color color, float radius=1)
- static void DrawCapsule (Vector3 start, Vector3 end, float radius=1)
- static string MethodsOfObject (System.Object obj, bool includeInfo=false)
- static string MethodsOfType (System.Type type, bool includeInfo=false)

7.8.1 Detailed Description

Debug Extension

- Static class that extends Unity's debugging functionallity.
- Attempts to mimic Unity's existing debugging behaviour for ease-of-use.
- Includes gizmo drawing methods for less memory-intensive debug visualization.

7.8.2 Member Function Documentation

7.8.2.1 DebugArrow() [1/2]

```
static void DebugExtension.DebugArrow (
            Vector3 position,
            Vector3 direction,
            Color color,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs an arrow.

Parameters

position	

The start position of the arrow.

Parameters

direction	• The direction the arrow will point in.
color	• The color of the arrow.
duration	• How long to draw the arrow.

Parameters

depthTest	• Whether or not the arrow should be faded when behind other objects.

7.8.2.2 DebugArrow() [2/2]

```
static void DebugExtension.DebugArrow (
            Vector3 position,
            Vector3 direction,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs an arrow.

Parameters

position	

The start position of the arrow.

Parameters

direction	• The direction the arrow will point in.
duration	• How long to draw the arrow.
depthTest	• Whether or not the arrow should be faded when behind other objects.

7.8.2.3 DebugBounds() [1/2]

```
static void DebugExtension.DebugBounds (
            Bounds bounds,
            Color color,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs an axis-aligned bounding box.

Parameters

bounds	

The bounds to debug.

Parameters

color	• The color of the bounds.
duration	• How long to draw the bounds.
depthTest	• Whether or not the bounds should be faded when behind other objects.

7.8.2.4 DebugBounds() [2/2]

```
static void DebugExtension.DebugBounds (
            Bounds bounds,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs an axis-aligned bounding box.

Parameters

bounds	

The bounds to debug.

Parameters

duration	• How long to draw the bounds.
depthTest	• Whether or not the bounds should be faded when behind other objects.

7.8.2.5 DebugCapsule() [1/2]

```
static void DebugExtension.DebugCapsule (
            Vector3 start,
```

```
            Vector3 end,
            Color color,
            float radius = 1,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a capsule.

Parameters

start	

The position of one end of the capsule.

Parameters

end	• The position of the other end of the capsule.
color	• The color of the capsule.
radius	• The radius of the capsule.
duration	• How long to draw the capsule.
depthTest	• Whether or not the capsule should be faded when behind other objects.

7.8.2.6 DebugCapsule() [2/2]

```
static void DebugExtension.DebugCapsule (
            Vector3 start,
            Vector3 end,
            float radius = 1,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a capsule.

Parameters

start	

The position of one end of the capsule.

Parameters

end	• The position of the other end of the capsule.
radius	• The radius of the capsule.
duration	• How long to draw the capsule.
depthTest	• Whether or not the capsule should be faded when behind other objects.

7.8.2.7 DebugCircle() [1/4]

```
static void DebugExtension.DebugCircle (
            Vector3 position,
            Color color,
            float radius = 1.0f,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a circle.

Parameters

position	

Where the center of the circle will be positioned.

Parameters

color	• The color of the circle.
radius	• The radius of the circle.
duration	• How long to draw the circle.
depthTest	• Whether or not the circle should be faded when behind other objects.

7.8.2.8 DebugCircle() [2/4]

```
static void DebugExtension.DebugCircle (
            Vector3 position,
            float radius = 1.0f,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a circle.

Parameters

position	

Where the center of the circle will be positioned.

Parameters

radius	• The radius of the circle.
duration	• How long to draw the circle.
depthTest	• Whether or not the circle should be faded when behind other objects.

7.8.2.9 DebugCircle() [3/4]

```
static void DebugExtension.DebugCircle (
            Vector3 position,
            Vector3 up,
            Color color,
            float radius = 1.0f,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a circle.

Parameters

position	

Where the center of the circle will be positioned.

Parameters

up	• The direction perpendicular to the surface of the circle.
color	• The color of the circle.
radius	• The radius of the circle.
duration	• How long to draw the circle.
depthTest	• Whether or not the circle should be faded when behind other objects.

7.8.2.10 DebugCircle() [4/4]

```
static void DebugExtension.DebugCircle (
            Vector3 position,
            Vector3 up,
            float radius = 1.0f,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a circle.

Parameters

position	

Where the center of the circle will be positioned.

Parameters

up	• The direction perpendicular to the surface of the circle.
radius	• The radius of the circle.
duration	• How long to draw the circle.
depthTest	• Whether or not the circle should be faded when behind other objects.

7.8.2.11 DebugCone() [1/4]

```
static void DebugExtension.DebugCone (
            Vector3 position,
            Color color,
            float angle = 45,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a cone.

Parameters

position	

The position for the tip of the cone.

Parameters

angle	• The angle of the cone.
color	• The color of the cone.
duration	• How long to draw the cone.
depthTest	• Whether or not the cone should be faded when behind other objects.

7.8.2.12 DebugCone() [2/4]

```
static void DebugExtension.DebugCone (
            Vector3 position,
            float angle = 45,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a cone.

Parameters

position	

The position for the tip of the cone.

Parameters

angle	• The angle of the cone.
duration	• How long to draw the cone.
depthTest	• Whether or not the cone should be faded when behind other objects.

7.8.2.13 DebugCone() [3/4]

```
static void DebugExtension.DebugCone (
            Vector3 position,
            Vector3 direction,
            Color color,
            float angle = 45,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a cone.

Parameters

position	

The position for the tip of the cone.

Parameters

direction	• The direction for the cone gets wider in.
angle	• The angle of the cone.
color	• The color of the cone.
duration	• How long to draw the cone.
depthTest	• Whether or not the cone should be faded when behind other objects.

7.8.2.14 DebugCone() [4/4]

```
static void DebugExtension.DebugCone (
            Vector3 position,
            Vector3 direction,
            float angle = 45,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a cone.

Parameters

position	

The position for the tip of the cone.

Parameters

direction	• The direction for the cone gets wider in.
angle	• The angle of the cone.
duration	• How long to draw the cone.
depthTest	• Whether or not the cone should be faded when behind other objects.

7.8.2.15 DebugCylinder() [1/2]

```
static void DebugExtension.DebugCylinder (
            Vector3 start,
            Vector3 end,
            Color color,
            float radius = 1,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a cylinder.

Parameters

start	

The position of one end of the cylinder.

Parameters

end	• The position of the other end of the cylinder.
color	• The color of the cylinder.
radius	• The radius of the cylinder.
duration	• How long to draw the cylinder.
depthTest	• Whether or not the cylinder should be faded when behind other objects.

7.8.2.16 DebugCylinder() [2/2]

```
static void DebugExtension.DebugCylinder (
            Vector3 start,
            Vector3 end,
            float radius = 1,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a cylinder.

Parameters

start	

The position of one end of the cylinder.

Parameters

end	• The position of the other end of the cylinder.
radius	• The radius of the cylinder.

Parameters

duration	• How long to draw the cylinder.
depthTest	• Whether or not the cylinder should be faded when behind other objects.

7.8.2.17 DebugLocalCube() [1/4]

```
static void DebugExtension.DebugLocalCube (
            Matrix4x4 space,
            Vector3 size,
            Color color,
            Vector3 center = default(Vector3),
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a local cube.

Parameters

space	

The space the cube will be local to.

Parameters

size	• The size of the cube.
color	• Color of the cube.
center	• The position (relative to transform) where the cube will be debugged.
duration	• How long to draw the cube.
depthTest	• Whether or not the cube should be faded when behind other objects.

7.8.2.18 DebugLocalCube() [2/4]

```
static void DebugExtension.DebugLocalCube (
            Matrix4x4 space,
            Vector3 size,
            Vector3 center = default(Vector3),
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a local cube.

Parameters

space	

The space the cube will be local to.

Parameters

size	• The size of the cube.
center	• The position (relative to transform) where the cube will be debugged.
duration	• How long to draw the cube.
depthTest	• Whether or not the cube should be faded when behind other objects.

7.8.2.19 DebugLocalCube() [3/4]

```
static void DebugExtension.DebugLocalCube (
            Transform transform,
            Vector3 size,
            Color color,
            Vector3 center = default(Vector3),
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a local cube.

Parameters

transform	

The transform that the cube will be local to.

Parameters

size	• The size of the cube.
color	• Color of the cube.
center	• The position (relative to transform) where the cube will be debugged.
duration	• How long to draw the cube.
depthTest	• Whether or not the cube should be faded when behind other objects.

7.8.2.20 DebugLocalCube() [4/4]

```
static void DebugExtension.DebugLocalCube (
            Transform transform,
            Vector3 size,
            Vector3 center = default(Vector3),
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a local cube.

Parameters

transform	

The transform that the cube will be local to.

Parameters

size	• The size of the cube.
center	• The position (relative to transform) where the cube will be debugged.
duration	• How long to draw the cube.

Parameters

depthTest	• Whether or not the cube should be faded when behind other objects.

7.8.2.21 DebugPoint() [1/2]

```
static void DebugExtension.DebugPoint (
            Vector3 position,
            Color color,
            float scale = 1.0f,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a point.

Parameters

position	

The point to debug.

Parameters

color	• The color of the point.
scale	• The size of the point.
duration	• How long to draw the point.
depthTest	• Whether or not this point should be faded when behind other objects.

7.8.2.22 DebugPoint() [2/2]

```
static void DebugExtension.DebugPoint (
            Vector3 position,
            float scale = 1.0f,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a point.

Parameters

position	

The point to debug.

Parameters

scale	• The size of the point.
duration	• How long to draw the point.
depthTest	• Whether or not this point should be faded when behind other objects.

7.8.2.23 DebugWireSphere() [1/2]

```
static void DebugExtension.DebugWireSphere (
            Vector3 position,
            Color color,
            float radius = 1.0f,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a wire sphere.

Parameters

position	

The position of the center of the sphere.

Parameters

color	• The color of the sphere.
radius	• The radius of the sphere.
duration	• How long to draw the sphere.
depthTest	• Whether or not the sphere should be faded when behind other objects.

7.8.2.24 DebugWireSphere() [2/2]

```
static void DebugExtension.DebugWireSphere (
            Vector3 position,
            float radius = 1.0f,
            float duration = 0,
            bool depthTest = true )  [static]
```

- Debugs a wire sphere.

Parameters

position	

The position of the center of the sphere.

Parameters

radius	• The radius of the sphere.
duration	• How long to draw the sphere.
depthTest	• Whether or not the sphere should be faded when behind other objects.

7.8.2.25 DrawArrow() [1/2]

```
static void DebugExtension.DrawArrow (
            Vector3 position,
            Vector3 direction )  [static]
```

- Draws an arrow.

Parameters

position	

The start position of the arrow.

Parameters

direction	• The direction the arrow will point in.

7.8.2.26 DrawArrow() [2/2]

```
static void DebugExtension.DrawArrow (
            Vector3 position,
            Vector3 direction,
            Color color )  [static]
```

- Draws an arrow.

Parameters

position	

The start position of the arrow.

Parameters

direction	• The direction the arrow will point in.
color	• The color of the arrow.

7.8.2.27 DrawBounds() [1/2]

```
static void DebugExtension.DrawBounds (
            Bounds bounds )  [static]
```

- Draws an axis-aligned bounding box.

Parameters

bounds	

The bounds to draw.

7.8.2.28 DrawBounds() [2/2]

```
static void DebugExtension.DrawBounds (
            Bounds bounds,
            Color color )  [static]
```

- Draws an axis-aligned bounding box.

Parameters

bounds	

The bounds to draw.

Parameters

color	• The color of the bounds.

7.8.2.29 DrawCapsule() [1/2]

```
static void DebugExtension.DrawCapsule (
            Vector3 start,
            Vector3 end,
            Color color,
            float radius = 1 )  [static]
```

- Draws a capsule.

Parameters

start	

The position of one end of the capsule.

Parameters

end	• The position of the other end of the capsule.
color	• The color of the capsule.
radius	• The radius of the capsule.

7.8.2.30 DrawCapsule() [2/2]

```
static void DebugExtension.DrawCapsule (
            Vector3 start,
            Vector3 end,
            float radius = 1 )  [static]
```

- Draws a capsule.

Parameters

start	

The position of one end of the capsule.

Parameters

end	• The position of the other end of the capsule.
radius	• The radius of the capsule.

7.8.2.31 DrawCircle() [1/4]

```
static void DebugExtension.DrawCircle (
            Vector3 position,
            Color color,
            float radius = 1.0f )  [static]
```

- Draws a circle.

Parameters

position	

Where the center of the circle will be positioned.

Parameters

color	• The color of the circle.

Parameters

radius	• The radius of the circle.

7.8.2.32 DrawCircle() [2/4]

```
static void DebugExtension.DrawCircle (
            Vector3 position,
            float radius = 1.0f )  [static]
```

- Draws a circle.

Parameters

position	

Where the center of the circle will be positioned.

Parameters

radius	• The radius of the circle.

7.8.2.33 DrawCircle() [3/4]

```
static void DebugExtension.DrawCircle (
            Vector3 position,
            Vector3 up,
            Color color,
            float radius = 1.0f )  [static]
```

- Draws a circle.

Parameters

position	

Where the center of the circle will be positioned.

Parameters

up	• The direction perpendicular to the surface of the circle.
color	• The color of the circle.
radius	• The radius of the circle.

7.8.2.34 DrawCircle() [4/4]

```
static void DebugExtension.DrawCircle (
            Vector3 position,
            Vector3 up,
            float radius = 1.0f )  [static]
```

- Draws a circle.

Parameters

position	

Where the center of the circle will be positioned.

Parameters

up	• The direction perpendicular to the surface of the circle.
radius	• The radius of the circle.

7.8.2.35 DrawCone() [1/4]

```
static void DebugExtension.DrawCone (
            Vector3 position,
            Color color,
            float angle = 45 )  [static]
```

- Draws a cone.

Parameters

position	

The position for the tip of the cone.

Parameters

color	• The color of the cone.
angle	• The angle of the cone.

7.8.2.36 DrawCone() [2/4]

```
static void DebugExtension.DrawCone (
            Vector3 position,
            float angle = 45 )  [static]
```

- Draws a cone.

Parameters

position	

The position for the tip of the cone.

Parameters

angle	• The angle of the cone.

7.8.2.37 DrawCone() [3/4]

```
static void DebugExtension.DrawCone (
            Vector3 position,
            Vector3 direction,
            Color color,
            float angle = 45 )  [static]
```

- Draws a cone.

Parameters

position	

The position for the tip of the cone.

Parameters

direction	• The direction for the cone to get wider in.
color	• The color of the cone.
angle	• The angle of the cone.

7.8.2.38 DrawCone() [4/4]

```
static void DebugExtension.DrawCone (
            Vector3 position,
            Vector3 direction,
            float angle = 45 )  [static]
```

- Draws a cone.

Parameters

position	

The position for the tip of the cone.

Parameters

direction	• The direction for the cone to get wider in.
angle	• The angle of the cone.

7.8.2.39 DrawCylinder() [1/2]

```
static void DebugExtension.DrawCylinder (
            Vector3 start,
```

```
            Vector3 end,
            Color color,
            float radius = 1.0f )  [static]
```

- Draws a cylinder.

Parameters

start	

The position of one end of the cylinder.

Parameters

end	• The position of the other end of the cylinder.
color	• The color of the cylinder.
radius	• The radius of the cylinder.

7.8.2.40 DrawCylinder() [2/2]

```
static void DebugExtension.DrawCylinder (
            Vector3 start,
            Vector3 end,
            float radius = 1.0f )  [static]
```

- Draws a cylinder.

Parameters

start	

The position of one end of the cylinder.

Parameters

end	• The position of the other end of the cylinder.
radius	• The radius of the cylinder.

7.8.2.41 DrawLocalCube() [1/4]

```
static void DebugExtension.DrawLocalCube (
            Matrix4x4 space,
            Vector3 size,
            Color color,
            Vector3 center = default(Vector3) )  [static]
```

- Draws a local cube.

Parameters

space	

The space the cube will be local to.

Parameters

size	• The local size of the cube.
center	• The local position of the cube.
color	• The color of the cube.

7.8.2.42 DrawLocalCube() [2/4]

```
static void DebugExtension.DrawLocalCube (
            Matrix4x4 space,
            Vector3 size,
            Vector3 center = default(Vector3) )  [static]
```

- Draws a local cube.

Parameters

space	

The space the cube will be local to.

Parameters

size	• The local size of the cube.
center	• The local position of the cube.

7.8.2.43 DrawLocalCube() [3/4]

```
static void DebugExtension.DrawLocalCube (
            Transform transform,
            Vector3 size,
            Color color,
            Vector3 center = default(Vector3) )  [static]
```

- Draws a local cube.

Parameters

transform	

The transform the cube will be local to.

Parameters

size	• The local size of the cube.
center	• The local position of the cube.
color	• The color of the cube.

7.8.2.44 DrawLocalCube() [4/4]

```
static void DebugExtension.DrawLocalCube (
            Transform transform,
            Vector3 size,
            Vector3 center = default(Vector3) )  [static]
```

- Draws a local cube.

Parameters

transform	

The transform the cube will be local to.

Parameters

size	• The local size of the cube.
center	• The local position of the cube.

7.8.2.45 DrawPoint() [1/2]

```
static void DebugExtension.DrawPoint (
            Vector3 position,
            Color color,
            float duration = 2f,
            float scale = 1.0f )  [static]
```

- Draws a point.

Parameters

position	

The point to draw.

Parameters

color	• The color of the drawn point.
scale	• The size of the drawn point.

7.8.2.46 DrawPoint() [2/2]

```
static void DebugExtension.DrawPoint (
            Vector3 position,
            float scale = 1.0f )  [static]
```

- Draws a point.

Parameters

position	

The point to draw.

Parameters

scale	• The size of the drawn point.

7.8.2.47 MethodsOfObject()

```
static string DebugExtension.MethodsOfObject (
            System.Object obj,
            bool includeInfo = false )  [static]
```

- Gets the methods of an object.

Returns

A list of methods accessible from this object.

Parameters

obj	

The object to get the methods of.

Parameters

includeInfo	• Whether or not to include each method's method info in the list.

7.8.2.48 MethodsOfType()

```
static string DebugExtension.MethodsOfType (
            System.Type type,
            bool includeInfo = false )  [static]
```

- Gets the methods of a type.

Returns

A list of methods accessible from this type.

Parameters

type	

The type to get the methods of.

Parameters

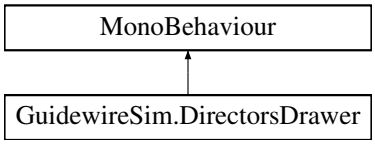
includeInfo	• Whether or not to include each method's method info in the list.

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

- DebugExtension.cs

7.9 GuidewireSim.DirectorsDrawer Class Reference

Inheritance diagram for GuidewireSim.DirectorsDrawer:



Private Member Functions

- void Awake ()
- void Update ()
- void DrawDirectors (Vector3[ ] cylinderPositions, Vector3[ ][ ] directors)
- Vector3[ ] CalculateArrowHeadPositions (Vector3 startPosition, Vector3 endPosition)
- void DrawArrowHeadLines (int directorIndex, Vector3 endPosition, Vector3[ ] arrowHeadPositions)
- void DrawArrowHeadConnectionLines (int directorIndex, Vector3[ ] arrowHeadPositions)

Private Attributes

- SimulationLoop simulationLoop

  The component SimulationLoop.
- float scaleFactor

  The scale factor that gets multiplied to the length of the respective director.
- float arrowHeadAngle

  The angle spread of the arrow head.
- float arrowHeadPercentage

The percentage of the length of the arrow that the arrow head covers.

- Color directorOneColor = Color.green

  The color that the lines representing the first director are drawn with.

- Color directorTwoColor = Color.blue

  The color that the lines representing the second director are drawn with.

- Color directorThreeColor = Color.red

  The color that the lines representing the third director are drawn with.

- Color[ ] directorColors = new Color[3] {Color.red, Color.green, Color.blue}

7.9.1 Detailed Description

This class represents each orientation by drawing all of its directors as arrows in each frame.

7.9.2 Member Function Documentation

7.9.2.1 Awake()

```
void GuidewireSim.DirectorsDrawer.Awake ( )  [private]
```

7.9.2.2 CalculateArrowHeadPositions()

```
Vector3[] GuidewireSim.DirectorsDrawer.CalculateArrowHeadPositions (
            Vector3 startPosition,
            Vector3 endPosition )  [private]
```

Calculates the end position of each line of each arrow head. E.g. an arrow head consists of four lines, each of them starting at `endPosition` and spreading in different directions to form the shape of an arrow tip.

Parameters

startPosition	The start position of the director, i.e. the position of the orientation.
endPosition	The position of the tip of the arrow head.

Returns

The end positions of the four lines that form the arrow head.

Requirements `arrowHeadPositions` has a length of 4.

7.9.2.3 DrawArrowHeadConnectionLines()

```
void GuidewireSim.DirectorsDrawer.DrawArrowHeadConnectionLines (
            int directorIndex,
            Vector3[] arrowHeadPositions )  [private]
```

Draws the four lines that connect the arrow head tips with each other. E.g. draws the line from `arrowHead↩Positions` 0 and `arrowHeadPositions` 1.

Parameters

directorIndex	The index of the director under consideration.
arrowHeadPositions	The end positions of the four lines that form the arrow head.

7.9.2.4 DrawArrowHeadLines()

```
void GuidewireSim.DirectorsDrawer.DrawArrowHeadLines (
            int directorIndex,
            Vector3 endPosition,
            Vector3[] arrowHeadPositions )  [private]
```

Draws the four lines that form the arrow head for the director that corresponds to `directorIndex`.

Parameters

directorIndex	The index of the director under consideration.
endPosition	The position of the tip of the arrow head.
arrowHeadPositions	The end positions of the four lines that form the arrow head.

Requirements `arrowHeadPositions` has a length of 4.

7.9.2.5 DrawDirectors()

```
void GuidewireSim.DirectorsDrawer.DrawDirectors (
            Vector3[] cylinderPositions,
            Vector3 directors[][] )  [private]
```

Draws the director basis of each orientation element as arrows.

Parameters

cylinderPositions	The center of mass of each cylinder, i.e. the position of each orientation element.
directors	The orthonormal basis of each orientation element / cylinder, also called directors.

7.9.2.6 Update()

```
void GuidewireSim.DirectorsDrawer.Update ( )  [private]
```

7.9.3 Member Data Documentation

7.9.3.1 arrowHeadAngle

```
float GuidewireSim.DirectorsDrawer.arrowHeadAngle  [private]
```

The angle spread of the arrow head.

7.9.3.2 arrowHeadPercentage

```
float GuidewireSim.DirectorsDrawer.arrowHeadPercentage  [private]
```

The percentage of the length of the arrow that the arrow head covers.

7.9.3.3 directorColors

```
Color [] GuidewireSim.DirectorsDrawer.directorColors = new Color[3] {Color.red, Color.green,
Color.blue}  [private]
```

The color that the lines representing the three directors are drawn with.

Note

The i-th director is drawn in the i-th Color.

7.9.3.4 directorOneColor

```
Color GuidewireSim.DirectorsDrawer.directorOneColor = Color.green  [private]
```

The color that the lines representing the first director are drawn with.

7.9.3.5 directorThreeColor

```
Color GuidewireSim.DirectorsDrawer.directorThreeColor = Color.red  [private]
```

The color that the lines representing the third director are drawn with.

7.9.3.6 directorTwoColor

```
Color GuidewireSim.DirectorsDrawer.directorTwoColor = Color.blue  [private]
```

The color that the lines representing the second director are drawn with.

7.9.3.7 scaleFactor

```
float GuidewireSim.DirectorsDrawer.scaleFactor  [private]
```

The scale factor that gets multiplied to the length of the respective director.

7.9.3.8 simulationLoop

```
SimulationLoop GuidewireSim.DirectorsDrawer.simulationLoop  [private]
```

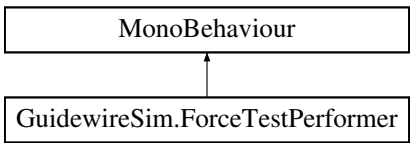
The component SimulationLoop.

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

- DirectorsDrawer.cs

7.10 GuidewireSim.ForceTestPerformer Class Reference

Inheritance diagram for GuidewireSim.ForceTestPerformer:



Private Member Functions

- void Awake ()
- void Start ()
- void PerformForceTests ()
- void PerformForceTestOne ()
- void PerformForceTestTwo ()
- IEnumerator PerformForceTestThree (Vector3 pullForce, float applyForceTime=1f)
- void PerformForceTestFour ()
- void PerformSingleLoopTest ()

Private Attributes

- SimulationLoop simulationLoop

  The SimulationLoop component that executes all steps of the simulation loop.
- bool doForceTestOne = false

  Whether to run Force Test One. This test applies gravity to all spheres.
- bool doForceTestTwo = false

  Whether to run Force Test Two. This test applies an external force to one end of the guidewire.
- bool doForceTestThree = false
- bool doForceTestFour = false
- bool doSingleLoopTest = false
- Vector3 pullForceTestThree = new Vector3(0f, 3f, 0f)

  External force that is applied in Force Test Three.

7.10.1 Detailed Description

This class enables the user to test the impact of external forces with one button within the Unity inspector.

7.10.2 Member Function Documentation

7.10.2.1 Awake()

```
void GuidewireSim.ForceTestPerformer.Awake ( )  [private]
```

7.10.2.2 PerformForceTestFour()

```
void GuidewireSim.ForceTestPerformer.PerformForceTestFour ( )  [private]
```

Performs force test four. This test applies an external force to one end of the guidewire and the opposite force at the other end of the guidewire.

7.10.2.3 PerformForceTestOne()

```
void GuidewireSim.ForceTestPerformer.PerformForceTestOne ( )  [private]
```

Performs force test one. This test applies gravity to all spheres.

7.10.2.4 PerformForceTests()

```
void GuidewireSim.ForceTestPerformer.PerformForceTests ( )  [private]
```

Performs each Force Test whose respective serialized boolean is set to true in the Unity inspector.

7.10.2.5 PerformForceTestThree()

```
IEnumerator GuidewireSim.ForceTestPerformer.PerformForceTestThree (
            Vector3 pullForce,
            float applyForceTime = 1f )  [private]
```

Performs force test three. This test applies an external force to one end of the guidewire for a fixed amount of time and then the opposite force at the same sphere for the same amount of time.

Parameters

applyForceTime	For how many seconds to apply the force to the particles.

7.10.2.6 PerformForceTestTwo()

```
void GuidewireSim.ForceTestPerformer.PerformForceTestTwo ( )  [private]
```

Performs force test two. This test applies an external force to one end of the guidewire.

7.10.2.7 PerformSingleLoopTest()

```
void GuidewireSim.ForceTestPerformer.PerformSingleLoopTest ( )  [private]
```

Performs the single loop test. This test shifts one end of the guidewire and runs the simulation for exactly one loop iteration to test constraint solving.

Note

Position of particle one stays at (0, 0, 0), while the section particle shifts to about (10, 2, 0). Expected result is that both particles move a bit towards each other and reestablish a distance of 10 between them.

7.10.2.8 Start()

```
void GuidewireSim.ForceTestPerformer.Start ( )  [private]
```

7.10.3 Member Data Documentation

7.10.3.1 doForceTestFour

```
bool GuidewireSim.ForceTestPerformer.doForceTestFour = false  [private]
```

Whether to run Force Test Four. This test applies an external force to one end of the guidewire and the opposite force at the other end of the guidewire.

7.10.3.2 doForceTestOne

```
bool GuidewireSim.ForceTestPerformer.doForceTestOne = false  [private]
```

Whether to run Force Test One. This test applies gravity to all spheres.

7.10.3.3 doForceTestThree

```
bool GuidewireSim.ForceTestPerformer.doForceTestThree = false  [private]
```

Whether to run Force Test Three. This test applies an external force to one end of the guidewire for a fixed amount of time and then the opposite force at the same sphere for the same amount of time.

7.10.3.4 doForceTestTwo

```
bool GuidewireSim.ForceTestPerformer.doForceTestTwo = false  [private]
```

Whether to run Force Test Two. This test applies an external force to one end of the guidewire.

7.10.3.5 doSingleLoopTest

```
bool GuidewireSim.ForceTestPerformer.doSingleLoopTest = false  [private]
```

Whether to run the Single Loop Test. This test shifts one end of the guidewire and runs the simulation for exactly one loop iteration to test constraint solving.

7.10.3.6 pullForceTestThree

```
Vector3 GuidewireSim.ForceTestPerformer.pullForceTestThree = new Vector3(0f, 3f, 0f)  [private]
```

External force that is applied in Force Test Three.

7.10.3.7 simulationLoop

```
SimulationLoop GuidewireSim.ForceTestPerformer.simulationLoop  [private]
```

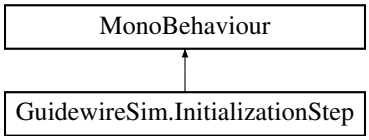
The SimulationLoop component that executes all steps of the simulation loop.

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

- ForceTestPerformer.cs

7.11 GuidewireSim.InitializationStep Class Reference

Inheritance diagram for GuidewireSim.InitializationStep:



Public Member Functions

- void InitSpherePositions (GameObject[ ] spheres, int spheresCount, out Vector3[ ] spherePositions)
- void InitSphereVelocities (int spheresCount, out Vector3[ ] sphereVelocities)
- void InitSphereInverseMasses (int spheresCount, out float[ ] sphereInverseMasses)
- void InitCylinderPositions (int cylinderCount, Vector3[ ] spherePositions, out Vector3[ ] cylinderPositions)
- void InitCylinderOrientations (int cylinderCount, out BSM.Quaternion[ ] cylinderOrientations)
- void InitDiscreteRestDarbouxVectors (int cylinderCount, BSM.Quaternion[ ] cylinderOrientations, out Vector3[ ] discreteRestDarbouxVectors, float rodElementLength)
- void InitCylinderAngularVelocities (int cylinderCount, out Vector3[ ] cylinderAngularVelocities)
- void InitCylinderScalarWeights (int cylinderCount, out float[ ] cylinderScalarWeights)
- void InitSphereExternalForces (int spheresCount, out Vector3[ ] sphereExternalForces)
- void InitSpherePositionPredictions (GameObject[ ] spheres, int spheresCount, out Vector3[ ] spherePosition↩ Predictions)
- void InitCylinderOrientationPredictions (int cylinderCount, out BSM.Quaternion[ ] cylinderOrientation↩ Predictions)
- void InitInertiaTensor (out float[,] inertiaTensor)
- void InitInverseInertiaTensor (float[,] inertiaTensor, out float[,] inverseInertiaTensor)
- void InitCylinderExternalTorques (int cylinderCount, out Vector3[ ] cylinderExternalTorques)
- void InitWorldSpaceBasis (out BSM.Quaternion[ ] worldSpaceBasis)
- void InitDirectors (int cylinderCount, BSM.Quaternion[ ] worldSpaceBasis, out Vector3[ ][ ] directors)
- void InitSphereColliders (int spheresCount, GameObject[ ] spheres)

Private Member Functions

- void Awake ()

Private Attributes

- CollisionHandler collisionHandler

  The component CollisionHandler that solves all collisions.
- MathHelper mathHelper

  The component MathHelper that provides math related helper functions.
- float materialDensity = 7860
- float materialRadius = 0.001f

7.11.1 Detailed Description

This class is responsible for initializing all data with their initial values of the simulation at the start of the simulation.

7.11.2 Member Function Documentation

7.11.2.1 Awake()

```
void GuidewireSim.InitializationStep.Awake ( )  [private]
```

7.11.2.2 InitCylinderAngularVelocities()

```
void GuidewireSim.InitializationStep.InitCylinderAngularVelocities (
            int cylinderCount,
            out Vector3[] cylinderAngularVelocities )
```

Initializes `cylinderAngularVelocities` with the default value of zero at the start of the simulation.

Parameters

	cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
`out`	*cylinderAngularVelocities*	The angular velocity of the current frame of each orientation element/ cylinder.

7.11.2.3 InitCylinderExternalTorques()

```
void GuidewireSim.InitializationStep.InitCylinderExternalTorques (
            int cylinderCount,
            out Vector3[] cylinderExternalTorques )
```

Initializes `cylinderExternalTorques` with the default value of zero at the start of the simulation.

Parameters

	cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
out	*cylinderExternalTorques*	The sum of all current external torques that are applied per orientation element/ cylinder.

7.11.2.4 InitCylinderOrientationPredictions()

```
void GuidewireSim.InitializationStep.InitCylinderOrientationPredictions (
            int cylinderCount,
            out BSM.Quaternion[] cylinderOrientationPredictions )
```

Initializes `cylinderOrientationPredictions` with the default value of (0f, 0f, 0f, 1f) which equals the quaternion identity at the start of the simulation.

Parameters

	cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
out	*cylinderOrientationPredictions*	The prediction of the orientation of each cylinder at its center of mass.

7.11.2.5 InitCylinderOrientations()

```
void GuidewireSim.InitializationStep.InitCylinderOrientations (
            int cylinderCount,
            out BSM.Quaternion[] cylinderOrientations )
```

Initializes `cylinderOrientations` with the default value of (0f, 0f, 0f, 1f) which equals the quaternion identity at the start of the simulation.

Parameters

	cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientations`.
out	*cylinderOrientations*	The orientation of each cylinder at its center of mass.

7.11.2.6 InitCylinderPositions()

```
void GuidewireSim.InitializationStep.InitCylinderPositions (
            int cylinderCount,
            Vector3[] spherePositions,
            out Vector3[] cylinderPositions )
```

Initializes `cylinderPositions` as middle points of the positions of `spheres` at the start of the simulation.

Parameters

	spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
	cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
`out`	*cylinderPositions*	The position/ center of mass of each cylinder.

7.11.2.7 InitCylinderScalarWeights()

```
void GuidewireSim.InitializationStep.InitCylinderScalarWeights (
            int cylinderCount,
            out float[] cylinderScalarWeights )
```

Initializes `cylinderScalarWeights` with the default value of one at the start of the simulation.

Parameters

	cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
`out`	*cylinderScalarWeights*	The constant scalar weights of each orientation/ quaternion similar to `sphereInverseMasses`.

7.11.2.8 InitDirectors()

```
void GuidewireSim.InitializationStep.InitDirectors (
            int cylinderCount,
            BSM.Quaternion[] worldSpaceBasis,
            out Vector3 directors[][] )
```

Initializes the `directors` array of arrays. The zero-th array defines all first directors of each director basis and so on.

Parameters

	cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
	worldSpaceBasis	The three basis vectors of the world coordinate system.
`out`	*directors*	The orthonormal basis of each orientation element / cylinder, also called directors.

Note

Example: The (i, j)th element holds the (i-1)th director of orientation element j.

7.11.2.9 InitDiscreteRestDarbouxVectors()

```
void GuidewireSim.InitializationStep.InitDiscreteRestDarbouxVectors (
            int cylinderCount,
            BSM.Quaternion[] cylinderOrientations,
            out Vector3[] discreteRestDarbouxVectors,
            float rodElementLength )
```

Calculates the discrete darboux vector for each orientation pair (two adjacent orientations) at its rest configuration, i.e. at frame 0.

Parameters

	cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
	cylinderOrientations	The orientation of each cylinder at its center of mass.
`out`	*discreteRestDarbouxVectors*	The array of all discrete Darboux Vectors at the rest configuration, i.e. at frame 0. Has (n-1) elements, if n is the number of orientations of the guidewire, because the darboux vector is taken of two adjacent orientations.
	rodElementLength	The distance between two spheres, also the distance between two orientations.

Requirements `cylinderCount` should be at least one.
`rodElementLength` should be positive.

Note

All cylinder orientations must be computed for frame 0 first.

7.11.2.10 InitInertiaTensor()

```
void GuidewireSim.InitializationStep.InitInertiaTensor (
            out float inertiaTensor[,] )
```

Initializes `inertiaTensor` so that all elements except the diagonal ones are zero. The first and second diagonal entry equal $\rho * \pi * \frac{r^2}{4}$, and the third diagonal entry equals $\rho * \pi * \frac{r^2}{2}$.

Parameters

out	*inertiaTensor*	The inertia tensor. Entries are approximates as in the CoRdE paper.

7.11.2.11 InitInverseInertiaTensor()

```
void GuidewireSim.InitializationStep.InitInverseInertiaTensor (
            float inertiaTensor[,],
            out float inverseInertiaTensor[,] )
```

Initializes `inverseInertiaTensor` as the inverse of `inertiaTensor`.

Parameters

	inertiaTensor	The inertia tensor. Entries are approximates as in the CoRdE paper.
out	*inverseInertiaTensor*	The inverse of `inertiaTensor`.

7.11.2.12 InitSphereColliders()

```
void GuidewireSim.InitializationStep.InitSphereColliders (
            int spheresCount,
            GameObject[] spheres )
```

7.11.2.13 InitSphereExternalForces()

```
void GuidewireSim.InitializationStep.InitSphereExternalForces (
            int spheresCount,
            out Vector3[] sphereExternalForces )
```

Initializes `sphereExternalForces` with the default value of zero at the start of the simulation.

Parameters

	spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
out	*sphereExternalForces*	The sum of all current external forces that are applied per particle/ sphere.

7.11.2.14 InitSphereInverseMasses()

```
void GuidewireSim.InitializationStep.InitSphereInverseMasses (
```

```
            int spheresCount,
            out float[] sphereInverseMasses )
```

Initializes `sphereInverseMasses` with the default value of one at the start of the simulation.

Parameters

	spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
out	*sphereInverseMasses*	The constant inverse masses of each sphere.

7.11.2.15 InitSpherePositionPredictions()

```
void GuidewireSim.InitializationStep.InitSpherePositionPredictions (
            GameObject[] spheres,
            int spheresCount,
            out Vector3[] spherePositionPredictions )
```

Initializes `spherePositionPredictions` with the default value of zero at the start of the simulation.

Parameters

	spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
out	*spherePositionPredictions*	The prediction of the position at the current frame of each sphere.

7.11.2.16 InitSpherePositions()

```
void GuidewireSim.InitializationStep.InitSpherePositions (
            GameObject[] spheres,
            int spheresCount,
            out Vector3[] spherePositions )
```

Initializes `spherePositions` with the positions of `spheres` at the start of the simulation.

Parameters

	spheres	All spheres that are part of the guidewire.
	spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
out	*spherePositions*	The position at the current frame of each sphere.

Requirements `spheresCount` should be at least one.

7.11.2.17 InitSphereVelocities()

```
void GuidewireSim.InitializationStep.InitSphereVelocities (
            int spheresCount,
            out Vector3[] sphereVelocities )
```

Initializes `sphereVelocities` with the default value of zero at the start of the simulation.

Parameters

	spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
`out`	*sphereVelocities*	The velocity of the current frame of each sphere.

Note

Velocities are set to zero at the start of the simulation.

7.11.2.18 InitWorldSpaceBasis()

```
void GuidewireSim.InitializationStep.InitWorldSpaceBasis (
            out BSM.Quaternion[] worldSpaceBasis )
```

Initializes the world space basis vectors (1, 0, 0), (0, 1, 0), (0, 0, 1) as embedded quaternions with scalar part zero.

Parameters

`out`	*worldSpaceBasis*	The three basis vectors of the world coordinate system.

7.11.3 Member Data Documentation

7.11.3.1 collisionHandler

```
CollisionHandler GuidewireSim.InitializationStep.collisionHandler  [private]
```

The component CollisionHandler that solves all collisions.

7.11.3.2 materialDensity

```
float GuidewireSim.InitializationStep.materialDensity = 7860  [private]
```

The density of the rod material. The value 7960 is taken from Table 2 of the CoRdE paper.

7.11.3.3 materialRadius

```
float GuidewireSim.InitializationStep.materialRadius = 0.001f  [private]
```

The radius of the cross-section of the rod. Tha value 0.001 or 1mm is taken from Table 2 of the CoRdE paper.

7.11.3.4 mathHelper

```
MathHelper GuidewireSim.InitializationStep.mathHelper  [private]
```

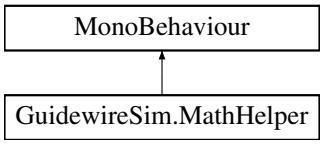
The component MathHelper that provides math related helper functions.

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

- InitializationStep.cs

7.12 GuidewireSim.MathHelper Class Reference

Inheritance diagram for GuidewireSim.MathHelper:



Public Member Functions

- void CalculateCylinderPositions (int cylinderCount, Vector3[ ] spherePositions, Vector3[ ] cylinderPositions)
- Vector3 MatrixVectorMultiplication (float[,] matrix, Vector3 vector)
- Vector3 ColumnVectorMatrixMultiplication (Vector3 columnVector, float[,] matrix)
- float[,] VectorColumnVectorMultiplication (Vector3 vectorOne, Vector3 columnVectorTwo)
- float[,] ScalarMatrixMultiplication (float scalar, float[,] matrix)
- float[,] MatrixInverse (float[,] matrix)
- BSM.Quaternion EmbeddedVector (Vector3 vector)
- Vector3 ImaginaryPart (BSM.Quaternion quaternion)
- Quaternion QuaternionConversionFromBSM (BSM.Quaternion bsmQuaternion)
- BSM.Quaternion QuaternionConversionToBSM (Quaternion quaternion)
- Vector3 DiscreteDarbouxVector (BSM.Quaternion orientationOne, BSM.Quaternion orientationTwo, float rodElementLength)
- float DarbouxSignFactor (Vector3 currentDarbouxVector, Vector3 restDarbouxVector)
- float VectorLength (Vector3 vector)
- float QuaternionLength (BSM.Quaternion quaternion)
- float RodElementLengthDeviation (Vector3 particlePositionOne, Vector3 particlePositionTwo, float default↩ RodElementLength)
- float StretchConstraintDeviation (Vector3 particlePositionOne, Vector3 particlePositionTwo, BSM.Quaternion orientation, BSM.Quaternion e_3, float rodElementLength, bool logIntermediateResults=false)
- float BendTwistConstraintDeviation (BSM.Quaternion orientationOne, BSM.Quaternion orientationTwo, float rodElementLength, Vector3 discreteRestDarbouxVector, bool logIntermediateResults=false)
- float RodElementLength (Vector3 particlePositionOne, Vector3 particlePositionTwo)
- Vector3[ ][ ] UpdateDirectors (int cylinderCount, BSM.Quaternion[ ] cylinderOrientations, Vector3[ ][ ] directors, BSM.Quaternion[ ] worldSpaceBasis)
- BSM.Quaternion RandomUnitQuaternion ()
- float GetGaussianRandomNumber ()

Private Member Functions

- float SquaredNorm (Vector3 vector)

7.12.1 Detailed Description

This class provides various helper methods for calculation.

7.12.2 Member Function Documentation

7.12.2.1 BendTwistConstraintDeviation()

```
float GuidewireSim.MathHelper.BendTwistConstraintDeviation (
            BSM.Quaternion orientationOne,
            BSM.Quaternion orientationTwo,
            float rodElementLength,
            Vector3 discreteRestDarbouxVector,
            bool logIntermediateResults = false )
```

Returns the deviation of the bend twist constraint from zero.

Parameters

orientationOne	q of the equation (32).
orientationTwo	u of the equation (32).
rodElementLength	The Rod Element Length between `orientationOne` and `orientationTwo`. Used to calculate $\not<$ of the equation (32).
discreteRestDarbouxVector	$\not<^0$ of the equation (32).
logIntermediateResults	Whether to output several logs that contain intermediate results of the calculation. Default is false.

Returns

The Deviation of the calculated bend twist constraint and zero.

Note

Check the Position and Orientation Based Cosserat Rods Paper (2016), equation (32), for more information on the bend twist constraint.

7.12.2.2 CalculateCylinderPositions()

```
void GuidewireSim.MathHelper.CalculateCylinderPositions (
            int cylinderCount,
```

```
Vector3[] spherePositions,
Vector3[] cylinderPositions )
```

Calculates `cylinderPositions` as the middle points of two adjacent spheres.

Parameters

cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
spherePositions	The position at the current frame of each sphere.
cylinderPositions	The position/ center of mass of each cylinder.

Note

`cylinderPositions` is not marked as an out parameter, since `cylinderPositions` is not initialized in this method, but its values are changed.

7.12.2.3 ColumnVectorMatrixMultiplication()

```
Vector3 GuidewireSim.MathHelper.ColumnVectorMatrixMultiplication (
            Vector3 columnVector,
            float matrix[,] )
```

Calculates the multiplication of $x^T M$, where M is the `matrix`, and x^T is the `columnVector` input.

Parameters

matrix	The matrix to be multiplied with the vector.
vector	The column vector x^T to be multiplied with the matrix.

Returns

The multiplication $x^T M$.

Requirements `matrix` must be a 3×3 matrix.

Attention

The input vector and the output vector are both column vectors.

7.12.2.4 DarbouxSignFactor()

```
float GuidewireSim.MathHelper.DarbouxSignFactor (
            Vector3 currentDarbouxVector,
            Vector3 restDarbouxVector )
```

Calculates the sign factor of the current discrete Darboux Vector and the rest Darboux Vector of the same orientations.

Note

Check the Position and Orientation Based Cosserat Rods Paper (2016) for more information on the sign factor.

Parameters

currentDarbouxVector	The discrete Darboux Vector of two fixed orientations at the current frame.
restDarbouxVector	The rest Darboux Vector of the same two orientations at frame 0.

Returns

The Sign Factor between these two entities.

7.12.2.5 DiscreteDarbouxVector()

```
Vector3 GuidewireSim.MathHelper.DiscreteDarbouxVector (
            BSM.Quaternion orientationOne,
            BSM.Quaternion orientationTwo,
            float rodElementLength )
```

Calculates the discrete Darboux Vector of two adjacent orientations `orientationOne`, `orientationTwo`.

Parameters

orientationOne	The orientation with the lower index, e.g. i.
orientationTwo	The orientation with the higher index, e.g. $i + 1$.
rodElementLength	The distance between two spheres, also the distance between two orientations.

Returns

The discrete Darboux Vector between `orientationOne` and `orientationTwo`.

Note

There is only cylinderCount - 1 many darboux vectors. The i-th Darboux Vector is between orientation i and orientation i+1.

Attention

The order in which the orientations are entered matters. The Darboux Vector of q_1, q_2 is not the same as the Darboux Vector of q_2, q_1.

7.12.2.6 EmbeddedVector()

```
BSM.Quaternion GuidewireSim.MathHelper.EmbeddedVector (
            Vector3 vector )
```

Returns a quaternion that is the embedded vector with scalar part zero.

Example

$(x, y, z) \mapsto (x, y, z, 0)$.

Parameters

vector	The vector to be embedded.

Returns

The quaternion that is the embedded vector with scalar part zero.

7.12.2.7 GetGaussianRandomNumber()

```
float GuidewireSim.MathHelper.GetGaussianRandomNumber ( )
```

Provides a sample from $\mathcal{N}(0,1)$ by using the Marsaglia polar method to transform a uniform distribution to a normal distribution.

Returns

A sample from $\mathcal{N}(0,1)$.

Note

To understand this method, google the Marsaglia polar method. Note that unity does not provide a function to generate a random number following a gaussian distribution.

7.12.2.8 ImaginaryPart()

```
Vector3 GuidewireSim.MathHelper.ImaginaryPart (
            BSM.Quaternion quaternion )
```

Returns the imaginary part of a `quaternion`.

Example

$(x, y, z, w) \mapsto (x, y, z)$.

Parameters

quaternion	The quaternion whose imaginary part to return.

Returns

The imaginary part of a `quaternion`.

7.12.2.9 MatrixInverse()

```
float[,] GuidewireSim.MathHelper.MatrixInverse (
            float matrix[,] )
```

Calculates the inverse of a 3×3 matrix M.

Parameters

matrix	The matrix to
columnVectorTwo	The column vector x^T to be multiplied.

Returns

The resulting 3×3 matrix of the multiplication xv^T.

7.12.2.10 MatrixVectorMultiplication()

```
Vector3 GuidewireSim.MathHelper.MatrixVectorMultiplication (
            float matrix[,],
            Vector3 vector )
```

Calculates the multiplication of Mx, where M is the `matrix`, and x is the `vector` input.

Parameters

matrix	The matrix to be multiplied with the vector.
vector	The vector to be multiplied with the matrix.

Returns

The multiplication Mx.

Requirements `matrix` must be a 3×3 matrix.

7.12.2.11 QuaternionConversionFromBSM()

```
Quaternion GuidewireSim.MathHelper.QuaternionConversionFromBSM (
            BSM.Quaternion bsmQuaternion )
```

Takes as input a BSM.Quaternion and returns a UnityEngine.Quaternion.

Parameters

bsmQuaternion	The BSM.Quaternion to be converted.

Returns

The converted UnityEngine.Quaternion.

7.12.2.12 QuaternionConversionToBSM()

```
BSM.Quaternion GuidewireSim.MathHelper.QuaternionConversionToBSM (
            Quaternion quaternion )
```

Takes as input a UnityEngine.Quaternion and returns a BSM.Quaternion.

Parameters

bsmQuaternion	The UnityEngine.Quaternion to be converted.

Returns

The converted BSM.Quaternion.

7.12.2.13 QuaternionLength()

```
float GuidewireSim.MathHelper.QuaternionLength (
            BSM.Quaternion quaternion )
```

Returns the quaternion length of `quaternion`, i.e. $\sqrt{x^2 + y^2 + z^2 + w^2}$.

Parameters

quaternion	The quaternion whose length to return.

Returns

The quaternion length of `quaternion`.

7.12.2.14 RandomUnitQuaternion()

```
BSM.Quaternion GuidewireSim.MathHelper.RandomUnitQuaternion ( )
```

Provides a random unit quaternion drawn from a gaussian distribution.

Returns

A random unit quaternion drawn from a gaussian distribution.

Note

This works by drawing four random, gaussian distributed, numbers, and filling the components of the quaternion with these numbers. Mathematically, this is equal to drawing a quaternion from a gaussian distribution in $\mathcal{R}^4$, since the joint distribution of gaussian samples is again gaussian.

Requirements The length of the drawn quaternion is approximately equal to one.

7.12.2.15 RodElementLength()

```
float GuidewireSim.MathHelper.RodElementLength (
            Vector3 particlePositionOne,
            Vector3 particlePositionTwo )
```

Calculates the rod element length between `particlePositionOne` and `particlePositionTwo`.

Parameters

particlePositionOne	The first particle of the rod element under consideration.
particlePositionTwo	The first particle of the rod element under consideration.

Returns

The rod element length.

7.12.2.16 RodElementLengthDeviation()

```
float GuidewireSim.MathHelper.RodElementLengthDeviation (
            Vector3 particlePositionOne,
            Vector3 particlePositionTwo,
            float defaultRodElementLength )
```

Returns the deviation between the actual distance of `particlePositionOne` and `particlePositionTwo` (current Rod Element Length) and the `defaultRodElementLength`.

Parameters

particlePositionOne	The first particle under consideration for the rod element length.
particlePositionTwo	The first particle under consideration for the rod element length.
defaultRodElementLength	The rod element length at rest state (i.e. frame 0) between these two particles.

Returns

The deviation between the actual rod element length and the default rod element length.

7.12.2.17 ScalarMatrixMultiplication()

```
float[,] GuidewireSim.MathHelper.ScalarMatrixMultiplication (
            float scalar,
            float matrix[,] )
```

Calculates the multiplication of aM, where a is a scalar , and M is a 3×3 matrix.

Parameters

scalar	The scalar to be multiplied.
matrix	The matrix M to be multiplied.

Returns

The resulting 3×3 matrix of the multiplication aM.

7.12.2.18 SquaredNorm()

```
float GuidewireSim.MathHelper.SquaredNorm (
            Vector3 vector )  [private]
```

Returns the squared norm of a `vector`.

Parameters

vector	The vector whose squared norm to return.

Returns

The Squared norm of `vector`.

7.12.2.19 StretchConstraintDeviation()

```
float GuidewireSim.MathHelper.StretchConstraintDeviation (
            Vector3 particlePositionOne,
            Vector3 particlePositionTwo,
            BSM.Quaternion orientation,
```

```
            BSM.Quaternion e_3,
            float rodElementLength,
            bool logIntermediateResults = false )
```

Returns the deviation of the stretch constraint from zero.

Parameters

particlePositionOne	p_1 of the equation (31).
particlePositionTwo	p_2 of the equation (31).
orientation	q of the equation (31).
e_3	e_3 of the equation (31).
rodElementLength	l of the equation (31).
logIntermediateResults	Whether to output several logs that contain intermediate results of the calculation. Default is false.

Returns

The Deviation of the calculated stretch constraint and zero.

Note

Check the Position and Orientation Based Cosserat Rods Paper (2016), equation (31), for more information on the stretch constraint.

7.12.2.20 UpdateDirectors()

```
Vector3[][] GuidewireSim.MathHelper.UpdateDirectors (
            int cylinderCount,
            BSM.Quaternion[] cylinderOrientations,
            Vector3 directors[][],
            BSM.Quaternion[] worldSpaceBasis )
```

Updates all directors of each orientation at the update step of the simulation loop.

Example

The directors d_1, d_2, d_3 are calculated as $d_i = q \cdot e_i \cdot \bar{q}$ for each orientation q, where e_i is the i-th world space basis vector. In quaternion calculus, this means rotating e_i by q.

Parameters

cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
cylinderOrientations	The orientation of each cylinder at its center of mass.
directors	The orthonormal basis of each orientation element / cylinder, also called directors.
worldSpaceBasis	The three basis vectors of the world coordinate system.

Returns

All directors of each orientation.

7.12.2.21 VectorColumnVectorMultiplication()

```
float[,] GuidewireSim.MathHelper.VectorColumnVectorMultiplication (
            Vector3 vectorOne,
            Vector3 columnVectorTwo )
```

Calculates the multiplication of xv^T, where x is a (row) vector , and v^T is a column vector.

Parameters

vectorOne	The (row) vector to be multiplied.
columnVectorTwo	The column vector x^T to be multiplied.

Returns

The resulting 3×3 matrix of the multiplication xv^T.

7.12.2.22 VectorLength()

```
float GuidewireSim.MathHelper.VectorLength (
            Vector3 vector )
```

Returns the vector length of `vector`, i.e. $\sqrt{x_1^2 + x_2^2 + x_3^2}$ for a three-dimensional vector.

Parameters

vector	The vector whose length to return.

Returns

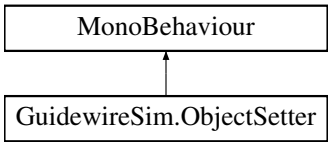
The vector length of `vector`.

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

- MathHelper.cs

7.13 GuidewireSim.ObjectSetter Class Reference

Inheritance diagram for GuidewireSim.ObjectSetter:



Public Member Functions

- void SetSpherePositions (GameObject[ ] spheres, int spheresCount, Vector3[ ] spherePositions)
- void SetCylinderPositions (GameObject[ ] cylinders, int cylinderCount, Vector3[ ] cylinderPositions)
- void SetCylinderOrientations (GameObject[ ] cylinders, int cylinderCount, BSM.Quaternion[ ] cylinder↩ Orientations, Vector3[ ][ ] directors)

Private Member Functions

- void Awake ()

Private Attributes

- MathHelper mathHelper

  The component MathHelper that provides math related helper functions.

7.13.1 Detailed Description

This class is responsible for setting the transformation positions of the GameObjects in the scene to their respective simulation data like `spherePositions`.

7.13.2 Member Function Documentation

7.13.2.1 Awake()

```
void GuidewireSim.ObjectSetter.Awake ( )  [private]
```

7.13.2.2 SetCylinderOrientations()

```
void GuidewireSim.ObjectSetter.SetCylinderOrientations (
            GameObject[] cylinders,
            int cylinderCount,
            BSM.Quaternion[] cylinderOrientations,
            Vector3 directors[][] )
```

Rotates each cylinder GameObject such that its centerline is parallel with the line segment that is spanned by the two adjacent sphere's center of masses.

Parameters

cylinders	All cylinders that are part of the guidewire.
cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
cylinderOrientations	The orientation of each cylinder at its center of mass.
directors	The orthonormal basis of each orientation element / cylinder, also called directors.

Note

`appliedTransformation` is the rotation that aligns the y-axis of the cylinder with the z-axis of the orientations (the third director). This is needed, because the y-axis of the cylinder is parallel with its centerline, while the z-axis of the orientations (the third director) is also defined as being parallel with the cylinder's centerline. Thus `appliedTransformation` is necessary.

7.13.2.3 SetCylinderPositions()

```
void GuidewireSim.ObjectSetter.SetCylinderPositions (
            GameObject[] cylinders,
            int cylinderCount,
            Vector3[] cylinderPositions )
```

Sets the positions of the GameObjects `cylinders` to their respective `cylinderPositions`.

Parameters

cylinders	All cylinders that are part of the guidewire.
cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
cylinderPositions	The position/ center of mass of each cylinder.

7.13.2.4 SetSpherePositions()

```
void GuidewireSim.ObjectSetter.SetSpherePositions (
            GameObject[] spheres,
            int spheresCount,
            Vector3[] spherePositions )
```

Sets the positions of the GameObjects `spheres` to their respective `spherePositions`.

Parameters

spheres	All spheres that are part of the guidewire.
spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
spherePositions	The position at the current frame of each sphere.

7.13.3 Member Data Documentation

7.13.3.1 mathHelper

```
MathHelper GuidewireSim.ObjectSetter.mathHelper  [private]
```

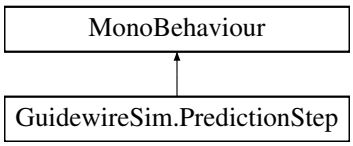
The component MathHelper that provides math related helper functions.

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

- ObjectSetter.cs

7.14 GuidewireSim.PredictionStep Class Reference

Inheritance diagram for GuidewireSim.PredictionStep:



Public Member Functions

- Vector3[ ] PredictSphereVelocities (Vector3[ ] sphereVelocities, float[ ] sphereInverseMasses, Vector3[ ] sphereExternalForces)
- Vector3[ ] PredictSpherePositions (Vector3[ ] spherePositionPredictions, int spheresCount, Vector3[ ] spherePositions, Vector3[ ] sphereVelocities)
- Vector3[ ] PredictAngularVelocities (Vector3[ ] cylinderAngularVelocities, int cylinderCount, float[,] inertia↩ Tensor, Vector3[ ] cylinderExternalTorques, float[,] inverseInertiaTensor)
- BSM.Quaternion[ ] PredictCylinderOrientations (BSM.Quaternion[ ] cylinderOrientationPredictions, int cylinderCount, Vector3[ ] cylinderAngularVelocities, BSM.Quaternion[ ] cylinderOrientations)

Private Member Functions

- void Awake ()

Private Attributes

- MathHelper mathHelper

  The component MathHelper that provides math related helper functions.

7.14.1 Detailed Description

This class implements the prediction step of the algorithm.

7.14.2 Member Function Documentation

7.14.2.1 Awake()

```
void GuidewireSim.PredictionStep.Awake ( )  [private]
```

7.14.2.2 PredictAngularVelocities()

```
Vector3[] GuidewireSim.PredictionStep.PredictAngularVelocities (
            Vector3[] cylinderAngularVelocities,
            int cylinderCount,
            float inertiaTensor[,],
            Vector3[] cylinderExternalTorques,
            float inverseInertiaTensor[,] )
```

Calculates the predictions for the angular velocities for the prediction step of the algorithm.

Parameters

cylinderAngularVelocities	The angular velocity of the current frame of each orientation element/ cylinder.
cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
inertiaTensor	The inertia tensor. Entries are approximates as in the CoRdE paper.
cylinderExternalTorques	The sum of all current external torques that are applied per orientation element/ cylinder.
inverseInertiaTensor	The inverse of `inertiaTensor`.

Returns

The angular velocity of the current frame of each orientation element/ cylinder, i.e. `cylinderAngular↩Velocities`.

Note

The predictions are again stored in `cylinderAngularVelocities`.

7.14.2.3 PredictCylinderOrientations()

```
BSM.Quaternion[] GuidewireSim.PredictionStep.PredictCylinderOrientations (
            BSM.Quaternion[] cylinderOrientationPredictions,
            int cylinderCount,
            Vector3[] cylinderAngularVelocities,
            BSM.Quaternion[] cylinderOrientations )
```

Calculates the predictions for the cylinder orientations for the prediction step of the algorithm.

Parameters

cylinderOrientationPredictions	The prediction of the orientation of each cylinder at its center of mass.
cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
cylinderAngularVelocities	The angular velocity of the current frame of each orientation element/ cylinder.
cylinderOrientations	The orientation of each cylinder at its center of mass.

Returns

The prediction of the orientation of each cylinder at its center of mass, i.e. `cylinderOrientation↩Predictions`.

7.14.2.4 PredictSpherePositions()

```
Vector3[] GuidewireSim.PredictionStep.PredictSpherePositions (
            Vector3[] spherePositionPredictions,
            int spheresCount,
            Vector3[] spherePositions,
            Vector3[] sphereVelocities )
```

Calculates the predictions for the sphere positions for the prediction step of the algorithm.

Parameters

spherePositionPredictions	The prediction of the position at the current frame of each sphere (in this case of the last frame).
spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
spherePositions	The position at the current frame of each sphere.
sphereVelocities	The velocity of the current frame of each sphere.

Returns

The prediction of the position at the current frame of each sphere, i.e. spherePositionPredictions.

7.14.2.5 PredictSphereVelocities()

```
Vector3[] GuidewireSim.PredictionStep.PredictSphereVelocities (
            Vector3[] sphereVelocities,
            float[] sphereInverseMasses,
            Vector3[] sphereExternalForces )
```

Calculates the predictions for the sphere velocities for the prediction step of the algorithm.

Parameters

sphereVelocities	The velocity of the current frame of each sphere.
sphereInverseMasses	The constant inverse masses of each sphere.
sphereExternalForces	The sum of all current external forces that are applied per particle/ sphere.

Returns

The predictions of the positions of the spheres, i.e. `spherePositionPredictions`.

Note

The predictions are again stored in `sphereVelocities`.

7.14.3 Member Data Documentation

7.14.3.1 mathHelper

`MathHelper GuidewireSim.PredictionStep.mathHelper [private]`

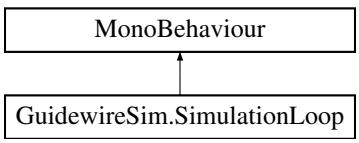
The component MathHelper that provides math related helper functions.

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

- PredictionStep.cs

7.15 GuidewireSim.SimulationLoop Class Reference

Inheritance diagram for GuidewireSim.SimulationLoop:



Public Member Functions

- void PerformSimulationLoop ()

Public Attributes

- GameObject[ ] spheres
- Vector3[ ] spherePositions

  The position at the current frame of each sphere.
- Vector3[ ] sphereVelocities

  The velocity of the current frame of each sphere. Initalized with zero entries.
- float[ ] sphereInverseMasses
- Vector3[ ] sphereExternalForces

  The sum of all current external forces that are applied per particle/ sphere.
- Vector3[ ] cylinderPositions

  The center of mass of each cylinder.
- float[ ] cylinderScalarWeights
- Vector3[ ] cylinderExternalTorques

  The sum of all current external torques that are applied per orientation element/ cylinder.
- Vector3[ ][ ] directors
- bool solveStretchConstraints = true

  Whether or not to perform the constraint solving of the stretch constraint.
- bool solveBendTwistConstraints = true

  Whether or not to perform the constraint solving of the bend twist constraint.
- bool solveCollisionConstraints = true

  Whether or not to perform the constraint solving of collision constraints.

Properties

- bool ExecuteSingleLoopTest = false `[get, set]`
- int ConstraintSolverSteps `[get, set]`
- float TimeStep `[get]`
- int SpheresCount `[get, private set]`

  The count of all spheres of the guidewire.
- int CylinderCount `[get, private set]`

  The count of all cylinders of the guidewire.

Private Member Functions

- void Awake ()
- void Start ()
- void FixedUpdate ()
- void PerformInitializationStep ()
- void PerformConstraintSolvingStep ()
- void PerformUpdateStep ()
- void PerformPredictionStep ()
- void AdaptCalculations ()
- void SetCollidersStep ()

Private Attributes

- InitializationStep initializationStep

  The component InitializationStep that is responsible for initializing the simulation.
- PredictionStep predictionStep

  The component PredictionStep that is responsible for executing the Prediction Step of the algorithm.
- ConstraintSolvingStep constraintSolvingStep
- UpdateStep updateStep

  The component UpdateStep that is responsible for executing the Update Step of the algorithm.
- ObjectSetter objectSetter

  The component ObjectSetter that is responsible for setting all positions and rotations the the GameObjects.
- MathHelper mathHelper

  The component MathHelper that provides math related helper functions.
- CollisionSolvingStep collisionSolvingStep

  The component CollisionSolvingStep that solves all collisions.
- CollisionHandler collisionHandler

  The component CollisionHandler that tracks all collisions.
- GameObject[ ] cylinders
- Vector3[ ] spherePositionPredictions

  The prediction of the position at the current frame of each sphere.
- BSM.Quaternion[ ] cylinderOrientations

  The orientation of each cylinder at its center of mass.
- BSM.Quaternion[ ] cylinderOrientationPredictions

  The prediction of the orientation of each cylinder at its center of mass.
- Vector3[ ] discreteRestDarbouxVectors
- Vector3[ ] cylinderAngularVelocities
- float[,] inertiaTensor

  The inertia tensor. Entries are approximates as in the CoRdE paper.
- float[,] inverseInertiaTensor

  The inverse of inertiaTensor.
- BSM.Quaternion[ ] worldSpaceBasis
- float rodElementLength = 10f
- int constraintSolverSteps = 1000
- float timeStep = 0.01f

7.15.1 Detailed Description

This class executes the outer simuluation loop of the algorithm and calls the implementations of each algorithm step and manages all coherent data.

7.15.2 Member Function Documentation

7.15.2.1 AdaptCalculations()

```
void GuidewireSim.SimulationLoop.AdaptCalculations ( )  [private]
```

Adapts the data to the Unity GameObjects. For example, sets the positions of the GameObjects spheres to spherePositions.

Requirements Sets the positions of the GameObjects spheres to spherePositions.

Calculates cylinderPositions based on spherePositions.

Sets the positions of the GameObjects cylinders to cylinderPositions.

Sets the rotations of the GameObjects cylinders to cylinderOrientations.

7.15.2.2 Awake()

```
void GuidewireSim.SimulationLoop.Awake ( )  [private]
```

7.15.2.3 FixedUpdate()

```
void GuidewireSim.SimulationLoop.FixedUpdate ( )  [private]
```

Requirements Execute the simulation loop if and only if ExecuteSingleLoopTest is false.

7.15.2.4 PerformConstraintSolvingStep()

```
void GuidewireSim.SimulationLoop.PerformConstraintSolvingStep ( )  [private]
```

Performs the constraint solving step of the algorithm.

Requirements Performs the constraint solving of every constraint #solverStep many times.

Solve stretch constraints, if and only if solveStretchConstraints is true.

Solve bend twist constraints, if and only if solveBendTwistConstraints is true.

If solveStretchConstraints, then SpheresCount is at least two.

If solveStretchConstraints, then CylinderCount is at least one.

If solveBendTwistConstraints, then SpheresCount is at least three.

If solveBendTwistConstraints, then CylinderCount is at least two.

If solveStretchConstraints, after the step is complete the deviation between the actual rod element length and the default (rest state) rodElementLength should be close to zero.

If solveStretchConstraints, after the step is complete the deviation of the stretch constraint to zero should be close to zero.

If solveCollisionConstraints, after this step is complete clear the list `registeredCollisions`, since these collisions are now resolved.

7.15.2.5 PerformInitializationStep()

```
void GuidewireSim.SimulationLoop.PerformInitializationStep ( )  [private]
```

Calls every step that is mandatory to declare and initialize all data.

Requirements Set SpheresCount to the length of spheres.
Set CylinderCount to the length of cylinders.
Call every init method of initializationStep.

7.15.2.6 PerformPredictionStep()

```
void GuidewireSim.SimulationLoop.PerformPredictionStep ( )  [private]
```

Performs the prediction step of the algorithm.

Requirements Predict the sphereVelocities.
Predict the spherePositionPredictions.
Predict the cylinderAngularVelocities.
Predict the cylinderOrientationPredictions.

7.15.2.7 PerformSimulationLoop()

```
void GuidewireSim.SimulationLoop.PerformSimulationLoop ( )
```

Performs the outer simulation loop of the algorithm.

Note

In a late version, CollisionDetection and GenerateCollisionConstraints will be added to the algorithm.

7.15.2.8 PerformUpdateStep()

```
void GuidewireSim.SimulationLoop.PerformUpdateStep ( )  [private]
```

Performs the update step of the algorithm.

Requirements Upate sphereVelocities.
Upate spherePositions.
Upate cylinderAngularVelocities.
Upate cylinderOrientations.
Upate directors.

7.15.2.9 SetCollidersStep()

```
void GuidewireSim.SimulationLoop.SetCollidersStep ( )  [private]
```

Sets the position of the collider of each sphere of the guidewire to the sphere's position prediciton.

7.15.2.10 Start()

```
void GuidewireSim.SimulationLoop.Start ( )  [private]
```

7.15.3 Member Data Documentation

7.15.3.1 collisionHandler

```
CollisionHandler GuidewireSim.SimulationLoop.collisionHandler  [private]
```

The component CollisionHandler that tracks all collisions.

7.15.3.2 collisionSolvingStep

```
CollisionSolvingStep GuidewireSim.SimulationLoop.collisionSolvingStep  [private]
```

The component CollisionSolvingStep that solves all collisions.

7.15.3.3 constraintSolverSteps

```
int GuidewireSim.SimulationLoop.constraintSolverSteps = 1000  [private]
```

How often the constraint solver iterates over each constraint during the Constraint Solving Step.

Attention

This value must be positive.

7.15.3.4 constraintSolvingStep

```
ConstraintSolvingStep GuidewireSim.SimulationLoop.constraintSolvingStep  [private]
```

The component ConstraintSolvingStep that is responsible for correcting the predictions with the collision and model constraints.

7.15.3.5 cylinderAngularVelocities

```
Vector3 [] GuidewireSim.SimulationLoop.cylinderAngularVelocities  [private]
```

The angular velocity of the current frame of each orientation element/ cylinder. Initalized with zero entries.

7.15.3.6 cylinderExternalTorques

```
Vector3 [] GuidewireSim.SimulationLoop.cylinderExternalTorques
```

The sum of all current external torques that are applied per orientation element/ cylinder.

7.15.3.7 cylinderOrientationPredictions

```
BSM.Quaternion [] GuidewireSim.SimulationLoop.cylinderOrientationPredictions  [private]
```

The prediction of the orientation of each cylinder at its center of mass.

7.15.3.8 cylinderOrientations

```
BSM.Quaternion [] GuidewireSim.SimulationLoop.cylinderOrientations  [private]
```

The orientation of each cylinder at its center of mass.

7.15.3.9 cylinderPositions

```
Vector3 [] GuidewireSim.SimulationLoop.cylinderPositions
```

The center of mass of each cylinder.

7.15.3.10 cylinders

```
GameObject [] GuidewireSim.SimulationLoop.cylinders  [private]
```

All cylinders that are part of the guidewire.

Attention

The order in which the cylinders are assigned matters. Assign them such that two adjacent cylinders are adjacent in the array as well.

7.15.3.11 cylinderScalarWeights

```
float [] GuidewireSim.SimulationLoop.cylinderScalarWeights
```

The constant scalar weights of each orientation/ quaternion similar to sphereInverseMasses.

Note

Set to 1 for moving orientations (so that angular motion can be applied) and to 0 for fixed orientations.

7.15.3.12 directors

```
Vector3 [][] GuidewireSim.SimulationLoop.directors
```

The orthonormal basis of each orientation element / cylinder, also called directors.

Note

In the 0th row are the first directors of each orientation element, not in the 1th row. Example: The (i, j)th element holds the (i-1)th director of orientation element j.

7.15.3.13 discreteRestDarbouxVectors

```
Vector3 [] GuidewireSim.SimulationLoop.discreteRestDarbouxVectors  [private]
```

The discrete Darboux Vector at the rest configuration, i.e. at frame 0.

Note

It is important to only take the imaginary part in the calculation for the discrete Darboux Vector, thus we only save it as a Vector3. To use it in a quaternion setting, embedd the Vector3 with scalar part 0, i.e. with EmbeddedVector().

Attention

There is only CylinderCount - 1 many darboux vectors. The i-th Darboux Vector is between orientation i and orientation i+1.

7.15.3.14 inertiaTensor

```
float [,] GuidewireSim.SimulationLoop.inertiaTensor  [private]
```

The inertia tensor. Entries are approximates as in the CoRdE paper.

7.15.3.15 initializationStep

```
InitializationStep GuidewireSim.SimulationLoop.initializationStep [private]
```

The component InitializationStep that is responsible for initializing the simulation.

7.15.3.16 inverseInertiaTensor

```
float [,] GuidewireSim.SimulationLoop.inverseInertiaTensor [private]
```

The inverse of inertiaTensor.

7.15.3.17 mathHelper

```
MathHelper GuidewireSim.SimulationLoop.mathHelper [private]
```

The component MathHelper that provides math related helper functions.

7.15.3.18 objectSetter

```
ObjectSetter GuidewireSim.SimulationLoop.objectSetter [private]
```

The component ObjectSetter that is responsible for setting all positions and rotations the the GameObjects.

7.15.3.19 predictionStep

```
PredictionStep GuidewireSim.SimulationLoop.predictionStep [private]
```

The component PredictionStep that is responsible for executing the Prediction Step of the algorithm.

7.15.3.20 rodElementLength

```
float GuidewireSim.SimulationLoop.rodElementLength = 10f [private]
```

The distance between two spheres, also the distance between two orientations. Also the length of one cylinder.

Note

This should be two times the radius of a sphere.

Attention

Make sure that the guidewire setup fulfilles that the distance between two adjacent spheres is rodElementLength.

7.15.3.21 solveBendTwistConstraints

```
bool GuidewireSim.SimulationLoop.solveBendTwistConstraints = true
```

Whether or not to perform the constraint solving of the bend twist constraint.

7.15.3.22 solveCollisionConstraints

```
bool GuidewireSim.SimulationLoop.solveCollisionConstraints = true
```

Whether or not to perform the constraint solving of collision constraints.

7.15.3.23 solveStretchConstraints

```
bool GuidewireSim.SimulationLoop.solveStretchConstraints = true
```

Whether or not to perform the constraint solving of the stretch constraint.

7.15.3.24 sphereExternalForces

```
Vector3 [] GuidewireSim.SimulationLoop.sphereExternalForces
```

The sum of all current external forces that are applied per particle/ sphere.

7.15.3.25 sphereInverseMasses

```
float [] GuidewireSim.SimulationLoop.sphereInverseMasses
```

The constant inverse masses of each sphere.

Note

Set to 1 for moving spheres and to 0 for fixed spheres.

7.15.3.26 spherePositionPredictions

```
Vector3 [] GuidewireSim.SimulationLoop.spherePositionPredictions  [private]
```

The prediction of the position at the current frame of each sphere.

7.15.3.27 spherePositions

```
Vector3 [] GuidewireSim.SimulationLoop.spherePositions
```

The position at the current frame of each sphere.

7.15.3.28 spheres

```
GameObject [] GuidewireSim.SimulationLoop.spheres
```

All spheres that are part of the guidewire.

Attention

The order in which the spheres are assigned matters. Assign them such that two adjacent spheres are adjacent in the array as well.

7.15.3.29 sphereVelocities

```
Vector3 [] GuidewireSim.SimulationLoop.sphereVelocities
```

The velocity of the current frame of each sphere. Initalized with zero entries.

7.15.3.30 timeStep

```
float GuidewireSim.SimulationLoop.timeStep = 0.01f  [private]
```

The fixed time step in seconds at which the simulation runs.

Note

A lower timestep than 0.002 can not be guaranteed by the test hardware to be executed in time. Only choose a lower timestep if you are certain your hardware can handle it.

7.15.3.31 updateStep

```
UpdateStep GuidewireSim.SimulationLoop.updateStep  [private]
```

The component UpdateStep that is responsible for executing the Update Step of the algorithm.

7.15.3.32 worldSpaceBasis

```
BSM.Quaternion [] GuidewireSim.SimulationLoop.worldSpaceBasis  [private]
```

The three basis vectors of the world coordinate system as embedded quaternions with scalar part 0. E.g. the first basis vector is (1, 0, 0), the second (0, 1, 0) and the third (0, 0, 1).

7.15.4 Property Documentation

7.15.4.1 ConstraintSolverSteps

```
int GuidewireSim.SimulationLoop.ConstraintSolverSteps  [get], [set]
```

7.15.4.2 CylinderCount

```
int GuidewireSim.SimulationLoop.CylinderCount  [get], [private set]
```

The count of all cylinders of the guidewire.

7.15.4.3 ExecuteSingleLoopTest

```
bool GuidewireSim.SimulationLoop.ExecuteSingleLoopTest = false  [get], [set]
```

Whether or not to execute the Single Loop Test, in which the outer simulation loop is exactly executed once.

7.15.4.4 SpheresCount

```
int GuidewireSim.SimulationLoop.SpheresCount  [get], [private set]
```

The count of all spheres of the guidewire.

7.15.4.5 TimeStep

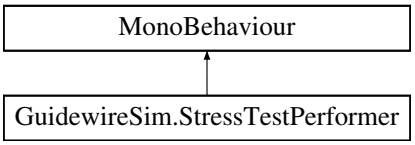
```
float GuidewireSim.SimulationLoop.TimeStep  [get]
```

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

- SimulationLoop.cs

7.16 GuidewireSim.StressTestPerformer Class Reference

Inheritance diagram for GuidewireSim.StressTestPerformer:



Private Member Functions

- void Awake ()
- void Start ()
- void PerformStressTests ()
- IEnumerator PerformStressTestOne (float applyForceTime=1f)

Private Attributes

- SimulationLoop simulationLoop

  The SimulationLoop component that executes all steps of the simulation loop.
- bool doStressTestOne = false

7.16.1 Detailed Description

This class enables the user to test the impact of mutliple external forces and external torques with one button within the Unity inspector.

Attention

In the current version, the user is not able to fix positions or orientations of the guidewire, which is necessary e.g. for stress test one.

7.16.2 Member Function Documentation

7.16.2.1 Awake()

```
void GuidewireSim.StressTestPerformer.Awake ( )  [private]
```

7.16.2.2 PerformStressTestOne()

```
IEnumerator GuidewireSim.StressTestPerformer.PerformStressTestOne (
            float applyForceTime = 1f )  [private]
```

Performs stress test one. This test fixes the position of one end of the guidewire, and applies `pullForce` at the other end for `applyForceTime` seconds, and then applies - `pullForce` for another `applyForceTime` seconds.

Parameters

applyForceTime	For how many seconds to apply the force to the particles.

Attention

In the current version, the user is not able to fix positions or orientations of the guidewire, which is necessary e.g. for stress test one.

Requirements Output a log message when no further forces are applied to the guidewire.

7.16.2.3 PerformStressTests()

```
void GuidewireSim.StressTestPerformer.PerformStressTests ( )  [private]
```

Performs each Stress Test whose respective serialized boolean is set to true in the Unity inspector.

7.16.2.4 Start()

```
void GuidewireSim.StressTestPerformer.Start ( )  [private]
```

7.16.3 Member Data Documentation

7.16.3.1 doStressTestOne

```
bool GuidewireSim.StressTestPerformer.doStressTestOne = false  [private]
```

Whether to run Stress Test One. This test fixes the position of one end of the guidewire, and applies `pullForce` at the other end for `applyForceTime` seconds, and then applies - `pullForce` for another `applyForceTime` seconds.

7.16.3.2 simulationLoop

```
SimulationLoop GuidewireSim.StressTestPerformer.simulationLoop  [private]
```

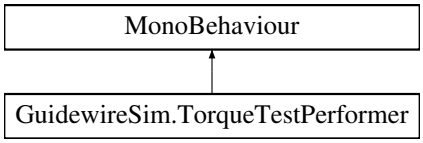
The SimulationLoop component that executes all steps of the simulation loop.

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

- StressTestPerformer.cs

7.17 GuidewireSim.TorqueTestPerformer Class Reference

Inheritance diagram for GuidewireSim.TorqueTestPerformer:



Private Member Functions

- void Awake ()
- void Start ()
- void PerformTorqueTests ()
- void PerformTorqueTestOne ()
- IEnumerator PerformTorqueTestTwo (Vector3 pullTorque, float applyTorqueTime=1f)
- IEnumerator PerformTorqueTestThree (Vector3 pullTorque, float applyTorqueTime=10f)

Private Attributes

- SimulationLoop simulationLoop

  The SimulationLoop component that executes all steps of the simulation loop.
- Vector3 pullTorque = new Vector3(0f, 0.3f, 0f)
- bool doTorqueTestOne = false

  Whether to run Torque Test One. This test applies an external torque to one end of the guidewire.
- bool doTorqueTestTwo = false
- bool doTorqueTestThree = false

7.17.1 Detailed Description

This class enables the user to test the impact of external torques with one button within the Unity inspector.

7.17.2 Member Function Documentation

7.17.2.1 Awake()

```
void GuidewireSim.TorqueTestPerformer.Awake ( )  [private]
```

7.17.2.2 PerformTorqueTestOne()

```
void GuidewireSim.TorqueTestPerformer.PerformTorqueTestOne ( )  [private]
```

Performs torque test one. This test applies an external torque to one end of the guidewire.

7.17.2.3 PerformTorqueTests()

```
void GuidewireSim.TorqueTestPerformer.PerformTorqueTests ( )  [private]
```

Performs each Torque Test whose respective serialized boolean is set to true in the Unity inspector.

7.17.2.4 PerformTorqueTestThree()

```
IEnumerator GuidewireSim.TorqueTestPerformer.PerformTorqueTestThree (
            Vector3 pullTorque,
            float applyTorqueTime = 10f )  [private]
```

Performs torque test three. This test applies an external torque to one end of the guidewire and at the same time the opposite torque at the other end of the guidewire. The applied torque starts at 0 and linearly interpolates until it reaches `pullTorque` at `applyTorqueTime` seconds.

Parameters

pullTorque	The external torque that is applied to one end of the guidewire.
applyTorqueTime	For how many seconds to apply the torque to the orientations.

Requirements Output a log message when no further torques are applied to the guidewire.

7.17.2.5 PerformTorqueTestTwo()

```
IEnumerator GuidewireSim.TorqueTestPerformer.PerformTorqueTestTwo (
            Vector3 pullTorque,
            float applyTorqueTime = 1f )  [private]
```

Performs torque test two. This test applies an external torque to one end of the guidewire for a fixed amount of time and then the opposite torque at the same orientation for the same amount of time.

Parameters

pullTorque	The external torque that is applied to one end of the guidewire.
applyTorqueTime	For how many seconds to apply the torque to the orientations.

Requirements Output a log message when no further torques are applied to the guidewire.

7.17.2.6 Start()

```
void GuidewireSim.TorqueTestPerformer.Start ( )  [private]
```

7.17.3 Member Data Documentation

7.17.3.1 doTorqueTestOne

```
bool GuidewireSim.TorqueTestPerformer.doTorqueTestOne = false  [private]
```

Whether to run Torque Test One. This test applies an external torque to one end of the guidewire.

7.17.3.2 doTorqueTestThree

```
bool GuidewireSim.TorqueTestPerformer.doTorqueTestThree = false  [private]
```

Whether to run Torque Test Three. This test applies an external torque to one end of the guidewire and at the same time the opposite torque at the other end of the guidewire. The applied torque starts at 0 and linearly interpolates until it reaches `pullTorque` at `applyTorqueTime` seconds.

7.17.3.3 doTorqueTestTwo

```
bool GuidewireSim.TorqueTestPerformer.doTorqueTestTwo = false  [private]
```

Whether to run Torque Test Two. This test applies an external torque to one end of the guidewire for a fixed amount of time and then the opposite torque at the same orientation for the same amount of time.

7.17.3.4 pullTorque

```
Vector3 GuidewireSim.TorqueTestPerformer.pullTorque = new Vector3(0f, 0.3f, 0f)  [private]
```

The external torque that is applied to the respective parts of the guidewire, depending on the test.

7.17.3.5 simulationLoop

```
SimulationLoop GuidewireSim.TorqueTestPerformer.simulationLoop  [private]
```

The SimulationLoop component that executes all steps of the simulation loop.

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

- TorqueTestPerformer.cs

7.18 UnitTest_SolveBendTwistConstraint Class Reference

Public Member Functions

- IEnumerator PerformUnitTests ()

Private Member Functions

- void Test_SolveBendTwistConstraint (int iterations, BSM.Quaternion orientationOne, BSM.Quaternion orientationTwo, float rodElementLength, Vector3 discreteRestDarbouxVector, GuidewireSim.MathHelper mathHelper, GuidewireSim.ConstraintSolvingStep constraintSolvingStep)

Private Attributes

- int sampleSize = 10
- int constraintSolverSteps = 50

  How often the constraint solver iterates over each constraint during the Constraint Solving Step.

7.18.1 Detailed Description

This class provides unit tests that test the method SolveBendTwistConstraint() of ConstraintSolvingStep. Executing this test once generates `sampleSize` many random value pairs and executes the unit test with each of these pairs.

7.18.2 Member Function Documentation

7.18.2.1 PerformUnitTests()

```
IEnumerator UnitTest_SolveBendTwistConstraint.PerformUnitTests ( )
```

Arranges all necessary data, generates sampleSize many random value pairs, and then passes all data to Test_SolveBendTwistConstraint(), where the unit tests are executed.

Note

Only tests the case that all rod elements are aligned at rest state. If you want to test deformed rods at rest state, change `discreteRestDarbouxVector` accordingly.

7.18.2.2 Test_SolveBendTwistConstraint()

```
void UnitTest_SolveBendTwistConstraint.Test_SolveBendTwistConstraint (
            int iterations,
            BSM.Quaternion orientationOne,
            BSM.Quaternion orientationTwo,
            float rodElementLength,
            Vector3 discreteRestDarbouxVector,
            GuidewireSim.MathHelper mathHelper,
            GuidewireSim.ConstraintSolvingStep constraintSolvingStep )  [private]
```

Executes SolveBendTwistConstraint() of ConstraintSolvingStep `iterations` many times for one values pair, and then asserts whether the results of the algorithm of SolveBendTwistConstraint() converged towards the expected values.

Parameters

iterations	The number of iterations that SolveBendTwistConstraint() of ConstraintSolvingStep is executed.
orientationOne	The first orientation for SolveBendTwistConstraint().
orientationOne	The second orientation for SolveBendTwistConstraint().
rodElementLength	The rod element length for SolveBendTwistConstraint().
discreteRestDarbouxVector	The discrete Darboux Vector at rest state for SolveBendTwistConstraint().
mathHelper	The component MathHelper.
constraintSolvingStep	The component ConstraintSolvingStep.

Requirements `orientationOne` and orientationTwo are still unit quaternions at the end of the test.

The deviation between the bend twist constraint and zero is lower than a reasonable tolerance, i.e. close to zero., which means that the algorithm of SolveBendTwistConstraint() converges towards the fulfillment of the bend twist constraint.

7.18.3 Member Data Documentation

7.18.3.1 constraintSolverSteps

```
int UnitTest_SolveBendTwistConstraint.constraintSolverSteps = 50  [private]
```

How often the constraint solver iterates over each constraint during the Constraint Solving Step.

7.18.3.2 sampleSize

```
int UnitTest_SolveBendTwistConstraint.sampleSize = 10  [private]
```

The number of value-pairs the test is executed with. E.g. if sampleSize is 10, then the unit test is executed with 10 randomly drawn value-pairs. A higher number needs more time to execute.

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

- UnitTest_SolveBendTwistConstraint.cs

7.19 UnitTest_SolveStretchConstraint Class Reference

Public Member Functions

- IEnumerator PerformUnitTests ()

Private Member Functions

- void PickRandomPositions (out Vector3 particlePositionOne, out Vector3 particlePositionTwo)
- void Test_SolveStretchConstraint (int iterations, Vector3 particlePositionOne, Vector3 particlePositionTwo, BSM.Quaternion orientation, GuidewireSim.MathHelper mathHelper, GuidewireSim.ConstraintSolvingStep constraintSolvingStep)

Private Attributes

- float maximalDistanceOffset = 1f
- int sampleSize = 10
- int constraintSolverSteps = 1000

  How often the constraint solver iterates over each constraint during the Constraint Solving Step.
- float rodElementLength = 10f

  The distance between two spheres, also the distance between two orientations.

7.19.1 Detailed Description

This class provides unit tests that test the method SolveStretchConstraint() of ConstraintSolvingStep. Executing this test once generates `sampleSize` many random value pairs and executes the unit test with each of these pairs.

7.19.2 Member Function Documentation

7.19.2.1 PerformUnitTests()

```
IEnumerator UnitTest_SolveStretchConstraint.PerformUnitTests ( )
```

Arranges all necessary data, generates sampleSize many random value pairs, and then passes all data to Test_SolveStretchConstraint(), where the unit tests are executed.

7.19.2.2 PickRandomPositions()

```
void UnitTest_SolveStretchConstraint.PickRandomPositions (
            out Vector3 particlePositionOne,
            out Vector3 particlePositionTwo )  [private]
```

Picks the first particle position uniformly distributed with $x, y, z \in [-5, 5]$ and the second uniformly distributed around the first position with a uniformly distributed distance in $[rodElementLength - maximalDistanceOffset, rodElementLength + maximalDistanceOffset]$.

Note

The method for picking the second position is inspired by https://math.stackexchange.com/q/50482

Parameters

out	*particlePositionOne*	The first particle position that got picked.
out	*particlePositionTwo*	The second particle position that got picked.

Requirements Picks the first particle position uniformly distributed so that $x, y, z \in [-5, 5]$.

Picks a distance between the two particles that is uniformly distributed in the interval $[rodElementLength - maximalDistanceOffset, rodElementLength + maximalDistanceOffset]$.

Picks the second particle position uniformly distributed on the surface of the sphere with center `particlePositionOne` and radius `startDistance`.

7.19.2.3 Test_SolveStretchConstraint()

```
void UnitTest_SolveStretchConstraint.Test_SolveStretchConstraint (
            int iterations,
            Vector3 particlePositionOne,
            Vector3 particlePositionTwo,
            BSM.Quaternion orientation,
            GuidewireSim.MathHelper mathHelper,
            GuidewireSim.ConstraintSolvingStep constraintSolvingStep )  [private]
```

Executes SolveStretchConstraint() of ConstraintSolvingStep `iterations` many times for one values pair, and then asserts whether the results of the algorithm of SolveStretchConstraint() converged towards the expected values.

Parameters

iterations	The number of iterations that SolveStretchConstraint() of ConstraintSolvingStep is executed.
particlePositionOne	The first particle position for SolveStretchConstraint().
particlePositionTwo	The second particle position for SolveStretchConstraint().
orientation	The orientation for SolveStretchConstraint().
mathHelper	The component MathHelper.
constraintSolvingStep	The component ConstraintSolvingStep.

Requirements `orientation` is still a unit quaternion at the end of the test.

The deviation between the stretch constraint and zero is lower than the tolerance 0.1, which means that the algorithm of SolveStretchConstraint() converges towards the fulfillment of the stretch constraint.

The deviation between the actual distance of `particlePositionOne` and `particlePositionTwo` and the rest rod element length is lower than a reasonable tolerance, i.e. close to zero.

Attention

The fulfillment of the requirement that the rod element length converges towards the rest rod element length depends on the initial deviation of both particle positions from each other and is just a byproduct of converging towards the constraint fulfillment. If this requirement is not fulfilled, the initial offset or the number of iterations was probably simply to high or low, respectively.

7.19.3 Member Data Documentation

7.19.3.1 constraintSolverSteps

```
int UnitTest_SolveStretchConstraint.constraintSolverSteps = 1000  [private]
```

How often the constraint solver iterates over each constraint during the Constraint Solving Step.

7.19.3.2 maximalDistanceOffset

```
float UnitTest_SolveStretchConstraint.maximalDistanceOffset = 1f  [private]
```

The maximal deviation from the rest `rodElementLength`.

Example

Let `rodElementLength` be 10 and maximalDistanceOffset be 2. Then the two random particle positions drawn will have a distance between 8 and 12.

7.19.3.3 rodElementLength

```
float UnitTest_SolveStretchConstraint.rodElementLength = 10f  [private]
```

The distance between two spheres, also the distance between two orientations.

7.19.3.4 sampleSize

```
int UnitTest_SolveStretchConstraint.sampleSize = 10  [private]
```

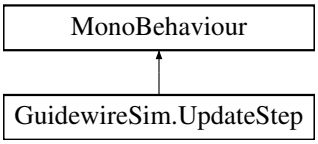
The number of value-pairs the test is executed with. E.g. if sampleSize is 10, then the unit test is executed with 10 randomly drawn value-pairs. A higher number needs more time to execute.

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

- UnitTest_SolveStretchConstraint.cs

7.20 GuidewireSim.UpdateStep Class Reference

Inheritance diagram for GuidewireSim.UpdateStep:



Public Member Functions

- Vector3[ ] UpdateSphereVelocities (Vector3[ ] sphereVelocities, int spheresCount, Vector3[ ] spherePosition↩ Predictions, Vector3[ ] spherePositions)
- Vector3[ ] UpdateSpherePositions (Vector3[ ] spherePositions, int spheresCount, Vector3[ ] spherePosition↩ Predictions)
- Vector3[ ] UpdateCylinderAngularVelocities (Vector3[ ] cylinderAngularVelocities, int cylinderCount, BSM.↩ Quaternion[ ] cylinderOrientations, BSM.Quaternion[ ] cylinderOrientationPredictions)
- BSM.Quaternion[ ] UpdateCylinderOrientations (BSM.Quaternion[ ] cylinderOrientations, int cylinderCount, BSM.Quaternion[ ] cylinderOrientationPredictions)

Private Member Functions

- void Awake ()

Private Attributes

- MathHelper mathHelper

  The component MathHelper that provides math related helper functions.

7.20.1 Detailed Description

This class implements the update step of the algorithm.

7.20.2 Member Function Documentation

7.20.2.1 Awake()

```
void GuidewireSim.UpdateStep.Awake ( )  [private]
```

7.20.2.2 UpdateCylinderAngularVelocities()

```
Vector3[] GuidewireSim.UpdateStep.UpdateCylinderAngularVelocities (
            Vector3[] cylinderAngularVelocities,
            int cylinderCount,
            BSM.Quaternion[] cylinderOrientations,
            BSM.Quaternion[] cylinderOrientationPredictions )
```

Updates the cylinder angular velocities for the update step of the simulation.

Parameters

cylinderAngularVelocities	The angular velocity of the current frame of each orientation element/ cylinder.
cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
cylinderOrientations	The orientation of each cylinder at its center of mass.
cylinderOrientationPredictions	The prediction of the orientation of each cylinder at its center of mass.

Returns

The angular velocity of the current frame of each orientation element/ cylinder, i.e. `cylinderAngular↩Velocities`.

7.20.2.3 UpdateCylinderOrientations()

```
BSM.Quaternion[] GuidewireSim.UpdateStep.UpdateCylinderOrientations (
            BSM.Quaternion[] cylinderOrientations,
            int cylinderCount,
            BSM.Quaternion[] cylinderOrientationPredictions )
```

Updates the cylinder orientations given the current orientation predictions for the update step of the simulation.

Parameters

cylinderOrientations	The orientation of each cylinder at its center of mass.
cylinderCount	The count of all cylinders of the guidewire. Equals the length of `cylinderOrientationPredictions`.
cylinderOrientationPredictions	The prediction of the orientation of each cylinder at its center of mass.

Returns

The orientation of each cylinder at its center of mass, i.e. `cylinderOrientations`.

7.20.2.4 UpdateSpherePositions()

```
Vector3[] GuidewireSim.UpdateStep.UpdateSpherePositions (
            Vector3[] spherePositions,
            int spheresCount,
            Vector3[] spherePositionPredictions )
```

Updates the sphere positions given the current position predictions.

Parameters

spherePositions	The position at the current frame of each sphere.
spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
spherePositionPredictions	The prediction of the position at the current frame of each sphere (in this case of the last frame).

Returns

The position at the current frame of each sphere, i.e. `spherePositions`.

7.20.2.5 UpdateSphereVelocities()

```
Vector3[] GuidewireSim.UpdateStep.UpdateSphereVelocities (
            Vector3[] sphereVelocities,
            int spheresCount,
            Vector3[] spherePositionPredictions,
            Vector3[] spherePositions )
```

Updates the sphere velocities given the current prediction and the current position.

Parameters

sphereVelocities	The velocity of the current frame of each sphere.
spheresCount	The count of all spheres of the guidewire. Equals the length of `spherePositionPredictions`.
spherePositionPredictions	The prediction of the position at the current frame of each sphere (in this case of the last frame).
spherePositions	The position at the current frame of each sphere.

Returns

The velocity of the current frame of each sphere, i.e. `sphereVelocities`.

7.20.3 Member Data Documentation

7.20.3.1 mathHelper

```
MathHelper GuidewireSim.UpdateStep.mathHelper  [private]
```

The component MathHelper that provides math related helper functions.

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

- UpdateStep.cs

Chapter 8

File Documentation

8.1 CollisionDetectionPrimitive.cs File Reference

Classes

- class GuidewireSim.CollisionDetectionPrimitive

Namespaces

- namespace GuidewireSim

8.2 CollisionDetectionVessel.cs File Reference

Classes

- class GuidewireSim.CollisionDetectionVessel

Namespaces

- namespace GuidewireSim

8.3 CollisionHandler.cs File Reference

Classes

- class GuidewireSim.CollisionHandler

Namespaces

- namespace GuidewireSim

8.4 CollisionPair.cs File Reference

Classes

- struct GuidewireSim.CollisionPair

Namespaces

- namespace GuidewireSim

8.5 CollisionSolvingStep.cs File Reference

Classes

- class GuidewireSim.CollisionSolvingStep

Namespaces

- namespace GuidewireSim

8.6 CollisionTestPerformer.cs File Reference

Classes

- class GuidewireSim.CollisionTestPerformer

Namespaces

- namespace GuidewireSim

8.7 ConstraintSolvingStep.cs File Reference

Classes

- class GuidewireSim.ConstraintSolvingStep

Namespaces

- namespace GuidewireSim

Typedefs

- using BSM = BulletSharp.Math

8.7.1 Typedef Documentation

8.7.1.1 BSM

```
using BSM = BulletSharp.Math
```

8.8 DebugExtension.cs File Reference

Classes

- class DebugExtension
  Debug Extension

8.9 DirectorsDrawer.cs File Reference

Classes

- class GuidewireSim.DirectorsDrawer

Namespaces

- namespace GuidewireSim

8.10 ForceTestPerformer.cs File Reference

Classes

- class GuidewireSim.ForceTestPerformer

Namespaces

- namespace GuidewireSim

8.11 InitializationStep.cs File Reference

Classes

- class GuidewireSim.InitializationStep

Namespaces

- namespace GuidewireSim

Typedefs

- using BSM = BulletSharp.Math

8.11.1 Typedef Documentation

8.11.1.1 BSM

```
using BSM = BulletSharp.Math
```

8.12 MathHelper.cs File Reference

Classes

- class GuidewireSim.MathHelper

Namespaces

- namespace GuidewireSim

Typedefs

- using BSM = BulletSharp.Math

8.12.1 Typedef Documentation

8.12.1.1 BSM

```
using BSM = BulletSharp.Math
```

8.13 ObjectSetter.cs File Reference

Classes

- class GuidewireSim.ObjectSetter

Namespaces

- namespace GuidewireSim

Typedefs

- using BSM = BulletSharp.Math

8.13.1 Typedef Documentation

8.13.1.1 BSM

```
using BSM = BulletSharp.Math
```

8.14 PredictionStep.cs File Reference

Classes

- class GuidewireSim.PredictionStep

Namespaces

- namespace GuidewireSim

Typedefs

- using BSM = BulletSharp.Math

8.14.1 Typedef Documentation

8.14.1.1 BSM

```
using BSM = BulletSharp.Math
```

8.15 SimulationLoop.cs File Reference

Classes

- class GuidewireSim.SimulationLoop

Namespaces

- namespace GuidewireSim

Typedefs

- using BSM = BulletSharp.Math

8.15.1 Typedef Documentation

8.15.1.1 BSM

```
using BSM = BulletSharp.Math
```

8.16 StressTestPerformer.cs File Reference

Classes

- class GuidewireSim.StressTestPerformer

Namespaces

- namespace GuidewireSim

8.17 TorqueTestPerformer.cs File Reference

Classes

- class GuidewireSim.TorqueTestPerformer

Namespaces

- namespace GuidewireSim

8.18 UpdateStep.cs File Reference

Classes

- class GuidewireSim.UpdateStep

Namespaces

- namespace GuidewireSim

Typedefs

- using BSM = BulletSharp.Math

8.18.1 Typedef Documentation

8.18.1.1 BSM

```
using BSM = BulletSharp.Math
```

8.19 UnitTest_SolveBendTwistConstraint.cs File Reference

Classes

- class UnitTest_SolveBendTwistConstraint

Typedefs

- using BSM = BulletSharp.Math

8.19.1 Typedef Documentation

8.19.1.1 BSM

```
using BSM = BulletSharp.Math
```

8.20 UnitTest_SolveStretchConstraint.cs File Reference

Classes

- class UnitTest_SolveStretchConstraint

Typedefs

- using BSM = BulletSharp.Math

8.20.1 Typedef Documentation

8.20.1.1 BSM

```
using BSM = BulletSharp.Math
```

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