SpatialAlgebra

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Chapter 1

Hierarchical Index

1.1 Class Hierarchy

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

Chapter 2

Class Index

2.1 Class List

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

Chapter 3

File Index

3.1 File List

Here is a list of all documented files with brief descriptions:

Chapter 4

Class Documentation

4.1 SpatialAlgebra::ArticulatedBodyInertia Class Reference

Class representing inertial properties of an articulated body.

`#include <ArticulatedBodyInertia.h>`

Public Member Functions

- ArticulatedBodyInertia (const Vector6d &inertia, const Eigen::Matrix3d &h, const Vector6d &M)
  Construct articulated body inertia.
- **ArticulatedBodyInertia** ()
  Default constructor creating zero inertia.
- const Vector6d & **getInertia** () const
- const Eigen::Matrix3d & **getH** () const
- const Vector6d & **getM** () const
- ArticulatedBodyInertia operator+ (const ArticulatedBodyInertia &other) const
  Add two articulated body inertias.
- ArticulatedBodyInertia operator+ (const RigidBodyInertia &other) const
  Add rigid body inertia to articulated body inertia.
- ArticulatedBodyInertia **operator**∗ (double scalar) const
- fv apply (const mv &mv) const
  Apply articulated body inertia to motion vector.
- void **print** () const
  Print inertia properties.

4.1.1 Detailed Description

Class representing inertial properties of an articulated body.

Stores and manages generalized inertia matrix components for articulated body dynamics calculations.

4.1.2 Constructor & Destructor Documentation

4.1.2.1 ArticulatedBodyInertia()

```
SpatialAlgebra::ArticulatedBodyInertia::ArticulatedBodyInertia (
            const Vector6d & inertia,
            const Eigen::Matrix3d & h,
            const Vector6d & M)
```

Construct articulated body inertia.

Parameters

inertia	Generalized inertia vector
h	Coupling matrix
M	Mass matrix components

4.1.3 Member Function Documentation

4.1.3.1 apply()

```
fv SpatialAlgebra::ArticulatedBodyInertia::apply (
            const mv & mv) const  [inline]
```

Apply articulated body inertia to motion vector.

Parameters

mv	Motion vector to apply

Returns

Resulting force vector

4.1.3.2 operator+() [1/2]

```
ArticulatedBodyInertia SpatialAlgebra::ArticulatedBodyInertia::operator+ (
            const ArticulatedBodyInertia & other) const  [inline]
```

Add two articulated body inertias.

Parameters

other	ArticulatedBodyInertia to add

Returns

Combined ArticulatedBodyInertia

4.1.3.3 operator+() [2/2]

```
ArticulatedBodyInertia SpatialAlgebra::ArticulatedBodyInertia::operator+ (
            const RigidBodyInertia & other) const  [inline]
```

Add rigid body inertia to articulated body inertia.

Parameters

other	RigidBodyInertia to add

Returns

Combined ArticulatedBodyInertia

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

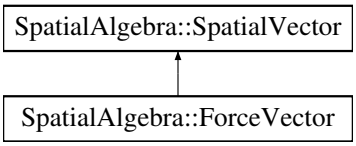
- include/ArticulatedBodyInertia.h

4.2 SpatialAlgebra::ForceVector Class Reference

Class representing spatial force vectors.

`#include <ForceVector.h>`

Inheritance diagram for SpatialAlgebra::ForceVector:



Public Member Functions

- **ForceVector** ()
  Default constructor creating zero force.
- ForceVector (const Vector3d &angular, const Vector3d &linear)
  Construct from angular and linear components.
- ForceVector (const SpatialVector &other)
  Construct from spatial vector.
- Vector3d **getAngular** () const
- Vector3d **getLinear** () const
- ForceVector **operator+** (const ForceVector &other) const
- ForceVector **operator-** (const ForceVector &other) const
- ForceVector **operator**∗ (double scalar) const
- ForceVector **crossMotion** (const ForceVector &other) const
- ForceVector **crossForce** (const ForceVector &other) const
- double **dot** (const ForceVector &other) const
- void **print** () const

Public Member Functions inherited from SpatialAlgebra::SpatialVector

- **SpatialVector** (const Vector3d &angular, const Vector3d &linear)
- **SpatialVector** (const SpatialVector &other)
- Vector3d **getAngular** () const
- Vector3d **getLinear** () const
- SpatialVector **operator+** (const SpatialVector &other) const
- SpatialVector **operator-** (const SpatialVector &other) const
- SpatialVector **operator*** (double scalar) const
- SpatialVector **crossMotion** (const SpatialVector &other) const
- SpatialVector **crossForce** (const SpatialVector &other) const
- double **dot** (const SpatialVector &other) const
- void **print** () const

Additional Inherited Members

Protected Attributes inherited from SpatialAlgebra::SpatialVector

- Vector3d **angular**
- Vector3d **linear**

4.2.1 Detailed Description

Class representing spatial force vectors.

Specialized spatial vector for representing force quantities like torques and linear forces.

4.2.2 Constructor & Destructor Documentation

4.2.2.1 ForceVector() [1/2]

```
SpatialAlgebra::ForceVector::ForceVector (
            const Vector3d & angular,
            const Vector3d & linear)
```

Construct from angular and linear components.

Parameters

angular	Torque component
linear	Force component

4.2.2.2 ForceVector() [2/2]

```
SpatialAlgebra::ForceVector::ForceVector (
            const SpatialVector & other)
```

Construct from spatial vector.

Parameters

other	Spatial vector to convert

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

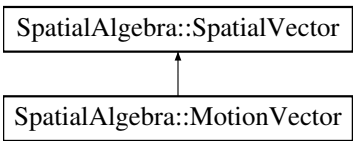
- include/ForceVector.h
- src/ForceVector.cpp

4.3 SpatialAlgebra::MotionVector Class Reference

Class representing spatial motion vectors.

`#include <MotionVector.h>`

Inheritance diagram for SpatialAlgebra::MotionVector:



Public Member Functions

- **MotionVector** ()
  Default constructor creating zero motion.
- MotionVector (const Vector3d &angular, const Vector3d &linear)
  Construct from angular and linear components.
- MotionVector (const SpatialVector &other)
  Construct from spatial vector.
- Vector3d **getAngular** () const
- Vector3d **getLinear** () const
- MotionVector **operator+** (const MotionVector &other) const
- MotionVector **operator-** (const MotionVector &other) const
- MotionVector **operator**∗ (double scalar) const
- MotionVector **crossMotion** (const MotionVector &other) const
- MotionVector **crossForce** (const MotionVector &other) const
- double **dot** (const MotionVector &other) const
- void **print** () const

Public Member Functions inherited from SpatialAlgebra::SpatialVector

- **SpatialVector** (const Vector3d &angular, const Vector3d &linear)
- **SpatialVector** (const SpatialVector &other)
- Vector3d **getAngular** () const
- Vector3d **getLinear** () const
- SpatialVector **operator+** (const SpatialVector &other) const
- SpatialVector **operator-** (const SpatialVector &other) const
- SpatialVector **operator**∗ (double scalar) const
- SpatialVector **crossMotion** (const SpatialVector &other) const
- SpatialVector **crossForce** (const SpatialVector &other) const
- double **dot** (const SpatialVector &other) const
- void **print** () const

Additional Inherited Members

Protected Attributes inherited from SpatialAlgebra::SpatialVector

- Vector3d **angular**
- Vector3d **linear**

4.3.1 Detailed Description

Class representing spatial motion vectors.

Specialized spatial vector for representing motion quantities like angular and linear velocities.

4.3.2 Constructor & Destructor Documentation

4.3.2.1 MotionVector() [1/2]

```
SpatialAlgebra::MotionVector::MotionVector (
            const Vector3d & angular,
            const Vector3d & linear)
```

Construct from angular and linear components.

Parameters

angular	Angular velocity component
linear	Linear velocity component

4.3.2.2 MotionVector() [2/2]

```
SpatialAlgebra::MotionVector::MotionVector (
            const SpatialVector & other)
```

Construct from spatial vector.

Parameters

other	Spatial vector to convert

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

- include/MotionVector.h
- src/MotionVector.cpp

4.4 SpatialAlgebra::PluckerTransform Class Reference

Class representing spatial coordinate transformations.

`#include <PluckerTransform.h>`

Public Member Functions

- PluckerTransform (const Rotation &rotation, const Vector3d &translation)
  Construct a Plucker transform.
- SpatialVector transformMotion (const SpatialVector &vec) const
  Transform a motion vector.
- SpatialVector transformForce (const SpatialVector &vec) const
  Transform a force vector.
- SpatialVector inverseTransformMotion (const SpatialVector &vec) const
  Inverse transform a motion vector.
- SpatialVector inverseTransformForce (const SpatialVector &vec) const
  Inverse transform a force vector.
- RigidBodyInertia tformRBI (const RigidBodyInertia &Ihat) const
  Transform rigid body inertia.
- RigidBodyInertia invtformRBI (const RigidBodyInertia &Ihat) const
  Inverse transform rigid body inertia.
- ArticulatedBodyInertia **tformABI** (const ArticulatedBodyInertia &Ia) const
- ArticulatedBodyInertia **invtformABI** (const ArticulatedBodyInertia &Ia) const
- PluckerTransform **inverse** () const
  Compute inverse transform.
- auto **multiply** (const PluckerTransform &X) const
- auto **apply** (const fv &v) const
- auto **apply** (const mv &v) const
- PluckerTransform **apply** (const PluckerTransform &X) const
- void **print** () const
  Print transform components.
- auto **get** (int &a)
- auto **get** (double &b)

4.4.1 Detailed Description

Class representing spatial coordinate transformations.

Implements rigid body transformations in Plucker coordinates, consisting of rotation and translation components.

4.4.2 Constructor & Destructor Documentation

4.4.2.1 PluckerTransform()

```
PluckerTransform::PluckerTransform (
            const Rotation & rotation,
            const Vector3d & translation)
```

Construct a Plucker transform.

Parameters

rotation	Rotation component
translation	Translation component

4.4.3 Member Function Documentation

4.4.3.1 inverseTransformForce()

```
SpatialVector SpatialAlgebra::PluckerTransform::inverseTransformForce (
            const SpatialVector & vec) const
```

Inverse transform a force vector.

Parameters

vec	Input force vector

Returns

Inverse transformed force vector

4.4.3.2 inverseTransformMotion()

```
SpatialVector SpatialAlgebra::PluckerTransform::inverseTransformMotion (
            const SpatialVector & vec) const
```

Inverse transform a motion vector.

Parameters

vec	Input motion vector

Returns

Inverse transformed motion vector

4.4.3.3 invtformRBI()

```
RigidBodyInertia SpatialAlgebra::PluckerTransform::invtformRBI (
            const RigidBodyInertia & Ihat) const
```

Inverse transform rigid body inertia.

Parameters

Ihat	Input rigid body inertia

Returns

Inverse transformed inertia

4.4.3.4 tformRBI()

```
RigidBodyInertia SpatialAlgebra::PluckerTransform::tformRBI (
            const RigidBodyInertia & Ihat) const
```

Transform rigid body inertia.

Parameters

Ihat	Input rigid body inertia

Returns

Transformed inertia

4.4.3.5 transformForce()

```
SpatialVector PluckerTransform::transformForce (
            const SpatialVector & vec) const
```

Transform a force vector.

Parameters

vec	Input force vector

Returns

Transformed force vector

4.4.3.6 transformMotion()

```
SpatialVector PluckerTransform::transformMotion (
            const SpatialVector & vec) const
```

Transform a motion vector.

Parameters

vec	Input motion vector

Returns

Transformed motion vector

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

- include/PluckerTransform.h
- src/PluckerTransform.cpp

4.5 SpatialAlgebra::RigidBodyInertia Class Reference

Class representing the inertial properties of a rigid body.

`#include <RigidBodyInertia.h>`

Public Member Functions

- RigidBodyInertia (double mass, const Vector3d &com, const Vector6d &inertiaMatrixLT)
  Construct a rigid body inertia.
- **RigidBodyInertia** ()
  Default constructor creating zero inertia.
- double **getMass** () const
- const Vector3d & **getCom** () const
- const Vector6d & **getInertiaMatrixLT** () const
- RigidBodyInertia operator+ (const RigidBodyInertia &other) const
  Add two rigid body inertias.
- RigidBodyInertia operator∗ (double scalar) const
  Scale rigid body inertia.
- ForceVector apply (const MotionVector &mv) const
  Apply rigid body inertia to motion vector.
- void **print** () const
  Print inertia properties.

4.5.1 Detailed Description

Class representing the inertial properties of a rigid body.

Stores and manages mass, center of mass, and rotational inertia matrix for rigid body dynamics calculations.

4.5.2 Constructor & Destructor Documentation

4.5.2.1 RigidBodyInertia()

```
SpatialAlgebra::RigidBodyInertia::RigidBodyInertia (
            double mass,
            const Vector3d & com,
            const Vector6d & inertiaMatrixLT)  [inline]
```

Construct a rigid body inertia.

Parameters

mass	Mass of the body
com	Center of mass position
inertiaMatrixLT	Lower triangular part of inertia matrix

4.5.3 Member Function Documentation

4.5.3.1 apply()

```
ForceVector SpatialAlgebra::RigidBodyInertia::apply (
            const MotionVector & mv) const  [inline]
```

Apply rigid body inertia to motion vector.

Parameters

mv	Motion vector to apply

Returns

Resulting force vector

Implements: [I + com × v; m∗v - com ×]

4.5.3.2 operator∗()

```
RigidBodyInertia SpatialAlgebra::RigidBodyInertia::operator* (
            double scalar) const  [inline]
```

Scale rigid body inertia.

Parameters

scalar	Scaling factor

Returns

Scaled RigidBodyInertia

4.5.3.3 operator+()

```
RigidBodyInertia SpatialAlgebra::RigidBodyInertia::operator+ (
            const RigidBodyInertia & other) const  [inline]
```

Add two rigid body inertias.

Parameters

other	RigidBodyInertia to add

Returns

Combined RigidBodyInertia

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

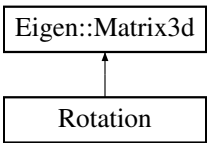
- include/RigidBodyInertia.h

4.6 Rotation Class Reference

Class for handling 3D rotations with multiple representations.

`#include <Rotation.h>`

Inheritance diagram for Rotation:



Public Member Functions

- **Rotation** ()
  Default constructor initializing to identity rotation.
- Rotation (const Eigen::Matrix3d &matrix)
  Construct from 3x3 rotation matrix.
- Rotation (const Eigen::AngleAxisd &angleAxis)
  Construct from angle-axis representation.
- Rotation (const Eigen::Quaterniond &quaternion)
  Construct from quaternion representation.
- void setFromAngleAxis (const Eigen::AngleAxisd &angleAxis)
  Set rotation from angle-axis representation.
- void setFromQuaternion (const Eigen::Quaterniond &quaternion)
  Set rotation from quaternion representation.
- Eigen::AngleAxisd **toAngleAxis** () const
  Convert to angle-axis representation.
- Eigen::Quaterniond **toQuaternion** () const
  Convert to quaternion representation.
- Rotation **inverse** () const
  Compute inverse rotation.
- Rotation **transpose** () const
  Compute matrix transpose.
- Rotation operator∗ (const Rotation &other) const
  Multiply with another rotation.
- Eigen::Vector3d operator∗ (const Eigen::Vector3d &vector) const
  Apply rotation to a vector.

4.6.1 Detailed Description

Class for handling 3D rotations with multiple representations.

Extends Eigen::Matrix3d to provide additional functionality for rotation operations including conversions between different rotation representations.

4.6.2 Constructor & Destructor Documentation

4.6.2.1 Rotation() [1/3]

```
Rotation::Rotation (
            const Eigen::Matrix3d & matrix)
```

Construct from 3x3 rotation matrix.

Parameters

matrix	Input rotation matrix

4.6.2.2 Rotation() [2/3]

```
Rotation::Rotation (
            const Eigen::AngleAxisd & angleAxis)
```

Construct from angle-axis representation.

Parameters

angleAxis	Angle-axis rotation

4.6.2.3 Rotation() [3/3]

```
Rotation::Rotation (
            const Eigen::Quaterniond & quaternion)
```

Construct from quaternion representation.

Parameters

quaternion	Unit quaternion representing rotation

4.6.3 Member Function Documentation

4.6.3.1 operator*() [1/2]

```
Eigen::Vector3d Rotation::operator* (
            const Eigen::Vector3d & vector) const
```

Apply rotation to a vector.

Parameters

vector	3D vector to rotate

Returns

Rotated vector

4.6.3.2 operator*() [2/2]

```
Rotation Rotation::operator* (
            const Rotation & other) const
```

Multiply with another rotation.

Parameters

other	Right-hand side rotation

Returns

Combined rotation

4.6.3.3 setFromAngleAxis()

```
void Rotation::setFromAngleAxis (
            const Eigen::AngleAxisd & angleAxis)
```

Set rotation from angle-axis representation.

Parameters

angleAxis	Angle-axis rotation

4.6.3.4 setFromQuaternion()

```
void Rotation::setFromQuaternion (
            const Eigen::Quaterniond & quaternion)
```

Set rotation from quaternion representation.

Parameters

quaternion	Unit quaternion

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

- include/Rotation.h
- src/Rotation.cpp

4.7 SpatialAlgebra::SpatialOperations Class Reference

Static class providing utility operations for spatial vectors and transforms.

`#include <SpatialOperations.h>`

Static Public Member Functions

- static SpatialVector crossProductMotion (const SpatialVector &v1, const SpatialVector &v2)

  Computes the motion cross product between two spatial vectors.
- static SpatialVector crossProductForce (const SpatialVector &v, const SpatialVector &f)

  Computes the force cross product between two spatial vectors.
- static RigidBodyInertia transformInertia (const RigidBodyInertia &inertia, const PluckerTransform &transform)

  Transforms rigid body inertia using a Plucker transform.

4.7.1 Detailed Description

Static class providing utility operations for spatial vectors and transforms.

4.7.2 Member Function Documentation

4.7.2.1 crossProductForce()

```
static SpatialVector SpatialAlgebra::SpatialOperations::crossProductForce (
            const SpatialVector & v,
            const SpatialVector & f)  [static]
```

Computes the force cross product between two spatial vectors.

Parameters

v	Force spatial vector
f	Motion spatial vector

Returns

Result of force cross product

4.7.2.2 crossProductMotion()

```
static SpatialVector SpatialAlgebra::SpatialOperations::crossProductMotion (
            const SpatialVector & v1,
            const SpatialVector & v2)  [static]
```

Computes the motion cross product between two spatial vectors.

Parameters

v1	First spatial vector
v2	Second spatial vector

Returns

Result of motion cross product

4.7.2.3 transformInertia()

```
static RigidBodyInertia SpatialAlgebra::SpatialOperations::transformInertia (
            const RigidBodyInertia & inertia,
            const PluckerTransform & transform)  [static]
```

Transforms rigid body inertia using a Plucker transform.

Parameters

inertia	Input rigid body inertia
transform	Plucker transform to apply

Returns

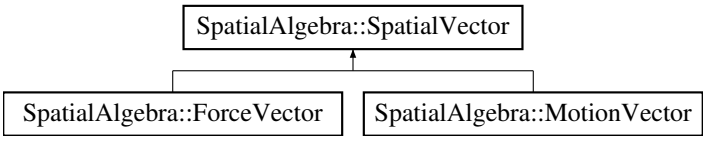
Transformed rigid body inertia

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

- include/SpatialOperations.h

4.8 SpatialAlgebra::SpatialVector Class Reference

Inheritance diagram for SpatialAlgebra::SpatialVector:



Public Member Functions

- **SpatialVector** (const Vector3d &angular, const Vector3d &linear)
- **SpatialVector** (const SpatialVector &other)
- Vector3d **getAngular** () const
- Vector3d **getLinear** () const
- SpatialVector **operator+** (const SpatialVector &other) const
- SpatialVector **operator-** (const SpatialVector &other) const
- SpatialVector **operator**∗ (double scalar) const
- SpatialVector **crossMotion** (const SpatialVector &other) const
- SpatialVector **crossForce** (const SpatialVector &other) const
- double **dot** (const SpatialVector &other) const
- void **print** () const

Protected Attributes

- Vector3d **angular**
- Vector3d **linear**

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

- include/SpatialVector.h
- src/SpatialVector.cpp

Chapter 5

File Documentation

5.1 include/ArticulatedBodyInertia.h File Reference

Class representing articulated body inertia properties.

```
#include <array>
#include <iostream>
#include "RigidBodyInertia.h"
#include "SpatialUtils.h"
#include <Eigen/Geometry>
```

Classes

- class SpatialAlgebra::ArticulatedBodyInertia

  Class representing inertial properties of an articulated body.

Typedefs

- using **Vector6d** = Eigen::Matrix<double, 6, 1>
- using **SpatialAlgebra::abi** = ArticulatedBodyInertia

5.1.1 Detailed Description

Class representing articulated body inertia properties.

5.2 ArticulatedBodyInertia.h

Go to the documentation of this file.

```
00001 #ifndef ARTIC_BODY_INERTIA_H
00002 #define ARTIC_BODY_INERTIA_H
00003
00009 #include <array>
00010 #include <iostream>
00011 #include "RigidBodyInertia.h"
00012 #include "SpatialUtils.h"
00013 #include <Eigen/Geometry> // Include for RotationMatrix
00014
00015 using Vector6d = Eigen::Matrix<double, 6, 1>;
00016
00017 namespace SpatialAlgebra
00018 {
00025     class ArticulatedBodyInertia
00026     {
00027     private:
00028         Vector6d Inertia;
00029         Eigen::Matrix3d H;
00030         Vector6d M;
00031
00032     public:
00039         ArticulatedBodyInertia(const Vector6d &inertia, const Eigen::Matrix3d &h, const Vector6d &M);
00040
00042         ArticulatedBodyInertia();
00043
00044         // getters
00045         inline const Vector6d &getInertia() const { return Inertia; }
00046         inline const Eigen::Matrix3d &getH() const { return H; }
00047         inline const Vector6d &getM() const { return M; }
00048
00054         inline ArticulatedBodyInertia operator+(const ArticulatedBodyInertia &other) const;
00055
00061         inline ArticulatedBodyInertia operator+(const RigidBodyInertia &other) const;
00062
00063         inline ArticulatedBodyInertia operator*(double scalar) const
00064         {
00065             return ArticulatedBodyInertia(Inertia * scalar, H * scalar, M * scalar);
00066         }
00067
00073         inline fv apply(const mv &mv) const;
00074
00076         inline void print() const;
00077     };
00078
00079     using abi = ArticulatedBodyInertia;
00080
00081 } // namespace SpatialAlgebra
00082
00083 #endif
```

5.3 AxialScrewTransform.h

```
00001
```

5.4 include/ForceVector.h File Reference

Class representing spatial force vectors.

```
#include <iostream>
#include "SpatialVector.h"
```

Classes

- class SpatialAlgebra::ForceVector

  Class representing spatial force vectors.

Typedefs

- using **SpatialAlgebra::fv** = ForceVector

5.4.1 Detailed Description

Class representing spatial force vectors.

5.5 ForceVector.h

Go to the documentation of this file.

```
00001 #ifndef FORCE_VECTOR_H
00002 #define FORCE_VECTOR_H
00003
00009 #include <iostream>
00010
00011 #include "SpatialVector.h"
00012
00013 // Force vector class inherits from SpatialVector
00014 namespace SpatialAlgebra
00015 {
00022     class ForceVector : public SpatialVector
00023     {
00024     public:
00026         ForceVector();
00027
00033         ForceVector(const Vector3d &angular, const Vector3d &linear);
00034
00039         ForceVector(const SpatialVector &other);
00040
00041         // Accessors
00042         Vector3d getAngular() const;
00043         Vector3d getLinear() const;
00044
00045         // Basic operations
00046         ForceVector operator+(const ForceVector &other) const;
00047         ForceVector operator-(const ForceVector &other) const;
00048         ForceVector operator*(double scalar) const;
00049
00050         // Cross-product operations
00051         ForceVector crossMotion(const ForceVector &other) const; // crm equivalent
00052         ForceVector crossForce(const ForceVector &other) const;  // crf equivalent
00053
00054         // dot product
00055         double dot(const ForceVector &other) const;
00056
00057         // Printing
00058         void print() const;
00059     };
00060
00061     using fv = ForceVector;
00062
00063 } // namespace SpatialAlgebra
00064
00065 #endif
```

5.6 include/MotionVector.h File Reference

Class representing spatial motion vectors.

```
#include <array>
#include <iostream>
#include "SpatialVector.h"
```

Classes

- class SpatialAlgebra::MotionVector

  Class representing spatial motion vectors.

Typedefs

- using **SpatialAlgebra::mv** = MotionVector

5.6.1 Detailed Description

Class representing spatial motion vectors.

5.7 MotionVector.h

Go to the documentation of this file.

```
00001 #ifndef MOTION_VECTOR_H
00002 #define MOTION_VECTOR_H
00003
00009 #include <array>
00010 #include <iostream>
00011
00012 #include "SpatialVector.h"
00013
00014 // Motion vector class inherits from SpatialVector
00015
00016 namespace SpatialAlgebra
00017 {
00024     class MotionVector : public SpatialVector
00025     {
00026     public:
00028         MotionVector();
00029
00035         MotionVector(const Vector3d &angular, const Vector3d &linear);
00036
00041         MotionVector(const SpatialVector &other);
00042
00043         // Accessors
00044         Vector3d getAngular() const;
00045         Vector3d getLinear() const;
00046
00047         // Basic operations
00048         MotionVector operator+(const MotionVector &other) const;
00049         MotionVector operator-(const MotionVector &other) const;
00050         MotionVector operator*(double scalar) const;
00051
00052         // Cross-product operations
00053         MotionVector crossMotion(const MotionVector &other) const; // crm equivalent
00054         MotionVector crossForce(const MotionVector &other) const;  // crf equivalent
00055
00056         // dot product
00057         double dot(const MotionVector &other) const;
00058
00059         // Printing
00060         void print() const;
00061     };
00062
00063     using mv = MotionVector;
00064
00065 } // namespace SpatialAlgebra
00066
00067 #endif
```

5.8 include/PluckerTransform.h File Reference

Class representing coordinate transformations in Plucker coordinates.

```
#include "SpatialVector.h"
#include "Rotation.h"
#include "ForceVector.h"
#include "MotionVector.h"
#include "RigidBodyInertia.h"
#include "ArticulatedBodyInertia.h"
#include <Eigen/Geometry>
```

Classes

- class SpatialAlgebra::PluckerTransform

  Class representing spatial coordinate transformations.

Typedefs

- using **Vector3d** = Eigen::Matrix<double, 3, 1>
- using **SpatialAlgebra::plux** = PluckerTransform

5.8.1 Detailed Description

Class representing coordinate transformations in Plucker coordinates.

5.9 PluckerTransform.h

Go to the documentation of this file.

```
00001 #ifndef PLUCKER_TRANSFORM_H
00002 #define PLUCKER_TRANSFORM_H
00003
00009 #include "SpatialVector.h"
00010 #include "Rotation.h"
00011 #include "ForceVector.h"
00012 #include "MotionVector.h"
00013 #include "RigidBodyInertia.h"
00014 #include "ArticulatedBodyInertia.h"
00015 #include <Eigen/Geometry> // Include for RotationMatrix
00016
00017 using Vector3d = Eigen::Matrix<double, 3, 1>;
00018
00019 namespace SpatialAlgebra
00020 {
00027     class PluckerTransform
00028     {
00029     private:
00030         Rotation rotation;
00031         Vector3d translation;
00032
00033     public:
00039         PluckerTransform(const Rotation &rotation, const Vector3d &translation);
00040
00046         SpatialVector transformMotion(const SpatialVector &vec) const;
00047
00053         SpatialVector transformForce(const SpatialVector &vec) const;
00054
00060         SpatialVector inverseTransformMotion(const SpatialVector &vec) const;
00061
00067         SpatialVector inverseTransformForce(const SpatialVector &vec) const;
```

```
00068
00074         RigidBodyInertia tformRBI(const RigidBodyInertia &Ihat) const;
00075
00081         RigidBodyInertia invtformRBI(const RigidBodyInertia &Ihat) const;
00082
00083         // transform abi
00084         ArticulatedBodyInertia tformABI(const ArticulatedBodyInertia &Ia) const;
00085         ArticulatedBodyInertia invtformABI(const ArticulatedBodyInertia &Ia) const;
00086
00088         PluckerTransform inverse() const;
00089
00090         // multiply by X
00091         // PluckerTransform multiply(const PluckerTransform &X) const;
00092         auto multiply(const PluckerTransform &X) const;
00093
00094         auto apply(const fv& v) const{
00095             return transformMotion(v);
00096         }
00097         auto apply(const mv& v) const{
00098             return transformForce(v);
00099         }
00100
00101         PluckerTransform apply(const PluckerTransform &X) const;
00102
00103         // template <typename T>
00104         // T apply(const T&) const{
00105
00106         // }
00107
00109         void print() const;
00110
00111         // testing
00112         auto get(int &a) { return a; }
00113         auto get(double &b)
00114         {
00115             char c{'c'};
00116             return c;
00117         }
00118     };
00119
00120     using plux = PluckerTransform;
00121
00122 } // namespace SpatialAlgebra
00123
00124 #endif
```

5.10 include/RigidBodyInertia.h File Reference

Class representing rigid body inertia properties.

```
#include <array>
#include <iostream>
#include "SpatialVector.h"
#include "ForceVector.h"
#include "MotionVector.h"
#include <Eigen/Geometry>
```

Classes

- class SpatialAlgebra::RigidBodyInertia

  Class representing the inertial properties of a rigid body.

Typedefs

- using **Vector3d** = Eigen::Matrix<double, 3, 1>
- using **Vector6d** = Eigen::Matrix<double, 6, 1>
- using **SpatialAlgebra::rbi** = RigidBodyInertia

5.10.1 Detailed Description

Class representing rigid body inertia properties.

5.11 RigidBodyInertia.h

Go to the documentation of this file.

```
00001 #ifndef RIGID_BODY_INERTIA_H
00002 #define RIGID_BODY_INERTIA_H
00003
00009 #include <array>
00010 #include <iostream>
00011 #include "SpatialVector.h"
00012 #include "ForceVector.h"
00013 #include "MotionVector.h"
00014 #include <Eigen/Geometry> // Include for RotationMatrix
00015
00016 using Vector3d = Eigen::Matrix<double, 3, 1>;
00017 using Vector6d = Eigen::Matrix<double, 6, 1>;
00018
00019 namespace SpatialAlgebra
00020 {
00027     class RigidBodyInertia
00028     {
00029     private:
00030         double mass;
00031         Vector3d com;
00032         Vector6d inertiaMatrixLT;
00033
00034     public:
00041         inline RigidBodyInertia(double mass, const Vector3d &com, const Vector6d &inertiaMatrixLT)
00042             : mass(mass), com(com), inertiaMatrixLT(inertiaMatrixLT) {}
00043
00045         inline RigidBodyInertia()
00046         {
00047             RigidBodyInertia(0.0, {0.0, 0.0, 0.0}, {0.0, 0.0, 0.0, 0.0, 0.0, 0.0});
00048         }
00049
00050         // Getters
00051         inline double getMass() const { return mass; }
00052         inline const Vector3d &getCom() const { return com; }
00053         inline const Vector6d &getInertiaMatrixLT() const { return inertiaMatrixLT; }
00054
00060         inline RigidBodyInertia operator+(const RigidBodyInertia &other) const
00061         {
00062             // const double sumMass = mass + other.mass;
00063             // const Vector3d sumCom = com + other.com;
00064             return RigidBodyInertia(mass + other.mass, com + other.com, inertiaMatrixLT +
      other.inertiaMatrixLT);
00065         }
00066
00072         inline RigidBodyInertia operator*(double scalar) const // Changed to pass by value
00073         {
00074             return RigidBodyInertia(mass * scalar, com * scalar, inertiaMatrixLT * scalar);
00075         }
00076
00083         inline ForceVector apply(const MotionVector &mv) const
00084         {
00085             // rbi = [m, com, I_LT], mv = [, v]
00086             // rbi.apply(mv) = [I + com x v; m*v - com x ]
00087             Vector3d omega = mv.getAngular();
00088             Vector3d v = mv.getLinear();
00089             Vector3d comCrossV = com.cross(v);
00090             Vector3d comCrossOmega = com.cross(omega);
00091             Vector3d Iomega = inertiaMatrixLT.head<3>().cwiseProduct(omega) +
      inertiaMatrixLT.tail<3>().cwiseProduct(omega);
00092             Vector3d force = mass * v - comCrossOmega;
00093             Vector3d torque = Iomega + comCrossV;
00094             return ForceVector(torque, force);
00095         }
00096
00098         inline void print() const
00099         {
00100             std::cout « "Mass: " « mass « '\n'
00101                       « "Center of mass: " « com.transpose() « '\n'
00102                       « "Inertia matrix (LT): " « inertiaMatrixLT.transpose() « std::endl;
00103         }
00104     };
00105
```

```
00106     using rbi = RigidBodyInertia;
00107
00108 } // namespace SpatialAlgebra
00109
00110 #endif
```

5.12 include/Rotation.h File Reference

Class representing 3D rotations with various representations.

```
#include <Eigen/Dense>
```

Classes

- class Rotation

  Class for handling 3D rotations with multiple representations.

5.12.1 Detailed Description

Class representing 3D rotations with various representations.

5.13 Rotation.h

Go to the documentation of this file.

```
00001 #ifndef ROTATION_H
00002 #define ROTATION_H
00003
00009 #include <Eigen/Dense>
00010
00017 class Rotation : public Eigen::Matrix3d
00018 {
00019 public:
00021     Rotation();
00022
00027     Rotation(const Eigen::Matrix3d &matrix);
00028
00033     Rotation(const Eigen::AngleAxisd &angleAxis);
00034
00039     Rotation(const Eigen::Quaterniond &quaternion);
00040
00045     void setFromAngleAxis(const Eigen::AngleAxisd &angleAxis);
00046
00051     void setFromQuaternion(const Eigen::Quaterniond &quaternion);
00052
00054     Eigen::AngleAxisd toAngleAxis() const;
00055
00057     Eigen::Quaterniond toQuaternion() const;
00058
00060     Rotation inverse() const;
00061
00063     Rotation transpose() const;
00064
00070     Rotation operator*(const Rotation &other) const;
00071
00077     Eigen::Vector3d operator*(const Eigen::Vector3d &vector) const;
00078 };
00079
00080 #endif // ROTATION_H
```

5.14 include/SpatialOperations.h File Reference

Static utility class for spatial algebra operations.

```
#include "SpatialVector.h"
#include "PluckerTransform.h"
#include "RigidBodyInertia.h"
#include <Eigen/Geometry>
```

Classes

- class SpatialAlgebra::SpatialOperations

  Static class providing utility operations for spatial vectors and transforms.

5.14.1 Detailed Description

Static utility class for spatial algebra operations.

5.15 SpatialOperations.h

Go to the documentation of this file.

```
00001 #ifndef SPATIAL_OPERATIONS_H
00002 #define SPATIAL_OPERATIONS_H
00003
00009 #include "SpatialVector.h"
00010 #include "PluckerTransform.h"
00011 #include "RigidBodyInertia.h"
00012 #include <Eigen/Geometry> // Include for RotationMatrix
00013
00014 namespace SpatialAlgebra {
00015
00019 class SpatialOperations {
00020 public:
00027     static SpatialVector crossProductMotion(const SpatialVector& v1, const SpatialVector& v2);
00028
00035     static SpatialVector crossProductForce(const SpatialVector& v, const SpatialVector& f);
00036
00043     static RigidBodyInertia transformInertia(const RigidBodyInertia& inertia,
00044                                              const PluckerTransform& transform);
00045 };
00046
00047 }  // namespace SpatialAlgebra
00048
00049 #endif
```

5.16 include/SpatialUtils.h File Reference

Utility functions for spatial algebra operations.

```
#include "SpatialVector.h"
#include "MotionVector.h"
#include "ForceVector.h"
```

Functions

- Eigen::Matrix3d SpatialAlgebra::skew (const Eigen::Vector3d &v) noexcept

  Creates a 3x3 skew-symmetric matrix from a 3D vector.
- double SpatialAlgebra::dot (const SpatialVector &v1, const SpatialVector &v2) noexcept

  Computes the spatial dot product between two spatial vectors.
- double SpatialAlgebra::dot (const MotionVector &v1, const MotionVector &v2) noexcept

  Computes the spatial dot product between two motion vectors.
- double SpatialAlgebra::dot (const ForceVector &v1, const ForceVector &v2) noexcept

  Computes the spatial dot product between two force vectors.
- double **SpatialAlgebra::dot** (const MotionVector &v1, const ForceVector &v2) noexcept
- ForceVector SpatialAlgebra::cross (const MotionVector &v1, const ForceVector &v2) noexcept

  Computes the spatial cross product between a motion vector and a force vector.

5.16.1 Detailed Description

Utility functions for spatial algebra operations.

This file contains various utility functions used in spatial algebra computations, including cross products, dot products, and matrix operations.

5.16.2 Function Documentation

5.16.2.1 cross()

```
ForceVector SpatialAlgebra::cross (
            const MotionVector & v1,
            const ForceVector & v2)  [inline], [noexcept]
```

Computes the spatial cross product between a motion vector and a force vector.

Parameters

v1	Motion vector
v2	Force vector

Returns

Resulting force vector

Implements: crf(v1, v2) = [w1×f1 + v1×f2, w1×f1]

5.16.2.2 dot() [1/3]

```
double SpatialAlgebra::dot (
            const ForceVector & v1,
            const ForceVector & v2)  [inline], [noexcept]
```

Computes the spatial dot product between two force vectors.

Parameters

v1	First force vector
v2	Second force vector

Returns

Scalar dot product result

5.16.2.3 dot() [2/3]

```
double SpatialAlgebra::dot (
            const MotionVector & v1,
            const MotionVector & v2)  [inline], [noexcept]
```

Computes the spatial dot product between two motion vectors.

Parameters

v1	First motion vector
v2	Second motion vector

Returns

Scalar dot product result

5.16.2.4 dot() [3/3]

```
double SpatialAlgebra::dot (
            const SpatialVector & v1,
            const SpatialVector & v2)  [inline], [noexcept]
```

Computes the spatial dot product between two spatial vectors.

Parameters

v1	First spatial vector
v2	Second spatial vector

Returns

Scalar dot product result

5.16.2.5 skew()

```
Eigen::Matrix3d SpatialAlgebra::skew (
            const Eigen::Vector3d & v)  [inline], [noexcept]
```

Creates a 3x3 skew-symmetric matrix from a 3D vector.

Parameters

v	Input 3D vector

Returns

Skew-symmetric matrix representation

The resulting matrix S satisfies S∗x = v×x for any vector x

5.17 SpatialUtils.h

Go to the documentation of this file.

```
00001 #ifndef SPATIAL_UTILS_H
00002 #define SPATIAL_UTILS_H
00003
00012 #include "SpatialVector.h"
00013 #include "MotionVector.h"
00014 #include "ForceVector.h"
00015
00016 namespace SpatialAlgebra {
00017
00024 inline Eigen::Matrix3d skew(const Eigen::Vector3d& v) noexcept {
00025     Eigen::Matrix3d m;
00026     m << 0, -v(2), v(1),
00027          v(2), 0, -v(0),
00028          -v(1), v(0), 0;
00029     return m;
00030 }
00031
00038 inline double dot(const SpatialVector& v1, const SpatialVector& v2) noexcept {
00039     return v1.getAngular().dot(v2.getAngular()) +
00040            v1.getLinear().dot(v2.getLinear());
00041 }
00042
00049 inline double dot(const MotionVector& v1, const MotionVector& v2) noexcept {
00050     return dot(static_cast<const SpatialVector&>(v1),
00051                static_cast<const SpatialVector&>(v2));
00052 }
00053
00060 inline double dot(const ForceVector& v1, const ForceVector& v2) noexcept {
00061     return dot(static_cast<const SpatialVector&>(v1),
00062                static_cast<const SpatialVector&>(v2));
00063 }
00064
00065 inline double dot(const MotionVector& v1, const ForceVector& v2) noexcept {
00066     return dot(static_cast<const SpatialVector&>(v1),
00067                static_cast<const SpatialVector&>(v2));
00068 }
00069
00077 inline ForceVector cross(const MotionVector& v1, const ForceVector& v2) noexcept {
00078     const Vector3d& w1 = v1.getAngular();
00079     const Vector3d& v1_lin = v1.getLinear();
00080     const Vector3d& f1 = v2.getAngular();
00081     const Vector3d& f2 = v2.getLinear();
00082
00083     return ForceVector(
00084         w1.cross(f1),
00085         w1.cross(f2) + v1_lin.cross(f1)
00086     );
00087 };
00088
00089 } // namespace SpatialAlgebra
00090 #endif // SPATIAL_UTILS_H
```

5.18 SpatialVector.h

```
00001 #ifndef SPATIAL_VECTOR_H
00002 #define SPATIAL_VECTOR_H
00003
```

```
00004 // #include <array>
00005 // #include <iostream>
00006 #include <Eigen/Dense>
00007
00008 using Vector3d = Eigen::Matrix<double, 3, 1>;
00009
00010 namespace SpatialAlgebra
00011 {
00012
00013     class SpatialVector
00014     {
00015     protected:
00016         Vector3d angular; // : Angular velocity/force
00017         Vector3d linear;  // v or f: Linear velocity/force
00018
00019     public:
00020         // Constructors
00021         SpatialVector();
00022         SpatialVector(const Vector3d &angular, const Vector3d &linear);
00023
00024         SpatialVector(const SpatialVector &other);
00025
00026         // Accessors
00027         Vector3d getAngular() const;
00028         Vector3d getLinear() const;
00029
00030         // Basic operations
00031         SpatialVector operator+(const SpatialVector &other) const;
00032         SpatialVector operator-(const SpatialVector &other) const;
00033         SpatialVector operator*(double scalar) const;
00034
00035         // Cross-product operations
00036         SpatialVector crossMotion(const SpatialVector &other) const; // crm equivalent
00037         SpatialVector crossForce(const SpatialVector &other) const;  // crf equivalent
00038
00039         // dot product
00040         double dot(const SpatialVector &other) const;
00041
00042
00043         // Printing
00044         void print() const;
00045     };
00046
00047 } // namespace SpatialAlgebra
00048
00049 #endif
```