skrobot Documentation

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CONTENTS

Scikit-Robot is a simple pure-Python library for loading, manipulating, and visualizing URDF files and robot specifications. For example, here's a rendering of a PR2 robot moving after being loaded by this library.

CHAPTER

ONE

INSTALLATION AND SETUP GUIDE

1.1 Python Installation

This package is pip-installable for any Python version. Simply run the following command:

```
pip install scikit-robot
```

1.2 Installing in Development Mode

If you're planning on contributing to this repository, please see the *Development Guide*.

CHAPTER

TWO

USAGE EXAMPLES

This page documents several simple use cases for you to try out. For full details, see the *API Reference*, and check out the full class reference for `RobotModel`.

2.1 Loading from a File

You can load a URDF from any `.urdf` file, as long as you fix the links to be relative or absolute links rather than ROS resource URLs.

```
>>> import skrobot
>>> robot_model = skrobot.models.urdf.RobotModelFromURDF(urdf_file=skrobot.data.pr2_
→urdfpath())
```

2.2 Visualization

```
>>> viewer = skrobot.viewers.TrimeshSceneViewer(resolution=(640, 480))
>>> viewer.add(robot_model)
>>> viewer.show()
```

If you would like to update renderer:

```
>>> viewer.redraw()
```

2.3 Accessing Links and Joints

You have direct access to link and joint information.

```
>>> for link in robot_model.link_list:
...     print(link.name)
```

```
>>> for joint in robot_model.joint_list:
...     print(joint.name)
```

```
>>> robot_model.l_elbow_flex_joint.joint_angle()
0.0
```

```
>>> robot_model.l_elbow_flex_joint.joint_angle(-0.5)
-0.5
```

```
>>> robot_model.l_elbow_flex_joint.joint_angle()
-0.5
```

2.4 Inverse Kinematics

First, set the initial pose. Note that the position of the prismatic joint is in [m] and angles of rotational joints are in [rad].

```
>>> robot_model.torso_lift_joint.joint_angle(0.05)
>>> robot_model.l_shoulder_pan_joint.joint_angle(60 * 3.14/180.0)
>>> robot_model.l_shoulder_lift_joint.joint_angle(74 * 3.14/180.0)
>>> robot_model.l_upper_arm_roll_joint.joint_angle(70* 3.14/180.0)
>>> robot_model.l_elbow_flex_joint.joint_angle(-120 * 3.14/180.0)
>>> robot_model.l_forearm_roll_joint.joint_angle(20 * 3.14/180.0)
>>> robot_model.l_wrist_flex_joint.joint_angle(-30 * 3.14/180.0)
>>> robot_model.l_wrist_roll_joint.joint_angle(180 * 3.14/180.0)
>>> robot_model.r_shoulder_pan_joint.joint_angle(-60 * 3.14/180.0)
>>> robot_model.r_shoulder_lift_joint.joint_angle(74 * 3.14/180.0)
>>> robot_model.r_upper_arm_roll_joint.joint_angle(-70 * 3.14/180.0)
>>> robot_model.r_elbow_flex_joint.joint_angle(-120 * 3.14/180.0)
>>> robot_model.r_forearm_roll_joint.joint_angle(-20 * 3.14/180.0)
>>> robot_model.r_wrist_flex_joint.joint_angle(-30 * 3.14/180.0)
>>> robot_model.r_wrist_roll_joint.joint_angle(180 * 3.14/180.0)
>>> robot_model.head_pan_joint.joint_angle(0)
>>> robot_model.head_tilt_joint.joint_angle(0)
```

Next, set move_target and link_list

```
>>> rarm_end_coords = skrobot.coordinates.CascadedCoords(
...             parent=robot_model.r_gripper_tool_frame,
...             name='rarm_end_coords')
>>> move_target = rarm_end_coords
>>> link_list = [
...     robot_model.r_shoulder_pan_link,
...     robot_model.r_shoulder_lift_link,
...     robot_model.r_upper_arm_roll_link,
...     robot_model.r_elbow_flex_link,
...     robot_model.r_forearm_roll_link,
...     robot_model.r_wrist_flex_link,
...     robot_model.r_wrist_roll_link]
```

Set target_coords.

```
>>> target_coords = skrobot.coordinates.Coordinates([0.5, -0.3, 0.7], [0, 0, 0])
>>> robot_model.inverse_kinematics(
...     target_coords,
...     link_list=link_list,
...     move_target=move_target)
```

CHAPTER

THREE

API REFERENCE

3.1 Coordinates

3.1.1 Coordinates classes

skrobot.coordinates.Coordinates	Coordinates class to manipulate rotation and translation.
skrobot.coordinates.CascadedCoords	

skrobot.coordinates.Coordinates

`class skrobot.coordinates.`**`Coordinates`**(*pos=None*, *rot=None*, *name=None*, *hook=None*, *check_validity=True*)

Coordinates class to manipulate rotation and translation.

Parameters

- **pos** (*list or numpy.ndarray or None*) – shape of (3,) translation vector. or 4x4 homogeneous transformation matrix. If the homogeneous transformation matrix is given, *rot* will be overwritten. If this value is *None*, set [0, 0, 0] vector as default.
- **rot** (*list or numpy.ndarray or None*) – we can take 3x3 rotation matrix or [yaw, pitch, roll] or quaternion [w, x, y, z] order If this value is *None*, set the identity matrix as default.
- **name** (*str or None*) – name of this coordinates
- **check_validity** (*bool (optional)*) – Default *True*. If this value is *True*, check whether an input rotation and an input translation are valid.

Methods

`T`()

Return 4x4 homogeneous transformation matrix.

Returns matrix – homogeneous transformation matrix shape of (4, 4)

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.T()
array([[1., 0., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 0., 0., 1.]])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.rotate(pi / 2.0, 'y')
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00,
         1.00000000e-01],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00,
         2.00000000e-01],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16,
         3.00000000e-01],
       [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
         1.00000000e+00]])
```

axis(*ax*)

changed()
Return False

This is used for CascadedCoords compatibility

Returns **False** – always return False

Return type bool

coords()
Return a deep copy of the Coordinates.

copy()
Return a deep copy of the Coordinates.

copy_coords()
Return a deep copy of the Coordinates.

copy_worldcoords()
Return a deep copy of the Coordinates.

difference_position(*coords*, *translation_axis=True*)
Return differences in positoin of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **translation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xy', 'yz', 'zx', 'xx', 'yy', 'zz', True or False(None).

Returns **dif_pos** – difference position of self coordinates and coords considering translation_axis.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates import transform_coords
>>> from numpy import pi
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(
...          pi / 3.0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...          pi / 2.0, 'y')
>>> c1.difference_position(c2)
array([ 0.2       , -0.42320508,  0.3330127 ])
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...          pi / 3.0, 'x')
>>> c1.difference_position(c2)
array([ 0.2, -0.5, -0.2])
```

difference_rotation(*coords*, *rotation_axis=True*)

Return differences in rotation of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **rotation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xx', 'yy', 'zz', 'xm', 'ym', 'zm', 'xy', 'yx', 'yz', 'zy', 'zx', 'xz', True or False(None).

Returns **dif_rot** – difference rotation of self coordinates and coords considering rotation_axis.

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates.math import rpy_matrix
>>> coord1 = Coordinates()
>>> coord2 = Coordinates(rot=rpy_matrix(pi / 2.0, pi / 3.0, pi / 5.0))
>>> coord1.difference_rotation(coord2)
array([-0.32855112,  1.17434985,  1.05738936])
>>> coord1.difference_rotation(coord2, rotation_axis=False)
array([0, 0, 0])
>>> coord1.difference_rotation(coord2, rotation_axis='x')
array([0.        , 1.36034952, 0.78539816])
>>> coord1.difference_rotation(coord2, rotation_axis='y')
array([0.35398131, 0.        , 0.97442695])
>>> coord1.difference_rotation(coord2, rotation_axis='z')
array([-0.88435715,  0.74192175,  0.        ])
```

Using mirror option ['xm', 'ym', 'zm'], you can allow differences of mirror direction.

```
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
```

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```
array([-2.99951957e-32,  0.00000000e+00,  0.00000000e+00])
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi / 2.0, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-1.57079633,  0.        ,  0.        ])
```

disable_hook()

get_transform()
Return Transform object

Returns **transform** – corrensponding Transform to this coordinates

Return type skrobot.coordinates.base.Transform

inverse_rotate_vector(*v*)

inverse_transform_vector(*vec*)
Transform vector in world coordinates to local coordinates

Parameters **vec** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

inverse_transformation(*dest=None*)
Return a invese transformation of this coordinate system.

Create a new coordinate with inverse transformation of this coordinate system.

$$\begin{pmatrix} R^{-1} & -R^{-1}p \\ 0 & 1 \end{pmatrix}$$

Parameters **dest** (*None or skrobot.coordinates.Coordinates*) – If dest is given, the result of transformation is in-placed to dest.

Returns **dest** – result of inverse transformation.

Return type *skrobot.coordinates.Coordinates*

move_coords(*target_coords*, *local_coords*)
Transform this coordinate so that local_coords to target_coords.

Parameters

- **target_coords** (*skrobot.coordinates.Coordinates*) – target coords.
- **local_coords** (*skrobot.coordinates.Coordinates*) – local coords to be aligned.

Returns **self.worldcoords()** – world coordinates.

Return type *skrobot.coordinates.Coordinates*

newcoords(*c*, *pos=None*, *check_validity=True*)
Update of coords is always done through newcoords.

Parameters

- **c** (*skrobot.coordinates.Coordinates or numpy.ndarray*) – If pos is *None*, *c* means new Coordinates. If pos is given, *c* means rotation matrix.
- **pos** (*numpy.ndarray or None*) – new translation.

- **check_validity** (*bool*) – If this value is *True*, check whether an input rotation and an input translation are valid.

orient_with_matrix(*rotation_matrix*, *wrt='world'*)
Force update this coordinate system's rotation.

Parameters

- **rotation_matrix** (*numpy.ndarray*) – 3x3 rotation matrix.
- **wrt** (*str or skrobot.coordinates.Coordinates*) – reference coordinates.

parent_orientation(*v*, *wrt*)

rotate(*theta*, *axis=None*, *wrt='local'*)
Rotate this coordinate by given theta and axis.

This coordinate system is rotated relative to theta radians around the *axis* axis. Note that this function does not change a position of this coordinate. If you want to rotate this coordinates around with world frame, you can use *transform* function. Please see examples.

Parameters

- **theta** (*float*) – relartive rotation angle in radian.
- **axis** (*str or None or numpy.ndarray*) – axis of rotation. The value of *axis* is represented as *wrt* frame.
- **wrt** (*str or skrobot.coordinates.Coordinates*) –

Returns self

Return type *skrobot.coordinates.Coordinates*

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from numpy import pi
>>> c = Coordinates()
>>> c.translate((1.0, 0, 0))
>>> c.rotate(pi / 2.0, 'z', wrt='local')
>>> c.translation
array([1., 0., 0.])
```

```
>>> c.transform(Coordinates().rotate(np.pi / 2.0, 'z'), wrt='world')
>>> c.translation
array([0., 1., 0.])
```

rotate_vector(*v*)
Rotate 3-dimensional vector using rotation of this coordinate

Parameters **v** (*numpy.ndarray*) – vector shape of (3,)

Returns **np.matmul(self.rotation, v)** – rotated vector

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from numpy import pi
>>> c = Coordinates().rotate(pi, 'z')
>>> c.rotate_vector([1, 2, 3])
array([-1., -2.,  3.])
```

rotate_with_matrix(*mat*, *wrt='local'*)

Rotate this coordinate by given rotation matrix.

This is a subroutine of self.rotate function.

Parameters

- **mat** (*numpy.ndarray*) – rotation matrix shape of (3, 3)
- **wrt** (*str or* skrobot.coordinates.Coordinates) – with respect to.

Returns self

Return type *skrobot.coordinates.Coordinates*

rpy_angle()

Return a pair of rpy angles of this coordinates.

Returns rpy_angle(self.rotation) – a pair of rpy angles. See also skrobot.coordinates.math.rpy_angle

Return type tuple(numpy.ndarray, numpy.ndarray)

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates().rotate(np.pi / 2.0, 'x').rotate(np.pi / 3.0, 'z')
>>> r.rpy_angle()
(array([ 3.84592537e-16, -1.04719755e+00,  1.57079633e+00]),
array([ 3.14159265, -2.0943951 , -1.57079633]))
```

transform(*c*, *wrt='local'*, *out=None*)

Transform this coordinates by coords based on wrt

Note that this function changes this coordinates translation and rotation. If you would like not to change this coordinates, Please use copy_worldcoords() or give *out*.

Parameters

- **c** (skrobot.coordinates.Coordinates) – coordinate
- **wrt** (*str or* skrobot.coordinates.Coordinates) – If wrt is 'local' or self, multiply c from the right. If wrt is 'world' or 'parent' or self.parent, transform c with respect to worldcoord. If wrt is Coordinates, transform c with respect to c.
- **out** (*None or* skrobot.coordinates.Coordinates) – If the *out* is specified, set new coordinates to *out*. Note that if the *out* is given, these coordinates don't change.

Returns self – return this coordinate

Return type *skrobot.coordinates.Coordinates*

Examples

transform_vector(*v*)

“Return vector represented at world frame.

Vector v given in the local coords is converted to world representation.

Parameters **v** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

transformation(*c2*, *wrt='local'*)

translate(*vec*, *wrt='local'*)

Translate this coordinates.

Note that this function changes this coordinates self. So if you don’t want to change this class, use copy_worldcoords()

Parameters

- **vec** (*list or numpy.ndarray*) – shape of (3,) translation vector. unit is [m] order.
- **wrt** (*str or Coordinates (optional)*) – translate with respect to wrt.

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.], dtype=float32)
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3], dtype=float32)
```

```
>>> c = Coordinates()
>>> c.copy_worldcoords().translate([0.1, 0.2, 0.3])
>>> c.translation
array([0., 0., 0.], dtype=float32)
```

```
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([ 0.3,  0.2, -0.1])
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3], 'world')
>>> c.translation
array([0.1, 0.2, 0.3])
```

worldcoords()

Return thisself

worldpos()

Return translation of this coordinate

See also skrobot.coordinates.Coordinates.translation

Returns **self.translation** – translation of this coordinate

Return type numpy.ndarray

`worldrot()`

Return rotation of this coordinate

See also skrobot.coordinates.Coordinates.rotation

Returns **self.rotation** – rotation matrix of this coordinate

Return type numpy.ndarray

`__eq__`(*value*, /)

Return self==value.

`__ne__`(*value*, /)

Return self!=value.

`__lt__`(*value*, /)

Return self<value.

`__le__`(*value*, /)

Return self<=value.

`__gt__`(*value*, /)

Return self>value.

`__ge__`(*value*, /)

Return self>=value.

`__mul__`(*other_c*)

Return Transformed Coordinates.

Note that this function creates new Coordinates and does not change translation and rotation, unlike transform function.

Parameters **other_c** (`skrobot.coordinates.Coordinates`) – input coordinates.

Returns **out** – transformed coordinates multiplied other_c from the right. T = T_{self} T_{other_c}.

Return type *skrobot.coordinates.Coordinates*

`__pow__`(*exponent*)

Return exponential homogeneous matrix.

If exponent equals -1, return inverse transformation of this coords.

Parameters **exponent** (`numbers.Number`) – exponent value. If exponent equals -1, return inverse transformation of this coords. In current, support only -1 case.

Returns **out** – output.

Return type *skrobot.coordinates.Coordinates*

Attributes

dimension
Return dimension of this coordinate

Returns **len(self.translation)** – dimension of this coordinate

Return type int

dual_quaternion
Property of DualQuaternion

Return DualQuaternion representation of this coordinate.

Returns **DualQuaternion** – DualQuaternion representation of this coordinate

Return type *skrobot.coordinates.dual_quaternion.DualQuaternion*

name
Return this coordinate's name

Returns **self._name** – name of this coordinate

Return type str

quaternion
Property of quaternion

Returns **q** – [w, x, y, z] quaternion

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.quaternion
array([1., 0., 0., 0.])
>>> c.rotate(pi / 3, 'y').rotate(pi / 5, 'z')
>>> c.quaternion
array([0.8236391 , 0.1545085 , 0.47552826, 0.26761657])
```

rotation
Return rotation matrix of this coordinates.

Returns **self._rotation** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.rotation
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> c.rotate(np.pi / 2.0, 'y')
>>> c.rotation
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16]])
```

translation

Return translation of this coordinates.

Returns **self._translation** – vector shape of (3,). unit is [m]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3])
```

x_axis

Return x axis vector of this coordinates.

Returns **axis** – x axis.

Return type numpy.ndarray

y_axis

Return y axis vector of this coordinates.

Returns **axis** – y axis.

Return type numpy.ndarray

z_axis

Return z axis vector of this coordinates.

Returns **axis** – z axis.

Return type numpy.ndarray

skrobot.coordinates.CascadedCoords

class skrobot.coordinates.**CascadedCoords**(*parent=None*, **args*, ***kwargs*)

Methods

T()

Return 4x4 homogeneous transformation matrix.

Returns **matrix** – homogeneous transformation matrix shape of (4, 4)

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.T()
array([[1., 0., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 0., 0., 1.]])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.rotate(pi / 2.0, 'y')
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00,
         1.00000000e-01],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00,
         2.00000000e-01],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16,
         3.00000000e-01],
       [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
         1.00000000e+00]])
```

assoc(*child*, *relative_coords='world'*, *force=False*, ***kwargs*)

Associate child coords to this coordinate system.

If *relative_coords* is *None* or 'world', the translation and rotation of childcoords in the world coordinate system do not change. If *relative_coords* is specified, childcoords is assoced at translation and rotation of *relative_coords*. By default, if child is already assoced to some other coords, raise an exception. But if *force* is *True*, you can overwrite the existing assoc relation.

Parameters

- **child** (CascadedCoords) – child coordinates.
- **relative_coords** (*None or* Coordinates *or* *str*) – child coordinates' relative coordinates.
- **force** (*bool*) – predicate for overwriting the existing assoc-relation

Returns **child** – assoced child.

Return type *CascadedCoords*

Examples

```
>>> from skrobot.coordinates import CascadedCoords
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords)
#<CascadedCoords 0x7f1d30e29510 1.000 1.000 0.000 / 0.0 -0.0 0.0>
>>> child_coords.worldpos()
array([1., 1., 0.])
>>> child_coords.translation
array([0., 1., 0.])
```

None and 'world' have the same meaning.

```
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords, relative_coords='world')
#<CascadedCoords 0x7f1d30e29510 1.000 1.000 0.000 / 0.0 -0.0 0.0>
>>> child_coords.worldpos()
array([1., 1., 0.])
```

If *relative_coords* is 'local', *child* is associated at world translation and world rotation of *child* from this coordinate system.

```
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords, relative_coords='local')
>>> child_coords.worldpos()
array([2., 1., 0.])
>>> child_coords.translation
array([1., 1., 0.])
```

axis(*ax*)

changed()

Return False

This is used for CascadedCoords compatibility

Returns **False** – always return False

Return type bool

coords()

Return a deep copy of the Coordinates.

copy()

Return a deep copy of the Coordinates.

copy_coords()

Return a deep copy of the Coordinates.

copy_worldcoords()

Return a deep copy of the Coordinates.

difference_position(*coords*, *translation_axis=True*)

Return differences in positoin of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **translation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xy', 'yz', 'zx', 'xx', 'yy', 'zz', True or False(None).

Returns **dif_pos** – difference position of self coordinates and coords considering translation_axis.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates import transform_coords
>>> from numpy import pi
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(
...          pi / 3.0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...          pi / 2.0, 'y')
>>> c1.difference_position(c2)
array([ 0.2       , -0.42320508,  0.3330127 ])
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...          pi / 3.0, 'x')
>>> c1.difference_position(c2)
array([ 0.2, -0.5, -0.2])
```

difference_rotation(*coords*, *rotation_axis=True*)

Return differences in rotation of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **rotation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xx', 'yy', 'zz', 'xm', 'ym', 'zm', 'xy', 'yx', 'yz', 'zy', 'zx', 'xz', True or False(None).

Returns **dif_rot** – difference rotation of self coordinates and coords considering rotation_axis.

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates.math import rpy_matrix
>>> coord1 = Coordinates()
>>> coord2 = Coordinates(rot=rpy_matrix(pi / 2.0, pi / 3.0, pi / 5.0))
>>> coord1.difference_rotation(coord2)
array([-0.32855112,  1.17434985,  1.05738936])
>>> coord1.difference_rotation(coord2, rotation_axis=False)
array([0, 0, 0])
>>> coord1.difference_rotation(coord2, rotation_axis='x')
array([0.        , 1.36034952, 0.78539816])
>>> coord1.difference_rotation(coord2, rotation_axis='y')
```

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```
array([0.35398131, 0.        , 0.97442695])
>>> coord1.difference_rotation(coord2, rotation_axis='z')
array([-0.88435715,  0.74192175,  0.        ])
```

Using mirror option ['xm', 'ym', 'zm'], you can allow differences of mirror direction.

```
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-2.99951957e-32,  0.00000000e+00,  0.00000000e+00])
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi / 2.0, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-1.57079633,  0.        ,  0.        ])
```

disable_hook()

dissoc(*child*)

get_transform()

Return Transform object

Returns **transform** – corrensponding Transform to this coordinates

Return type skrobot.coordinates.base.Transform

inverse_rotate_vector(*v*)

inverse_transform_vector(*v*)

Transform vector in world coordinates to local coordinates

Parameters **vec** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

inverse_transformation(*dest=None*)

Return a invese transformation of this coordinate system.

Create a new coordinate with inverse transformation of this coordinate system.

$$\begin{pmatrix} R^{-1} & -R^{-1}p \\ 0 & 1 \end{pmatrix}$$

Parameters **dest** (*None or* skrobot.coordinates.Coordinates) – If dest is given, the result of transformation is in-placed to dest.

Returns **dest** – result of inverse transformation.

Return type *skrobot.coordinates.Coordinates*

move_coords(*target_coords, local_coords*)

Transform this coordinate so that local_coords to target_coords.

Parameters

- **target_coords** (skrobot.coordinates.Coordinates) – target coords.
- **local_coords** (skrobot.coordinates.Coordinates) – local coords to be aligned.

Returns **self.worldcoords()** – world coordinates.

Return type *skrobot.coordinates.Coordinates*

`newcoords`(*c*, *pos=None*, *check_validity=True*)

Update this coordinates.

This function records that this CascadedCoords has changed and recursively records the change to descendants of this CascadedCoords.

Parameters

- **c** (`skrobot.coordinates.Coordinates` *or* *numpy.ndarray*) – If pos is *None*, *c* means new Coordinates. If pos is given, *c* means rotation matrix.
- **pos** (*numpy.ndarray* *or* *None*) – new translation.
- **check_validity** (*bool*) – If this value is *True*, check whether an input rotation and an input translation are valid.

`orient_with_matrix`(*rotation_matrix*, *wrt='world'*)

Force update this coordinate system's rotation.

Parameters

- **rotation_matrix** (*numpy.ndarray*) – 3x3 rotation matrix.
- **wrt** (*str* *or* `skrobot.coordinates.Coordinates`) – reference coordinates.

`parent_orientation`(*v*, *wrt*)

`parentcoords`()

`rotate`(*theta*, *axis*, *wrt='local'*)

Rotate this coordinate.

Rotate this coordinate relative to axis by theta radians with respect to wrt.

Parameters

- **theta** (*float*) – radian
- **axis** (*str* *or* *numpy.ndarray*) – 'x', 'y', 'z' or vector
- **wrt** (*str* *or* `Coordinates`) –

Return type self

`rotate_vector`(*v*)

Rotate 3-dimensional vector using rotation of this coordinate

Parameters **v** (*numpy.ndarray*) – vector shape of (3,)

Returns **np.matmul(self.rotation, v)** – rotated vector

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from numpy import pi
>>> c = Coordinates().rotate(pi, 'z')
>>> c.rotate_vector([1, 2, 3])
array([-1., -2.,  3.])
```

rotate_with_matrix(*matrix*, *wrt*)
Rotate this coordinate by given rotation matrix.

This is a subroutine of self.rotate function.

Parameters

- **mat** (*numpy.ndarray*) – rotation matrix shape of (3, 3)
- **wrt** (*str or* skrobot.coordinates.Coordinates) – with respect to.

Returns self

Return type *skrobot.coordinates.Coordinates*

rpy_angle()
Return a pair of rpy angles of this coordinates.

Returns **rpy_angle(self.rotation)** – a pair of rpy angles. See also skrobot.coordinates.math.rpy_angle

Return type tuple(numpy.ndarray, numpy.ndarray)

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates().rotate(np.pi / 2.0, 'x').rotate(np.pi / 3.0, 'z')
>>> r.rpy_angle()
(array([ 3.84592537e-16, -1.04719755e+00,  1.57079633e+00]),
array([ 3.14159265, -2.0943951 , -1.57079633]))
```

transform(*c*, *wrt='local'*, *out=None*)
Transform this coordinates

Parameters

- **c** (skrobot.coordinates.Coordinates) – coordinates
- **wrt** (*str or* skrobot.coordinates.Coordinates) – transform this coordinates with respect to wrt. If wrt is 'local' or self, multiply c from the right. If wrt is 'parent' or self.parent, transform c with respect to parentcoords. (multiply c from the left.) If wrt is Coordinates, transform c with respect to c.
- **out** (*None or* skrobot.coordinates.Coordinates) – If the *out* is specified, set new coordinates to *out*. Note that if the *out* is given, these coordinates don't change.

Returns **self** – return self

Return type *skrobot.coordinates.CascadedCoords*

transform_vector(*v*)

"Return vector represented at world frame.

Vector v given in the local coords is converted to world representation.

Parameters **v** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

transformation(*c2*, *wrt='local'*)

translate(*vec*, *wrt='local'*)

Translate this coordinates.

Note that this function changes this coordinates self. So if you don't want to change this class, use copy_worldcoords()

Parameters

- **vec** (*list or numpy.ndarray*) – shape of (3,) translation vector. unit is [m] order.
- **wrt** (*str or* Coordinates *(optional)*) – translate with respect to wrt.

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.], dtype=float32)
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3], dtype=float32)
```

```
>>> c = Coordinates()
>>> c.copy_worldcoords().translate([0.1, 0.2, 0.3])
>>> c.translation
array([0., 0., 0.], dtype=float32)
```

```
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([ 0.3,  0.2, -0.1])
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3], 'world')
>>> c.translation
array([0.1, 0.2, 0.3])
```

update(*force=False*)

worldcoords()

Calculate rotation and position in the world.

worldpos()

Return translation of this coordinate

See also skrobot.coordinates.Coordinates.translation

Returns **self.translation** – translation of this coordinate

Return type numpy.ndarray

worldrot()

Return rotation of this coordinate

See also skrobot.coordinates.Coordinates.rotation

Returns **self.rotation** – rotation matrix of this coordinate

Return type numpy.ndarray

__eq__(*value*, */*)

Return self==value.

__ne__(*value*, */*)

Return self!=value.

__lt__(*value*, */*)

Return self<value.

__le__(*value*, */*)

Return self<=value.

__gt__(*value*, */*)

Return self>value.

__ge__(*value*, */*)

Return self>=value.

__mul__(*other_c*)

Return Transformed Coordinates.

Note that this function creates new Coordinates and does not change translation and rotation, unlike transform function.

Parameters **other_c** (skrobot.coordinates.Coordinates) – input coordinates.

Returns **out** – transformed coordinates multiplied other_c from the right. T = T_{self} T_{other_c}.

Return type *skrobot.coordinates.Coordinates*

__pow__(*exponent*)

Return exponential homogeneous matrix.

If exponent equals -1, return inverse transformation of this coords.

Parameters **exponent** (*numbers.Number*) – exponent value. If exponent equals -1, return inverse transformation of this coords. In current, support only -1 case.

Returns **out** – output.

Return type *skrobot.coordinates.Coordinates*

Attributes

descendants

dimension

Return dimension of this coordinate

Returns **len(self.translation)** – dimension of this coordinate

Return type int

dual_quaternion

Property of DualQuaternion

Return DualQuaternion representation of this coordinate.

Returns **DualQuaternion** – DualQuaternion representation of this coordinate

Return type *skrobot.coordinates.dual_quaternion.DualQuaternion*

name

Return this coordinate's name

Returns **self._name** – name of this coordinate

Return type str

parent

quaternion

Property of quaternion

Returns **q** – [w, x, y, z] quaternion

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.quaternion
array([1., 0., 0., 0.])
>>> c.rotate(pi / 3, 'y').rotate(pi / 5, 'z')
>>> c.quaternion
array([0.8236391 , 0.1545085 , 0.47552826, 0.26761657])
```

rotation

Return rotation matrix of this coordinates.

Returns **self._rotation** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.rotation
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> c.rotate(np.pi / 2.0, 'y')
>>> c.rotation
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16]])
```

translation

Return translation of this coordinates.

Returns **self._translation** – vector shape of (3,). unit is [m]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3])
```

x_axis

Return x axis vector of this coordinates.

Returns **axis** – x axis.

Return type numpy.ndarray

y_axis

Return y axis vector of this coordinates.

Returns **axis** – y axis.

Return type numpy.ndarray

z_axis

Return z axis vector of this coordinates.

Returns **axis** – z axis.

Return type numpy.ndarray

3.1.2 Coordinates utilities

skrobot.coordinates.geo.midcoords	Returns mid (or p) coordinates of given two coordinates c1 and c2.
skrobot.coordinates.geo.orient_coords_to_axis	Orient axis to the direction
skrobot.coordinates.base.random_coords	Return Coordinates class has random translation and rotation
skrobot.coordinates.base.coordinates_distance	
skrobot.coordinates.base.transform_coords	Return Coordinates by applying c1 to c2 from the left

skrobot.coordinates.geo.midcoords

skrobot.coordinates.geo.**midcoords**(*p*, *c1*, *c2*)

Returns mid (or p) coordinates of given two coordinates c1 and c2.

Parameters

- **p** (*float*) – ratio of c1:c2
- **c1** (skrobot.coordinates.Coordinates) – Coordinates
- **c2** (skrobot.coordinates.Coordinates) – Coordinates

Returns **coordinates** – midcoords

Return type *skrobot.coordinates.Coordinates*

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates.geo import midcoords
>>> c1 = Coordinates()
>>> c2 = Coordinates(pos=[0.1, 0, 0])
>>> c = midcoords(0.5, c1, c2)
>>> c.translation
array([0.05, 0.  , 0.  ])
```

skrobot.coordinates.geo.orient_coords_to_axis

skrobot.coordinates.geo.**orient_coords_to_axis**(*target_coords*, *v*, *axis='z'*, *eps=0.005*)

Orient axis to the direction

Orient axis in target_coords to the direction specified by v.

Parameters

- **target_coords** (skrobot.coordinates.Coordinates) –
- **v** (*list or numpy.ndarray*) – position of target [x, y, z]
- **axis** (*list or string or numpy.ndarray*) – see _wrap_axis function
- **eps** (*float (optional)*) – eps

Returns target_coords

Return type *skrobot.coordinates.Coordinates*

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates.geo import orient_coords_to_axis
>>> c = Coordinates()
>>> oriented_coords = orient_coords_to_axis(c, [1, 0, 0])
>>> oriented_coords.translation
array([0., 0., 0.])
>>> oriented_coords.rpy_angle()
(array([0.        , 1.57079633, 0.        ]),
 array([3.14159265, 1.57079633, 3.14159265]))
```

```
>>> c = Coordinates(pos=[0, 1, 0])
>>> oriented_coords = orient_coords_to_axis(c, [0, 1, 0])
>>> oriented_coords.translation
array([0., 1., 0.])
>>> oriented_coords.rpy_angle()
(array([ 0.        , -0.        , -1.57079633]),
 array([ 3.14159265, -3.14159265,  1.57079633]))
```

```
>>> c = Coordinates(pos=[0, 1, 0]).rotate(np.pi / 3, 'y')
>>> oriented_coords = orient_coords_to_axis(c, [0, 1, 0])
>>> oriented_coords.translation
array([0., 1., 0.])
>>> oriented_coords.rpy_angle()
(array([-5.15256299e-17,  1.04719755e+00, -1.57079633e+00]),
 array([3.14159265, 2.0943951 , 1.57079633]))
```

skrobot.coordinates.base.random_coords

skrobot.coordinates.base.**random_coords**()

Return Coordinates class has random translation and rotation

skrobot.coordinates.base.coordinates_distance

skrobot.coordinates.base.**coordinates_distance**(*c1*, *c2*, *c=None*)

skrobot.coordinates.base.transform_coords

skrobot.coordinates.base.**transform_coords**(*c1*, *c2*, *out=None*)

Return Coordinates by applying c1 to c2 from the left

Parameters

- **c1** (skrobot.coordinates.Coordinates) –
- **c2** (skrobot.coordinates.Coordinates) – Coordinates
- **c3** (skrobot.coordinates.Coordinates *or None*) – Output argument. If this value is specified, the results will be in-placed.

Returns **Coordinates(pos=translation, rot=q)** – new coordinates

Return type *skrobot.coordinates.Coordinates*

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates import transform_coords
>>> from numpy import pi
>>> c1 = Coordinates()
>>> c2 = Coordinates()
>>> c3 = transform_coords(c1, c2)
>>> c3.translation
array([0., 0., 0.])
>>> c3.rotation
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(pi / 3.0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(pi / 2.0, 'y')
>>> c3 = transform_coords(c1, c2)
>>> c3.translation
array([ 0.4        , -0.03660254,  0.09019238])
>>> c3.rotation
>>> c3.rotation
array([[ 1.94289029e-16,  0.00000000e+00,  1.00000000e+00],
       [ 8.66025404e-01,  5.00000000e-01, -1.66533454e-16],
       [-5.00000000e-01,  8.66025404e-01,  2.77555756e-17]])
```

3.1.3 Quaternion Classes

skrobot.coordinates.quaternion.Quaternion	Class for handling Quaternion.
skrobot.coordinates.dual_quaternion.DualQuaternion	Class for handling dual quaternions and their interpolations.

skrobot.coordinates.quaternion.Quaternion

class skrobot.coordinates.quaternion.**Quaternion**(*w=1.0*, *x=0.0*, *y=0.0*, *z=0.0*, *q=None*)

Class for handling Quaternion.

Parameters

- **w** (*float or numpy.ndarray*) –
- **x** (*float*) –
- **y** (*float*) –
- **z** (*float*) –
- **q** (*None or numpy.ndarray*) – if q is not specified, use w, x, y, z.

Examples

```
>>> from skrobot.coordinates.quaternion import Quaternion
>>> q = Quaternion()
>>> q
#<Quaternion 0x1283bde48 w: 1.0 x: 0.0 y: 0.0 z: 0.0>
>>> q = Quaternion([1, 2, 3, 4])
>>> q
#<Quaternion 0x1283cad68 w: 1.0 x: 2.0 y: 3.0 z: 4.0>
>>> q = Quaternion(q=[1, 2, 3, 4])
>>> q
#<Quaternion 0x1283bd438 w: 1.0 x: 2.0 y: 3.0 z: 4.0>
>>> q = Quaternion(1, 2, 3, 4)
>>> q
#<Quaternion 0x128400198 w: 1.0 x: 2.0 y: 3.0 z: 4.0>
>>> q = Quaternion(w=0.0, x=1.0, y=0.0, z=0.0)
>>> q
#<Quaternion 0x1283cc2e8 w: 0.0 x: 1.0 y: 0.0 z: 0.0>
```

Methods

T()

Return 4x4 homogeneous transformation matrix.

Returns **matrix** – homogeneous transformation matrix shape of (4, 4)

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.quaternion import Quaternion
>>> q = Quaternion()
>>> q.T()
array([[1., 0., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 0., 0., 1.]])
```

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```
>>> q.q = [1, 2, 3, 4]
>>> q.T()
array([[-0.66666667,  0.13333333,  0.73333333,  0.        ],
       [ 0.66666667, -0.33333333,  0.66666667,  0.        ],
       [ 0.33333333,  0.93333333,  0.13333333,  0.        ],
       [ 0.        ,  0.        ,  0.        ,  1.        ]])
```

copy()

Return copy of this Quaternion

Returns **Quaternion(q=self.q.copy())** – copy of this quaternion

Return type *skrobot.coordinates.quaternion.Quaternion*

normalize()

Normalize this quaternion.

Note that this function changes wxyz property.

Examples

```
>>> from skrobot.coordinates.quaternion import Quaternion
>>> q = Quaternion([1, 2, 3, 4])
>>> q.q
array([1., 2., 3., 4.])
>>> q.normalize()
>>> q.q
array([0.18257419, 0.36514837, 0.54772256, 0.73029674])
```

__eq__(*value*, /)

Return self==value.

__ne__(*value*, /)

Return self!=value.

__lt__(*value*, /)

Return self<value.

__le__(*value*, /)

Return self<=value.

__gt__(*value*, /)

Return self>value.

__ge__(*value*, /)

Return self>=value.

__neg__()

__add__(*cls*)

__sub__(*cls*)

__mul__(*cls*)

__rmul__(*cls*)

__div__(*cls*)

__truediv__(*cls*)

Attributes

angle

Return rotation angle of this quaternion

Returns **theta** – rotation angle with respect to self.axis

Return type float

axis

Return axis of this quaternion.

Note that this property return normalized axis.

Returns **axis** – normalized axis vector

Return type numpy.ndarray

conjugate

Return conjugate of this quaternion

Returns **Quaternion** – new Quaternion class has this quaternion's conjugate

Return type *skrobot.coordinates.quaternion.Quaternion*

Examples

```
>>> from skrobot.coordinates.quaternion import Quaternion
>>> q = Quaternion()
>>> q.conjugate
#<Quaternion 0x12f2dfb38 w: 1.0 x: -0.0 y: -0.0 z: -0.0>
>>> q.q = [0, 1, 0, 0]
>>> q.conjugate
#<Quaternion 0x12f303c88 w: 0.0 x: -1.0 y: -0.0 z: -0.0>
```

inverse

Return inverse of this quaternion

Returns **q** – new Quaternion class has inverse of this quaternion

Return type *skrobot.coordinates.quaternion.Quaternion*

Examples

```
>>> from skrobot.coordinates.quaternion import Quaternion
>>> q = Quaternion()
>>> q
#<Quaternion 0x127e6da58 w: 1.0 x: 0.0 y: 0.0 z: 0.0>
>>> q.inverse
#<Quaternion 0x1281bbda0 w: 1.0 x: -0.0 y: -0.0 z: -0.0>
>>> q.q = [0, 1, 0, 0]
>>> q.inverse
#<Quaternion 0x1282b0cc0 w: 0.0 x: -1.0 y: -0.0 z: -0.0>
```

norm

Return norm of this quaternion

Returns **quaternion_norm(self.q)** – norm of this quaternion

Return type float

Examples

```
>>> from skrobot.coordinates.quaternion import Quaternion
>>> q = Quaternion()
>>> q.norm
1.0
>>> q = Quaternion([1, 2, 3, 4])
>>> q.norm
5.477225575051661
>>> q.normalized.norm
0.9999999999999999
```

normalized

Return Normalized quaternion.

Returns **normalized quaternion** – return quaternion which is norm == 1.0.

Return type *skrobot.coordinates.quaternion.Quaternion*

Examples

```
>>> from skrobot.coordinates.quaternion import Quaternion
>>> q = Quaternion([1, 2, 3, 4])
>>> normalized_q = q.normalized
>>> normalized_q.q
array([0.18257419, 0.36514837, 0.54772256, 0.73029674])
>>> q.q
array([1., 2., 3., 4.])
```

q

Return quaternion

Returns **self._q** – [w, x, y, z] quaternion

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.quaternion import Quaternion
>>> q = Quaternion()
>>> q.q
array([1., 0., 0., 0.])
>>> q = Quaternion(w=0.0, x=1.0, y=0.0, z=0.0)
>>> q.q
array([0., 1., 0., 0.])
```

rotation

Return rotation matrix.

Note that this property internally normalizes quaternion.

Returns **quaternion2matrix(self.q)** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.quaternion import Quaternion
>>> q = Quaternion()
>>> q
#<Quaternion 0x12f1aa6a0 w: 1.0 x: 0.0 y: 0.0 z: 0.0>
>>> q.rotation
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> q.q = [0, 1, 0, 0]
>>> q
#<Quaternion 0x12f1aa6a0 w: 0.0 x: 1.0 y: 0.0 z: 0.0>
>>> q.rotation
array([[ 1.,  0.,  0.],
       [ 0., -1.,  0.],
       [ 0.,  0., -1.]])
>>> q.q = [1, 2, 3, 4]
>>> q
#<Quaternion 0x12f1aa6a0 w: 1.0 x: 2.0 y: 3.0 z: 4.0>
>>> q.rotation
array([[-0.66666667,  0.13333333,  0.73333333],
       [ 0.66666667, -0.33333333,  0.66666667],
       [ 0.33333333,  0.93333333,  0.13333333]])
```

w

Return w element

Returns **self.q[0]** – w element of this quaternion

Return type float

x

Return x element

Returns **self.q[1]** – x element of this quaternion

Return type float

xyz

Return xyz vector of this quaternion

Returns **quaternion_xyz** – xyz elements of this quaternion

Return type numpy.ndarray

y

Return y element

Returns **self.q[2]** – y element of this quaternion

Return type float

z

Return z element

Returns **self.q[3]** – z element of this quaternion

Return type float

skrobot.coordinates.dual_quaternion.DualQuaternion

class skrobot.coordinates.dual_quaternion.**DualQuaternion**(*qr=[1, 0, 0, 0]*, *qd=[0, 0, 0, 0]*, *enforce_unit_norm=False*)

Class for handling dual quaternions and their interpolations.

Parameters

- **qr** (*list or numpy.ndarray*) –
- **qd** (*list or numpy.ndarray*) – element of dual quaternion
- **enforce_unit_norm** (*bool (optional)*) – if True, norm should be 1.0.

Methods

T()

Return 4x4 homogeneous transformation matrix.

Returns **matrix** – homogeneous transformation matrix shape of (4, 4)

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates.dual_quaternion import DualQuaternion
>>> dq = DualQuaternion()
>>> dq.T()
array([[1., 0., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 0., 0., 1.]])
>>> dq = Coordinates().rotate(pi / 2.0, 'y').         ...                   ␣
↪translate((0.1, 0.2, 0.3)).         ...                     dual_quaternion
>>> dq.T()
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00,
         3.00000000e-01],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00,
         2.00000000e-01],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16,
        -1.00000000e-01],
       [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
         1.00000000e+00]])
```

copy()

Return a copy of this quaternion.

Returns copied DualQuaternion instance

Return type *DualQuaternion*

difference_position(*other_dq*)
Return difference position

Parameters **other_dq** (skrobot.coordinates.dual_quaternion.DualQuaternion) – dual quaternion

Returns **dif_pos** – difference position's norm

Return type float

difference_rotation(*other_dq*)
Return difference rotation distance

Parameters **other_dq** (skrobot.coordinates.dual_quaternion.DualQuaternion) – dual quaternion

Returns **dif_rot** – angle distance in radian.

Return type float

enforce_positive_q_rot_w()

static interpolate(*dq0*, *dq1*, *t*)
Return interpolated dual quaternion

Parameters

- **dq0** (skrobot.coordinates.dual_quaternion.DualQuaternion) –
- **dq1** (skrobot.coordinates.dual_quaternion.DualQuaternion) – dual quaternion
- **t** (*float*) – ratio of interpolation. Must be 0 <= t <= 1.0.

normalize()
Normalize this dual quaternion

Note that this function changes property.

Returns **self** – return self

Return type *skrobot.coordinates.dual_quaternion.DualQuaternion*

pose()
Return [x, y, z, wx, wy, wz, wq] elements.

Returns **pose** – [x, y, z, wx, wy, wz, wq] pose

Return type numpy.ndarray

screw_axis()
Return screw axis

Calculates rotation, translation and screw axis from dual quaternion.

Returns **screw_axis, theta, translation** – screw axis of this dual quaternion. rotation angle in radian. translation

Return type tuple(numpy.ndarray, float, float)

__eq__(*value*, /)
Return self==value.

__ne__(*value*, /)
Return self!=value.

__lt__(*value*, /)
Return self<value.

__le__(*value*, /)
Return self<=value.

__gt__(*value*, /)
Return self>value.

__ge__(*value*, /)
Return self>=value.

__add__(*val*)

__mul__(*val*)

__rmul__(*val*)

Attributes

angle
Return rotation angle of this dual quaternion

Returns **self.qr.angle** – this dual quaternion's rotation angle with respect to self.axis. See skrobot.coordinates.quaternion.Quaternion.angle.

Return type float

axis
Return axis of this dual quaternion

Returns **self.qr.axis** – this dual quaternion's axis. See See skrobot.coordinates.quaternion.Quaternion.axis.

Return type numpy.ndarray

conjugate
Return conjugate of this dual quaternion

Returns **DualQuaternion** – new DualQuaternion class has this dual quaternion's conjugate

Return type *skrobot.coordinates.dual_quaternion.DualQuaternion*

dq
Return flatten vector of this dual quaternion

Returns **np.concatenate([self.qr.q, self.qd.q])** – (1x8) vector of this dual quaternion

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.dual_quaternion import DualQuaternion
>>> dq = DualQuaternion()
>>> dq.dq
array([1., 0., 0., 0., 0., 0., 0., 0.])
```

inverse
Return inverse of this dual quaternion

Returns **dq** – new DualQuaternion class has inverse of this dual quaternion

Return type *skrobot.coordinates.dual_quaternion.DualQuaternion*

norm

Return pair of norm of this dual quaternion

Returns **qr_norm, qd_norm** – qr and qd's norm

Return type tuple(float, float)

Examples

```
>>> from skrobot.coordinates.dual_quaternion import DualQuaternion
>>> dq = DualQuaternion()
>>> dq.norm
(1.0, 0.0)
```

normalized

Return normalized this dual quaternion

Returns skrobot.coordinates.dual_quaternion.DualQuaternion normalized dual quaternion

Return type *DualQuaternion*(qr, qd, True)

qd

Return translation quaternion

Returns **self._qd** – quaternion indicating translation

Return type *skrobot.coordinates.quaternion.Quaternion*

qr

Return orientation

Returns **self._qr** – [w, x, y, z] order

Return type numpy.narray

quaternion

Return this dual quaternion's qr (rotation)

Returns **dq.qr** – rotation quaternion

Return type *skrobot.coordinates.quaternion.Quaternion*

rotation

Return rotation matrix of this dual quaternion

Returns **dq.qr.rotation** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.dual_quaternion.rotation
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> c.rotate(np.pi / 2.0, 'y')
```

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```
>>> c.dual_quaternion.rotation
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16]])
```

scalar
The scalar part of the dual quaternion.

Returns **scalar** – scalar

Return type float

translation
Return translation of this dual quaternion.

Returns **q_translation.xyz** – vector shape of (3,). unit is [m]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.dual_quaternion.translation
array([0., 0., 0.])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.dual_quaternion.translation
array([0.1, 0.2, 0.3])
```

3.2 Models

3.2.1 Robot Model class

skrobot.model.RobotModel

skrobot.model.RobotModel

class skrobot.model.**RobotModel**(*link_list=None*, *joint_list=None*, *root_link=None*)

Methods

T()
Return 4x4 homogeneous transformation matrix.

Returns **matrix** – homogeneous transformation matrix shape of (4, 4)

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.T()
array([[1., 0., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 0., 0., 1.]])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.rotate(pi / 2.0, 'y')
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00,
         1.00000000e-01],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00,
         2.00000000e-01],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16,
         3.00000000e-01],
       [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
         1.00000000e+00]])
```

angle_vector(*av=None*, *return_av=None*)
Returns angle vector

If av is given, it updates angles of all joint. If given av violate min/max range, the value is modified.

assoc(*child*, *relative_coords='world'*, *force=False*, ***kwargs*)
Associate child coords to this coordinate system.

If *relative_coords* is *None* or 'world', the translation and rotation of childcoords in the world coordinate system do not change. If *relative_coords* is specified, childcoords is assoced at translation and rotation of *relative_coords*. By default, if child is already assoced to some other coords, raise an exception. But if *force* is *True*, you can overwrite the existing assoc relation.

Parameters

- **child** (CascadedCoords) – child coordinates.
- **relative_coords** (*None or* Coordinates *or str*) – child coordinates' relative coordinates.
- **force** (*bool*) – predicate for overwriting the existing assoc-relation

Returns **child** – assoced child.

Return type *CascadedCoords*

Examples

```
>>> from skrobot.coordinates import CascadedCoords
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords)
#<CascadedCoords 0x7f1d30e29510 1.000 1.000 0.000 / 0.0 -0.0 0.0>
>>> child_coords.worldpos()
array([1., 1., 0.])
>>> child_coords.translation
array([0., 1., 0.])
```

None and 'world' have the same meaning.

```
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords, relative_coords='world')
#<CascadedCoords 0x7f1d30e29510 1.000 1.000 0.000 / 0.0 -0.0 0.0>
>>> child_coords.worldpos()
array([1., 1., 0.])
```

If *relative_coords* is 'local', *child* is associated at world translation and world rotation of *child* from this coordinate system.

```
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords, relative_coords='local')
>>> child_coords.worldpos()
array([2., 1., 0.])
>>> child_coords.translation
array([1., 1., 0.])
```

axis(*ax*)

calc_inverse_jacobian(*jacobi*, *manipulability_limit=0.1*, *manipulability_gain=0.001*, *weight=None*, **args*, ***kwargs*)

calc_inverse_kinematics_nspace_from_link_list(*link_list*, *avoid_nspace_gain=0.01*, *union_link_list=None*, *n_joint_dimension=None*, *null_space=None*, *additional_nspace_list=None*, *weight=None*)

calc_inverse_kinematics_weight_from_link_list(*link_list*, *avoid_weight_gain=1.0*, *union_link_list=None*, *n_joint_dimension=None*, *weight=None*, *additional_weight_list=[]*)

Calculate all weight from link list.

calc_jacobian_for_interlocking_joints(*link_list*, *interlocking_joint_pairs=None*)

calc_jacobian_from_link_list(*move_target*, *link_list=None*, *transform_coords=None*, *rotation_axis=None*, *translation_axis=None*, *col_offset=0*, *dim=None*, *jacobian=None*, *additional_jacobi_dimension=0*, *n_joint_dimension=None*, **args*, ***kwargs*)

calc_joint_angle_from_min_max_table(*index*, *j*, *av*)

calc_joint_angle_speed(*union_vel*, *angle_speed=None*, *angle_speed_blending=0.5*, *jacobi=None*, *j_sharp=None*, *null_space=None*, **args*, ***kwargs*) `calc_joint_angle_speed_gain`(*union_link_list*, *dav*, *periodic_time*)

`calc_nspace_from_joint_limit`(*avoid_nspace_gain*, *union_link_list*, *weight*)
Calculate null-space according to joint limit.

`calc_target_axis_dimension`(*rotation_axis*, *translation_axis*)
rotation-axis, translation-axis -> both list and atom OK.

`calc_target_joint_dimension`(*link_list*)

`calc_union_link_list`(*link_list*)

`calc_vel_for_interlocking_joints`(*link_list*, *interlocking_joint_pairs=None*)
Calculate 0 velocity for keeping interlocking joint.

at the same joint angle.

`calc_vel_from_pos`(*dif_pos*, *translation_axis*, *p_limit=100.0*)
Calculate velocity from difference position

Parameters

- **dif_pos** (*np.ndarray*) – [m] order
- **translation_axis** (*str*) – see calc_dif_with_axis

Returns vel_p

Return type np.ndarray

`calc_vel_from_rot`(*dif_rot*, *rotation_axis*, *r_limit=0.5*)

`calc_weight_from_joint_limit`(*avoid_weight_gain*, *link_list*, *union_link_list*, *weight*, *n_joint_dimension=None*)
Calculate weight according to joint limit.

`changed`()
Return False

This is used for CascadedCoords compatibility

Returns **False** – always return False

Return type bool

`collision_avoidance_link_pair_from_link_list`(*link_list*, *obstacles=None*)

`compute_qp_common`(*target_coords*, *move_target*, *dt*, *link_list=None*, *gain=0.85*, *weight=1.0*, *translation_axis=True*, *rotation_axis=True*, *dof_limit_gain=0.5*)

`compute_velocity`(*target_coords*, *move_target*, *dt*, *link_list=None*, *gain=0.85*, *weight=1.0*, *translation_axis=True*, *rotation_axis=True*, *dof_limit_gain=0.5*, *fast=True*, *sym_proj=False*, *solver='cvxopt'*, **args*, ***kwargs*)

`coords`()
Return a deep copy of the Coordinates.

`copy`()
Return a deep copy of the Coordinates.

`copy_coords`()
Return a deep copy of the Coordinates.

`copy_worldcoords`()
Return a deep copy of the Coordinates.

difference_position(*coords*, *translation_axis=True*)

Return differences in positoin of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **translation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xy', 'yz', 'zx', 'xx', 'yy', 'zz', True or False(None).

Returns **dif_pos** – difference position of self coordinates and coords considering translation_axis.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates import transform_coords
>>> from numpy import pi
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(
...          pi / 3.0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...          pi / 2.0, 'y')
>>> c1.difference_position(c2)
array([ 0.2       , -0.42320508,  0.3330127 ])
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...          pi / 3.0, 'x')
>>> c1.difference_position(c2)
array([ 0.2, -0.5, -0.2])
```

difference_rotation(*coords*, *rotation_axis=True*)

Return differences in rotation of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **rotation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xx', 'yy', 'zz', 'xm', 'ym', 'zm', 'xy', 'yx', 'yz', 'zy', 'zx', 'xz', True or False(None).

Returns **dif_rot** – difference rotation of self coordinates and coords considering rotation_axis.

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates.math import rpy_matrix
>>> coord1 = Coordinates()
>>> coord2 = Coordinates(rot=rpy_matrix(pi / 2.0, pi / 3.0, pi / 5.0))
>>> coord1.difference_rotation(coord2)
array([-0.32855112,  1.17434985,  1.05738936])
>>> coord1.difference_rotation(coord2, rotation_axis=False)
```

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```
array([0, 0, 0])
>>> coord1.difference_rotation(coord2, rotation_axis='x')
array([0.        , 1.36034952, 0.78539816])
>>> coord1.difference_rotation(coord2, rotation_axis='y')
array([0.35398131, 0.        , 0.97442695])
>>> coord1.difference_rotation(coord2, rotation_axis='z')
array([-0.88435715,  0.74192175,  0.        ])
```

Using mirror option ['xm', 'ym', 'zm'], you can allow differences of mirror direction.

```
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-2.99951957e-32,  0.00000000e+00,  0.00000000e+00])
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi / 2.0, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-1.57079633,  0.        ,  0.        ])
```

disable_hook()

dissoc(*child*)

find_joint_angle_limit_weight_from_union_link_list(*union_link_list*)

find_link_path(*src_link*, *target_link*)
Find paths of src_link to target_link

Parameters

- **src_link** (*skrobot.model.link.Link*) – source link.
- **target_link** (*skrobot.model.link.Link*) – target link.

Returns **ret** – If the links are connected, return Link list. Otherwise, return an empty list.

Return type List[skrobot.model.link.Link]

find_link_route(*to*, *frm=None*)

fix_leg_to_coords(*fix_coords*, *leg='both'*, *mid=0.5*)
Fix robot's legs to a coords

In the Following codes, leged robot is assumed.

Parameters

- **fix_coords** (*Coordinates*) – target coordinate
- **leg** (*string*) – ['both', 'rleg', 'rleg', 'left', 'right']
- **mid** (*float*) – ratio of legs coord.

get_transform()
Return Transform object

Returns **transform** – corrensponding Transform to this coordinates

Return type skrobot.coordinates.base.Transform

ik_convergence_check(*dif_pos*, *dif_rot*, *rotation_axis*, *translation_axis*, *thre*, *rthre*, *centroid_thre=None*, *target_centroid_pos=None*, *centroid_offset_func=None*, *cog_translation_axis=None*, *update_mass_properties=True*)

check ik convergence.

Parameters

- **dif_pos** (*list of np.ndarray*) –
- **dif_rot** (*list of np.ndarray*) –
- **translation_axis** (*list of axis*) –
- **rotation_axis** (*list of axis*) – see _wrap_axis

init_pose()

inverse_kinematics(*target_coords*, *move_target=None*, *link_list=None*, ***kwargs*)

Solve inverse kinematics.

solve inverse kinematics, move move-target to target-coords look-at- target suppots t, nil, float-vector, coords, list of float-vector, list of coords link-list is set by default based on move-target -> root link link-list.

inverse_kinematics_args(*union_link_list=None*, *rotation_axis=None*, *translation_axis=None*, *additional_jacobi_dimension=0*, ***kwargs*)

inverse_kinematics_loop(*dif_pos*, *dif_rot*, *move_target*, *link_list=None*, *target_coords=None*, ***kwargs*)

move move_target using dif_pos and dif_rot.

Parameters **TODO** –

Return type TODO

inverse_kinematics_loop_for_look_at(*move_target*, *look_at*, *link_list*, *rotation_axis='z'*, *translation_axis=False*, *rthre=0.001*, ***kwargs*)

Solve look at inverse kinematics

Parameters **look_at** (*list or np.ndarray or Coordinates*) –

inverse_kinematics_optimization(*target_coords*, *move_target=None*, *link_list=None*, *regularization_parameter=None*, *init_angle_vector=None*, *translation_axis=True*, *rotation_axis=True*, *stop=100*, *dt=0.005*, *inverse_kinematics_hook=[]*, *thre=0.001*, *rthre=0.017453292519943295*, **args*, ***kwargs*)

inverse_rotate_vector(*v*)

inverse_transform_vector(*v*)

Transform vector in world coordinates to local coordinates

Parameters **vec** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

inverse_transformation(*dest=None*)

Return a invese transformation of this coordinate system.

Create a new coordinate with inverse transformation of this coordinate system.

$$\begin{pmatrix} R^{-1} & -R^{-1}p \\ 0 & 1 \end{pmatrix}$$

Parameters **dest** (*None or skrobot.coordinates.Coordinates*) – If dest is given, the result of transformation is in-placed to dest.

Returns **dest** – result of inverse transformation.

Return type *skrobot.coordinates.Coordinates*

link_lists(*to*, *frm=None*)
Find link list from to link to frm link.

load_urdf(*urdf*)

load_urdf_file(*file_obj*)

look_at_hand(*coords*)

move_coords(*target_coords*, *local_coords*)
Transform this coordinate so that local_coords to target_coords.

Parameters

- **target_coords** (skrobot.coordinates.Coordinates) – target coords.
- **local_coords** (skrobot.coordinates.Coordinates) – local coords to be aligned.

Returns **self.worldcoords()** – world coordinates.

Return type *skrobot.coordinates.Coordinates*

move_end_pos(*pos*, *wrt='local'*, **args*, ***kwargs*)

move_end_rot(*angle*, *axis*, *wrt='local'*, **args*, ***kwargs*)

move_joints(*union_vel*, *union_link_list=None*, *periodic_time=0.05*, *joint_args=None*, *move_joints_hook=None*, **args*, ***kwargs*)

move_joints_avoidance(*union_vel*, *union_link_list=None*, *link_list=None*, *n_joint_dimension=None*, *weight=None*, *null_space=None*, *avoid_nspace_gain=0.01*, *avoid_weight_gain=1.0*, *avoid_collision_distance=200*, *avoid_collision_null_gain=1.0*, *avoid_collision_joint_gain=1.0*, *collision_avoidance_link_pair=None*, *cog_gain=0.0*, *target_centroid_pos=None*, *centroid_offset_func=None*, *cog_translation_axis='z'*, *cog_null_space=False*, *additional_weight_list=None*, *additional_nspace_list=None*, *jacobi=None*, *obstacles=None*, **args*, ***kwargs*)

newcoords(*c*, *pos=None*, *check_validity=True*)
Update this coordinates.

This function records that this CascadedCoords has changed and recursively records the change to descendants of this CascadedCoords.

Parameters

- **c** (skrobot.coordinates.Coordinates *or* *numpy.ndarray*) – If pos is *None*, *c* means new Coordinates. If pos is given, *c* means rotation matrix.
- **pos** (*numpy.ndarray or None*) – new translation.
- **check_validity** (*bool*) – If this value is *True*, check whether an input rotation and an input translation are valid.

orient_with_matrix(*rotation_matrix*, *wrt='world'*)
Force update this coordinate system's rotation.

Parameters

- **rotation_matrix** (*numpy.ndarray*) – 3x3 rotation matrix.
- **wrt** (*str or* skrobot.coordinates.Coordinates) – reference coordinates.

parent_orientation(*v*, *wrt*)

parentcoords()

reset_joint_angle_limit_weight(*union_link_list*)

reset_manip_pose()

reset_pose()

rotate(*theta*, *axis*, *wrt='local'*)

Rotate this coordinate.

Rotate this coordinate relative to axis by theta radians with respect to wrt.

Parameters

- **theta** (*float*) – radian
- **axis** (*str or numpy.ndarray*) – 'x', 'y', 'z' or vector
- **wrt** (*str or* Coordinates) –

Return type self

rotate_vector(*v*)

Rotate 3-dimensional vector using rotation of this coordinate

Parameters **v** (*numpy.ndarray*) – vector shape of (3,)

Returns **np.matmul(self.rotation, v)** – rotated vector

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from numpy import pi
>>> c = Coordinates().rotate(pi, 'z')
>>> c.rotate_vector([1, 2, 3])
array([-1., -2.,  3.])
```

rotate_with_matrix(*matrix*, *wrt*)

Rotate this coordinate by given rotation matrix.

This is a subroutine of self.rotate function.

Parameters

- **mat** (*numpy.ndarray*) – rotation matrix shape of (3, 3)
- **wrt** (*str or* skrobot.coordinates.Coordinates) – with respect to.

Returns **self**

Return type *skrobot.coordinates.Coordinates*

rpy_angle()

Return a pair of rpy angles of this coordinates.

Returns **rpy_angle(self.rotation)** – a pair of rpy angles. See also skrobot.coordinates.math.rpy_angle

Return type tuple(numpy.ndarray, numpy.ndarray)

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates().rotate(np.pi / 2.0, 'x').rotate(np.pi / 3.0, 'z')
>>> r.rpy_angle()
(array([ 3.84592537e-16, -1.04719755e+00,  1.57079633e+00]),
array([ 3.14159265, -2.0943951 , -1.57079633]))
```

self_collision_check()

Return collision link pair

Returns

- **is_collision** (*bool*) – True if a collision occurred between any pair of objects and False otherwise
- **names** (*set of 2-tuple*) – The set of pairwise collisions. Each tuple contains two names in alphabetical order indicating that the two corresponding objects are in collision.

transform(*c*, *wrt='local'*, *out=None*)

Transform this coordinates

Parameters

- **c** (skrobot.coordinates.Coordinates) – coordinates
- **wrt** (*str or* skrobot.coordinates.Coordinates) – transform this coordinates with respect to wrt. If wrt is 'local' or self, multiply c from the right. If wrt is 'parent' or self.parent, transform c with respect to parentcoords. (multiply c from the left.) If wrt is Coordinates, transform c with respect to c.
- **out** (*None or* skrobot.coordinates.Coordinates) – If the *out* is specified, set new coordinates to *out*. Note that if the *out* is given, these coordinates don't change.

Returns **self** – return self

Return type *skrobot.coordinates.CascadedCoords*

transform_vector(*v*)

"Return vector represented at world frame.

Vector v given in the local coords is converted to world representation.

Parameters **v** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

transformation(*c2*, *wrt='local'*)

translate(*vec*, *wrt='local'*)

Translate this coordinates.

Note that this function changes this coordinates self. So if you don't want to change this class, use copy_worldcoords()

Parameters

- **vec** (*list or numpy.ndarray*) – shape of (3,) translation vector. unit is [m] order.
- **wrt** (*str or* Coordinates *(optional)*) – translate with respect to wrt.

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.], dtype=float32)
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3], dtype=float32)
```

```
>>> c = Coordinates()
>>> c.copy_worldcoords().translate([0.1, 0.2, 0.3])
>>> c.translation
array([0., 0., 0.], dtype=float32)
```

```
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([ 0.3,  0.2, -0.1])
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3], 'world')
>>> c.translation
array([0.1, 0.2, 0.3])
```

update(*force=False*)

worldcoords()
Calculate rotation and position in the world.

worldpos()
Return translation of this coordinate

See also skrobot.coordinates.Coordinates.translation

Returns **self.translation** – translation of this coordinate

Return type numpy.ndarray

worldrot()
Return rotation of this coordinate

See also skrobot.coordinates.Coordinates.rotation

Returns **self.rotation** – rotation matrix of this coordinate

Return type numpy.ndarray

__eq__(*value*, /)
Return self==value.

__ne__(*value*, /)
Return self!=value.

__lt__(*value*, /)
Return self<value.

__le__(*value*, /)
Return self<=value.

`__gt__`(*value*, */*)
Return self>value.

`__ge__`(*value*, */*)
Return self>=value.

`__mul__`(*other_c*)
Return Transformed Coordinates.

Note that this function creates new Coordinates and does not change translation and rotation, unlike transform function.

Parameters `other_c` (`skrobot.coordinates.Coordinates`) – input coordinates.

Returns **out** – transformed coordinates multiplied other_c from the right. T = T_{self} T_{other_c}.

Return type *skrobot.coordinates.Coordinates*

`__pow__`(*exponent*)
Return exponential homogeneous matrix.

If exponent equals -1, return inverse transformation of this coords.

Parameters `exponent` (*numbers.Number*) – exponent value. If exponent equals -1, return inverse transformation of this coords. In current, support only -1 case.

Returns **out** – output.

Return type *skrobot.coordinates.Coordinates*

Attributes

`descendants`

`dimension`
Return dimension of this coordinate

Returns **len(self.translation)** – dimension of this coordinate

Return type int

`dual_quaternion`
Property of DualQuaternion

Return DualQuaternion representation of this coordinate.

Returns **DualQuaternion** – DualQuaternion representation of this coordinate

Return type *skrobot.coordinates.dual_quaternion.DualQuaternion*

`interlocking_joint_pairs`
Interlocking joint pairs.

pairs are [(joint0, joint1), ...] If users want to use interlocking joints, please overwrite this method.

`joint_max_angles`

`joint_min_angles`

`larm`

`lleg`

`name`
Return this coordinate's name

Returns **self._name** – name of this coordinate

Return type str

parent

quaternion

Property of quaternion

Returns **q** – [w, x, y, z] quaternion

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.quaternion
array([1., 0., 0., 0.])
>>> c.rotate(pi / 3, 'y').rotate(pi / 5, 'z')
>>> c.quaternion
array([0.8236391 , 0.1545085 , 0.47552826, 0.26761657])
```

rarm

rleg

rotation

Return rotation matrix of this coordinates.

Returns **self._rotation** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.rotation
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> c.rotate(np.pi / 2.0, 'y')
>>> c.rotation
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16]])
```

translation

Return translation of this coordinates.

Returns **self._translation** – vector shape of (3,). unit is [m]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3])
```

x_axis
Return x axis vector of this coordinates.

Returns **axis** – x axis.

Return type numpy.ndarray

y_axis
Return y axis vector of this coordinates.

Returns **axis** – y axis.

Return type numpy.ndarray

z_axis
Return z axis vector of this coordinates.

Returns **axis** – z axis.

Return type numpy.ndarray

3.2.2 Robot Model classes

You can create use robot model classes. Here is a example of robot models.

Fetch

skrobot.models.fetch.Fetch	Fetch Robot Model.

skrobot.models.fetch.Fetch

class skrobot.models.fetch.**Fetch**(**args*, ***kwargs*)
Fetch Robot Model.

http://docs.fetchrobotics.com/robot_hardware.html

Methods

T()

Return 4x4 homogeneous transformation matrix.

Returns **matrix** – homogeneous transformation matrix shape of (4, 4)

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.T()
array([[1., 0., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 0., 0., 1.]])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.rotate(pi / 2.0, 'y')
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00,
         1.00000000e-01],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00,
         2.00000000e-01],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16,
         3.00000000e-01],
       [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
         1.00000000e+00]])
```

angle_vector(*av=None*, *return_av=None*)

Returns angle vector

If av is given, it updates angles of all joint. If given av violate min/max range, the value is modified.

assoc(*child*, *relative_coords='world'*, *force=False*, ***kwargs*)

Associate child coords to this coordinate system.

If *relative_coords* is *None* or 'world', the translation and rotation of childcoords in the world coordinate system do not change. If *relative_coords* is specified, childcoords is assoced at translation and rotation of *relative_coords*. By default, if child is already assoced to some other coords, raise an exception. But if *force* is *True*, you can overwrite the existing assoc relation.

Parameters

- **child** (CascadedCoords) – child coordinates.
- **relative_coords** (*None or* Coordinates *or str*) – child coordinates' relative coordinates.
- **force** (*bool*) – predicate for overwriting the existing assoc-relation

Returns **child** – assoced child.

Return type *CascadedCoords*

Examples

```
>>> from skrobot.coordinates import CascadedCoords
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords)
#<CascadedCoords 0x7f1d30e29510 1.000 1.000 0.000 / 0.0 -0.0 0.0>
>>> child_coords.worldpos()
array([1., 1., 0.])
>>> child_coords.translation
array([0., 1., 0.])
```

None and 'world' have the same meaning.

```
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords, relative_coords='world')
#<CascadedCoords 0x7f1d30e29510 1.000 1.000 0.000 / 0.0 -0.0 0.0>
>>> child_coords.worldpos()
array([1., 1., 0.])
```

If *relative_coords* is 'local', *child* is associated at world translation and world rotation of *child* from this coordinate system.

```
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords, relative_coords='local')
>>> child_coords.worldpos()
array([2., 1., 0.])
>>> child_coords.translation
array([1., 1., 0.])
```

axis(*ax*)

calc_inverse_jacobian(*jacobi*, *manipulability_limit=0.1*, *manipulability_gain=0.001*, *weight=None*, **args*, ***kwargs*)

calc_inverse_kinematics_nspace_from_link_list(*link_list*, *avoid_nspace_gain=0.01*, *union_link_list=None*, *n_joint_dimension=None*, *null_space=None*, *additional_nspace_list=None*, *weight=None*)

calc_inverse_kinematics_weight_from_link_list(*link_list*, *avoid_weight_gain=1.0*, *union_link_list=None*, *n_joint_dimension=None*, *weight=None*, *additional_weight_list=[]*)

Calculate all weight from link list.

calc_jacobian_for_interlocking_joints(*link_list*, *interlocking_joint_pairs=None*)

calc_jacobian_from_link_list(*move_target*, *link_list=None*, *transform_coords=None*, *rotation_axis=None*, *translation_axis=None*, *col_offset=0*, *dim=None*, *jacobian=None*, *additional_jacobi_dimension=0*, *n_joint_dimension=None*, **args*, ***kwargs*)

calc_joint_angle_from_min_max_table(*index*, *j*, *av*)

calc_joint_angle_speed(*union_vel*, *angle_speed=None*, *angle_speed_blending=0.5*, *jacobi=None*, *j_sharp=None*, *null_space=None*, **args*, ***kwargs*)

calc_joint_angle_speed_gain(*union_link_list*, *dav*, *periodic_time*)

calc_nspace_from_joint_limit(*avoid_nspace_gain*, *union_link_list*, *weight*)
Calculate null-space according to joint limit.

calc_target_axis_dimension(*rotation_axis*, *translation_axis*)
rotation-axis, translation-axis -> both list and atom OK.

calc_target_joint_dimension(*link_list*)

calc_union_link_list(*link_list*)

calc_vel_for_interlocking_joints(*link_list*, *interlocking_joint_pairs=None*)
Calculate 0 velocity for keeping interlocking joint.

at the same joint angle.

calc_vel_from_pos(*dif_pos*, *translation_axis*, *p_limit=100.0*)
Calculate velocity from difference position

Parameters

- **dif_pos** (*np.ndarray*) – [m] order
- **translation_axis** (*str*) – see calc_dif_with_axis

Returns **vel_p**

Return type np.ndarray

calc_vel_from_rot(*dif_rot*, *rotation_axis*, *r_limit=0.5*)

calc_weight_from_joint_limit(*avoid_weight_gain*, *link_list*, *union_link_list*, *weight*, *n_joint_dimension=None*)
Calculate weight according to joint limit.

changed()
Return False

This is used for CascadedCoords compatibility

Returns **False** – always return False

Return type bool

collision_avoidance_link_pair_from_link_list(*link_list*, *obstacles=None*)

compute_qp_common(*target_coords*, *move_target*, *dt*, *link_list=None*, *gain=0.85*, *weight=1.0*, *translation_axis=True*, *rotation_axis=True*, *dof_limit_gain=0.5*)

compute_velocity(*target_coords*, *move_target*, *dt*, *link_list=None*, *gain=0.85*, *weight=1.0*, *translation_axis=True*, *rotation_axis=True*, *dof_limit_gain=0.5*, *fast=True*, *sym_proj=False*, *solver='cvxopt'*, **args*, ***kwargs*)

coords()
Return a deep copy of the Coordinates.

copy()
Return a deep copy of the Coordinates.

copy_coords()
Return a deep copy of the Coordinates.

copy_worldcoords()
Return a deep copy of the Coordinates.

difference_position(*coords*, *translation_axis=True*)

Return differences in positoin of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **translation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xy', 'yz', 'zx', 'xx', 'yy', 'zz', True or False(None).

Returns **dif_pos** – difference position of self coordinates and coords considering translation_axis.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates import transform_coords
>>> from numpy import pi
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(
...         pi / 3.0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...         pi / 2.0, 'y')
>>> c1.difference_position(c2)
array([ 0.2       , -0.42320508,  0.3330127 ])
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...         pi / 3.0, 'x')
>>> c1.difference_position(c2)
array([ 0.2, -0.5, -0.2])
```

difference_rotation(*coords*, *rotation_axis=True*)

Return differences in rotation of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **rotation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xx', 'yy', 'zz', 'xm', 'ym', 'zm', 'xy', 'yx', 'yz', 'zy', 'zx', 'xz', True or False(None).

Returns **dif_rot** – difference rotation of self coordinates and coords considering rotation_axis.

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates.math import rpy_matrix
>>> coord1 = Coordinates()
>>> coord2 = Coordinates(rot=rpy_matrix(pi / 2.0, pi / 3.0, pi / 5.0))
>>> coord1.difference_rotation(coord2)
array([-0.32855112,  1.17434985,  1.05738936])
>>> coord1.difference_rotation(coord2, rotation_axis=False)
```

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```
array([0, 0, 0])
>>> coord1.difference_rotation(coord2, rotation_axis='x')
array([0.        , 1.36034952, 0.78539816])
>>> coord1.difference_rotation(coord2, rotation_axis='y')
array([0.35398131, 0.        , 0.97442695])
>>> coord1.difference_rotation(coord2, rotation_axis='z')
array([-0.88435715,  0.74192175,  0.        ])
```

Using mirror option [‘xm’, ‘ym’, ‘zm’], you can allow differences of mirror direction.

```
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-2.99951957e-32,  0.00000000e+00,  0.00000000e+00])
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi / 2.0, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-1.57079633,  0.        ,  0.        ])
```

disable_hook()

dissoc(*child*)

find_joint_angle_limit_weight_from_union_link_list(*union_link_list*)

find_link_path(*src_link*, *target_link*)

Find paths of src_link to target_link

Parameters

- **src_link** (*skrobot.model.link.Link*) – source link.
- **target_link** (*skrobot.model.link.Link*) – target link.

Returns **ret** – If the links are connected, return Link list. Otherwise, return an empty list.

Return type List[skrobot.model.link.Link]

find_link_route(*to*, *frm=None*)

fix_leg_to_coords(*fix_coords*, *leg='both'*, *mid=0.5*)

Fix robot’s legs to a coords

In the Following codes, leged robot is assumed.

Parameters

- **fix_coords** (Coordinates) – target coordinate
- **leg** (*string*) – [‘both’, ‘rleg’, ‘rleg’, ‘left’, ‘right’]
- **mid** (*float*) – ratio of legs coord.

get_transform()

Return Transform object

Returns **transform** – corrensponding Transform to this coordinates

Return type skrobot.coordinates.base.Transform

ik_convergence_check(*dif_pos*, *dif_rot*, *rotation_axis*, *translation_axis*, *thre*, *rthre*, *centroid_thre=None*, *target_centroid_pos=None*, *centroid_offset_func=None*, *cog_translation_axis=None*, *update_mass_properties=True*)

check ik convergence.

Parameters

- **dif_pos** (*list of np.ndarray*) –
- **dif_rot** (*list of np.ndarray*) –
- **translation_axis** (*list of axis*) –
- **rotation_axis** (*list of axis*) – see _wrap_axis

init_pose()

inverse_kinematics(*target_coords*, *move_target=None*, *link_list=None*, ***kwargs*)

Solve inverse kinematics.

solve inverse kinematics, move move-target to target-coords look-at- target suppots t, nil, float-vector, coords, list of float-vector, list of coords link-list is set by default based on move-target -> root link link-list.

inverse_kinematics_args(*union_link_list=None*, *rotation_axis=None*, *translation_axis=None*, *additional_jacobi_dimension=0*, ***kwargs*)

inverse_kinematics_loop(*dif_pos*, *dif_rot*, *move_target*, *link_list=None*, *target_coords=None*, ***kwargs*)

move move_target using dif_pos and dif_rot.

Parameters **TODO** –

Return type TODO

inverse_kinematics_loop_for_look_at(*move_target*, *look_at*, *link_list*, *rotation_axis='z'*, *translation_axis=False*, *rthre=0.001*, ***kwargs*)

Solve look at inverse kinematics

Parameters **look_at** (*list or np.ndarray or Coordinates*) –

inverse_kinematics_optimization(*target_coords*, *move_target=None*, *link_list=None*, *regularization_parameter=None*, *init_angle_vector=None*, *translation_axis=True*, *rotation_axis=True*, *stop=100*, *dt=0.005*, *inverse_kinematics_hook=[]*, *thre=0.001*, *rthre=0.017453292519943295*, **args*, ***kwargs*)

inverse_rotate_vector(*v*)

inverse_transform_vector(*v*)

Transform vector in world coordinates to local coordinates

Parameters **vec** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

inverse_transformation(*dest=None*)

Return a invese transformation of this coordinate system.

Create a new coordinate with inverse transformation of this coordinate system.

$$\begin{pmatrix} R^{-1} & -R^{-1}p \\ 0 & 1 \end{pmatrix}$$

Parameters **dest** (*None or skrobot.coordinates.Coordinates*) – If dest is given, the result of transformation is in-placed to dest.

Returns **dest** – result of inverse transformation.

Return type *skrobot.coordinates.Coordinates*

`link_lists`(*to*, *frm=None*)
Find link list from to link to frm link.

`load_urdf`(*urdf*)

`load_urdf_file`(*file_obj*)

`look_at_hand`(*coords*)

`move_coords`(*target_coords*, *local_coords*)
Transform this coordinate so that local_coords to target_coords.

Parameters

- **target_coords** (`skrobot.coordinates.Coordinates`) – target coords.
- **local_coords** (`skrobot.coordinates.Coordinates`) – local coords to be aligned.

Returns **self.worldcoords()** – world coordinates.

Return type *skrobot.coordinates.Coordinates*

`move_end_pos`(*pos*, *wrt='local'*, **args*, ***kwargs*)

`move_end_rot`(*angle*, *axis*, *wrt='local'*, **args*, ***kwargs*)

`move_joints`(*union_vel*, *union_link_list=None*, *periodic_time=0.05*, *joint_args=None*, *move_joints_hook=None*, **args*, ***kwargs*)

`move_joints_avoidance`(*union_vel*, *union_link_list=None*, *link_list=None*, *n_joint_dimension=None*, *weight=None*, *null_space=None*, *avoid_nspace_gain=0.01*, *avoid_weight_gain=1.0*, *avoid_collision_distance=200*, *avoid_collision_null_gain=1.0*, *avoid_collision_joint_gain=1.0*, *collision_avoidance_link_pair=None*, *cog_gain=0.0*, *target_centroid_pos=None*, *centroid_offset_func=None*, *cog_translation_axis='z'*, *cog_null_space=False*, *additional_weight_list=None*, *additional_nspace_list=None*, *jacobi=None*, *obstacles=None*, **args*, ***kwargs*)

`newcoords`(*c*, *pos=None*, *check_validity=True*)
Update this coordinates.

This function records that this CascadedCoords has changed and recursively records the change to descendants of this CascadedCoords.

Parameters

- **c** (`skrobot.coordinates.Coordinates` *or* *numpy.ndarray*) – If pos is *None*, *c* means new Coordinates. If pos is given, *c* means rotation matrix.
- **pos** (*numpy.ndarray* *or* *None*) – new translation.
- **check_validity** (*bool*) – If this value is *True*, check whether an input rotation and an input translation are valid.

`orient_with_matrix`(*rotation_matrix*, *wrt='world'*)
Force update this coordinate system's rotation.

Parameters

- **rotation_matrix** (*numpy.ndarray*) – 3x3 rotation matrix.
- **wrt** (*str* *or* `skrobot.coordinates.Coordinates`) – reference coordinates.

parent_orientation(*v*, *wrt*)

parentcoords()

reset_joint_angle_limit_weight(*union_link_list*)

reset_manip_pose()

reset_pose()

rotate(*theta*, *axis*, *wrt='local'*)

Rotate this coordinate.

Rotate this coordinate relative to axis by theta radians with respect to wrt.

Parameters

- **theta** (*float*) – radian
- **axis** (*str or numpy.ndarray*) – 'x', 'y', 'z' or vector
- **wrt** (*str or* Coordinates) –

Return type self

rotate_vector(*v*)

Rotate 3-dimensional vector using rotation of this coordinate

Parameters **v** (*numpy.ndarray*) – vector shape of (3,)

Returns **np.matmul(self.rotation, v)** – rotated vector

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from numpy import pi
>>> c = Coordinates().rotate(pi, 'z')
>>> c.rotate_vector([1, 2, 3])
array([-1., -2.,  3.])
```

rotate_with_matrix(*matrix*, *wrt*)

Rotate this coordinate by given rotation matrix.

This is a subroutine of self.rotate function.

Parameters

- **mat** (*numpy.ndarray*) – rotation matrix shape of (3, 3)
- **wrt** (*str or* skrobot.coordinates.Coordinates) – with respect to.

Returns **self**

Return type *skrobot.coordinates.Coordinates*

rpy_angle()

Return a pair of rpy angles of this coordinates.

Returns **rpy_angle(self.rotation)** – a pair of rpy angles. See also skrobot.coordinates.math.rpy_angle

Return type tuple(numpy.ndarray, numpy.ndarray)

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates().rotate(np.pi / 2.0, 'x').rotate(np.pi / 3.0, 'z')
>>> r.rpy_angle()
(array([ 3.84592537e-16, -1.04719755e+00,  1.57079633e+00]),
array([ 3.14159265, -2.0943951 , -1.57079633]))
```

self_collision_check()

Return collision link pair

Returns

- **is_collision** (*bool*) – True if a collision occurred between any pair of objects and False otherwise
- **names** (*set of 2-tuple*) – The set of pairwise collisions. Each tuple contains two names in alphabetical order indicating that the two corresponding objects are in collision.

transform(*c*, *wrt='local'*, *out=None*)

Transform this coordinates

Parameters

- **c** (`skrobot.coordinates.Coordinates`) – coordinates
- **wrt** (*str or* `skrobot.coordinates.Coordinates`) – transform this coordinates with respect to wrt. If wrt is 'local' or self, multiply c from the right. If wrt is 'parent' or self.parent, transform c with respect to parentcoords. (multiply c from the left.) If wrt is Coordinates, transform c with respect to c.
- **out** (*None or* `skrobot.coordinates.Coordinates`) – If the *out* is specified, set new coordinates to *out*. Note that if the *out* is given, these coordinates don't change.

Returns **self** – return self

Return type *skrobot.coordinates.CascadedCoords*

transform_vector(*v*)

"Return vector represented at world frame.

Vector v given in the local coords is converted to world representation.

Parameters **v** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

transformation(*c2*, *wrt='local'*)

translate(*vec*, *wrt='local'*)

Translate this coordinates.

Note that this function changes this coordinates self. So if you don't want to change this class, use copy_worldcoords()

Parameters

- **vec** (*list or numpy.ndarray*) – shape of (3,) translation vector. unit is [m] order.
- **wrt** (*str or* `Coordinates` *(optional)*) – translate with respect to wrt.

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.], dtype=float32)
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3], dtype=float32)
```

```
>>> c = Coordinates()
>>> c.copy_worldcoords().translate([0.1, 0.2, 0.3])
>>> c.translation
array([0., 0., 0.], dtype=float32)
```

```
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([ 0.3,  0.2, -0.1])
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3], 'world')
>>> c.translation
array([0.1, 0.2, 0.3])
```

update(*force=False*)

worldcoords()
Calculate rotation and position in the world.

worldpos()
Return translation of this coordinate

See also skrobot.coordinates.Coordinates.translation

Returns **self.translation** – translation of this coordinate

Return type numpy.ndarray

worldrot()
Return rotation of this coordinate

See also skrobot.coordinates.Coordinates.rotation

Returns **self.rotation** – rotation matrix of this coordinate

Return type numpy.ndarray

__eq__(*value*, */*)
Return self==value.

__ne__(*value*, */*)
Return self!=value.

__lt__(*value*, */*)
Return self<value.

__le__(*value*, */*)
Return self<=value.

`__gt__`(*value*, */*)
Return self>value.

`__ge__`(*value*, */*)
Return self>=value.

`__mul__`(*other_c*)
Return Transformed Coordinates.

Note that this function creates new Coordinates and does not change translation and rotation, unlike transform function.

Parameters `other_c` (`skrobot.coordinates.Coordinates`) – input coordinates.

Returns **out** – transformed coordinates multiplied other_c from the right. T = T_{self} T_{other_c}.

Return type *skrobot.coordinates.Coordinates*

`__pow__`(*exponent*)
Return exponential homogeneous matrix.

If exponent equals -1, return inverse transformation of this coords.

Parameters `exponent` (*numbers.Number*) – exponent value. If exponent equals -1, return inverse transformation of this coords. In current, support only -1 case.

Returns **out** – output.

Return type *skrobot.coordinates.Coordinates*

Attributes

`default_urdf_path`

`descendants`

`dimension`
Return dimension of this coordinate

Returns **len(self.translation)** – dimension of this coordinate

Return type int

`dual_quaternion`
Property of DualQuaternion

Return DualQuaternion representation of this coordinate.

Returns **DualQuaternion** – DualQuaternion representation of this coordinate

Return type *skrobot.coordinates.dual_quaternion.DualQuaternion*

`interlocking_joint_pairs`
Interlocking joint pairs.

pairs are [(joint0, joint1), . . .] If users want to use interlocking joints, please overwrite this method.

`joint_max_angles`

`joint_min_angles`

`larm`

`lleg`

name
Return this coordinate's name

Returns **self._name** – name of this coordinate

Return type str

parent

quaternion
Property of quaternion

Returns **q** – [w, x, y, z] quaternion

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.quaternion
array([1., 0., 0., 0.])
>>> c.rotate(pi / 3, 'y').rotate(pi / 5, 'z')
>>> c.quaternion
array([0.8236391 , 0.1545085 , 0.47552826, 0.26761657])
```

rarm

rleg

rotation
Return rotation matrix of this coordinates.

Returns **self._rotation** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.rotation
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> c.rotate(np.pi / 2.0, 'y')
>>> c.rotation
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16]])
```

translation
Return translation of this coordinates.

Returns **self._translation** – vector shape of (3,). unit is [m]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3])
```

x_axis
Return x axis vector of this coordinates.

Returns **axis** – x axis.

Return type numpy.ndarray

y_axis
Return y axis vector of this coordinates.

Returns **axis** – y axis.

Return type numpy.ndarray

z_axis
Return z axis vector of this coordinates.

Returns **axis** – z axis.

Return type numpy.ndarray

Kuka

skrobot.models.kuka.Kuka	Kuka Robot Model.

skrobot.models.kuka.Kuka

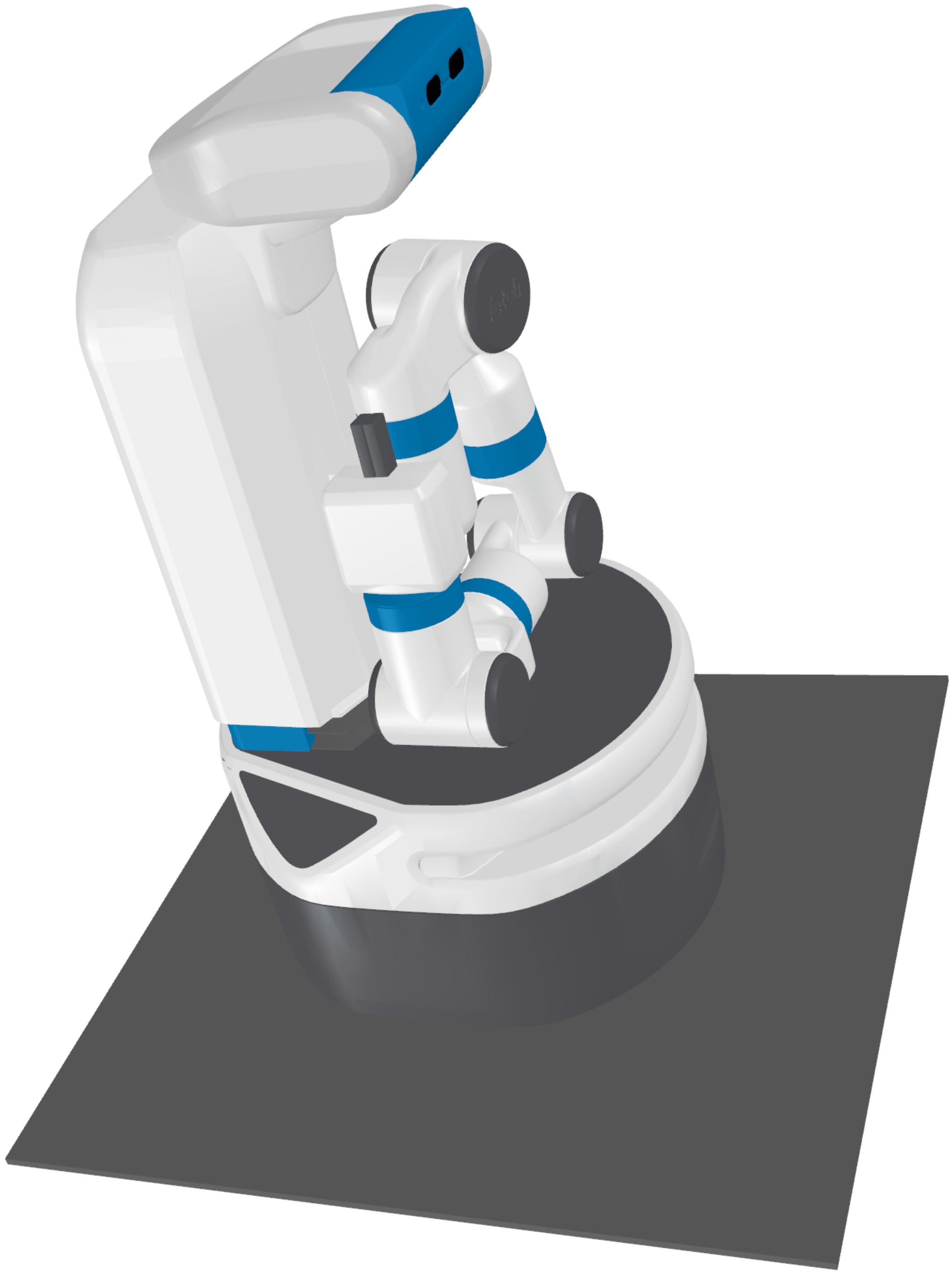
class skrobot.models.kuka.**Kuka**(**args*, ***kwargs*)
Kuka Robot Model.

Methods

T()
Return 4x4 homogeneous transformation matrix.

Returns **matrix** – homogeneous transformation matrix shape of (4, 4)

Return type numpy.ndarray



Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.T()
array([[1., 0., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 0., 0., 1.]])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.rotate(pi / 2.0, 'y')
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00,
         1.00000000e-01],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00,
         2.00000000e-01],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16,
         3.00000000e-01],
       [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
         1.00000000e+00]])
```

angle_vector(*av=None*, *return_av=None*)

Returns angle vector

If av is given, it updates angles of all joint. If given av violate min/max range, the value is modified.

assoc(*child*, *relative_coords='world'*, *force=False*, ***kwargs*)

Associate child coords to this coordinate system.

If *relative_coords* is *None* or 'world', the translation and rotation of childcoords in the world coordinate system do not change. If *relative_coords* is specified, childcoords is assoced at translation and rotation of *relative_coords*. By default, if child is already assoced to some other coords, raise an exception. But if *force* is *True*, you can overwrite the existing assoc relation.

Parameters

- **child** (CascadedCoords) – child coordinates.
- **relative_coords** (*None or* Coordinates *or str*) – child coordinates' relative coordinates.
- **force** (*bool*) – predicate for overwriting the existing assoc-relation

Returns child – assoced child.

Return type *CascadedCoords*

Examples

```
>>> from skrobot.coordinates import CascadedCoords
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords)
#<CascadedCoords 0x7f1d30e29510 1.000 1.000 0.000 / 0.0 -0.0 0.0>
>>> child_coords.worldpos()
array([1., 1., 0.])
```

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```
>>> child_coords.translation
array([0., 1., 0.])
```

None and 'world' have the same meaning.

```
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords, relative_coords='world')
#<CascadedCoords 0x7f1d30e29510 1.000 1.000 0.000 / 0.0 -0.0 0.0>
>>> child_coords.worldpos()
array([1., 1., 0.])
```

If *relative_coords* is 'local', *child* is associated at world translation and world rotation of *child* from this coordinate system.

```
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords, relative_coords='local')
>>> child_coords.worldpos()
array([2., 1., 0.])
>>> child_coords.translation
array([1., 1., 0.])
```

axis(*ax*)

calc_inverse_jacobian(*jacobi*, *manipulability_limit=0.1*, *manipulability_gain=0.001*, *weight=None*, **args*, ***kwargs*)

calc_inverse_kinematics_nspace_from_link_list(*link_list*, *avoid_nspace_gain=0.01*, *union_link_list=None*, *n_joint_dimension=None*, *null_space=None*, *additional_nspace_list=None*, *weight=None*)

calc_inverse_kinematics_weight_from_link_list(*link_list*, *avoid_weight_gain=1.0*, *union_link_list=None*, *n_joint_dimension=None*, *weight=None*, *additional_weight_list=[ ]*)

Calculate all weight from link list.

calc_jacobian_for_interlocking_joints(*link_list*, *interlocking_joint_pairs=None*)

calc_jacobian_from_link_list(*move_target*, *link_list=None*, *transform_coords=None*, *rotation_axis=None*, *translation_axis=None*, *col_offset=0*, *dim=None*, *jacobian=None*, *additional_jacobi_dimension=0*, *n_joint_dimension=None*, **args*, ***kwargs*)

calc_joint_angle_from_min_max_table(*index*, *j*, *av*)

calc_joint_angle_speed(*union_vel*, *angle_speed=None*, *angle_speed_blending=0.5*, *jacobi=None*, *j_sharp=None*, *null_space=None*, **args*, ***kwargs*)

calc_joint_angle_speed_gain(*union_link_list*, *dav*, *periodic_time*)

calc_nspace_from_joint_limit(*avoid_nspace_gain*, *union_link_list*, *weight*)

Calculate null-space according to joint limit.

calc_target_axis_dimension(*rotation_axis*, *translation_axis*)

rotation-axis, translation-axis -> both list and atom OK.

calc_target_joint_dimension(*link_list*)

calc_union_link_list(*link_list*)

calc_vel_for_interlocking_joints(*link_list*, *interlocking_joint_pairs=None*)
Calculate 0 velocity for keeping interlocking joint.

at the same joint angle.

calc_vel_from_pos(*dif_pos*, *translation_axis*, *p_limit=100.0*)
Calculate velocity from difference position

Parameters

- **dif_pos** (*np.ndarray*) – [m] order
- **translation_axis** (*str*) – see calc_dif_with_axis

Returns vel_p

Return type np.ndarray

calc_vel_from_rot(*dif_rot*, *rotation_axis*, *r_limit=0.5*)

calc_weight_from_joint_limit(*avoid_weight_gain*, *link_list*, *union_link_list*, *weight*, *n_joint_dimension=None*)
Calculate weight according to joint limit.

changed()
Return False

This is used for CascadedCoords compatibility

Returns **False** – always return False

Return type bool

close_hand(*av=None*)

collision_avoidance_link_pair_from_link_list(*link_list*, *obstacles=None*)

compute_qp_common(*target_coords*, *move_target*, *dt*, *link_list=None*, *gain=0.85*, *weight=1.0*, *translation_axis=True*, *rotation_axis=True*, *dof_limit_gain=0.5*)

compute_velocity(*target_coords*, *move_target*, *dt*, *link_list=None*, *gain=0.85*, *weight=1.0*, *translation_axis=True*, *rotation_axis=True*, *dof_limit_gain=0.5*, *fast=True*, *sym_proj=False*, *solver='cvxopt'*, **args*, ***kwargs*)

coords()
Return a deep copy of the Coordinates.

copy()
Return a deep copy of the Coordinates.

copy_coords()
Return a deep copy of the Coordinates.

copy_worldcoords()
Return a deep copy of the Coordinates.

difference_position(*coords*, *translation_axis=True*)
Return differences in positoin of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **translation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xy', 'yz', 'zx', 'xx', 'yy', 'zz', True or False(None).

Returns **dif_pos** – difference position of self coordinates and coords considering translation_axis.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates import transform_coords
>>> from numpy import pi
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(
...         pi / 3.0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...         pi / 2.0, 'y')
>>> c1.difference_position(c2)
array([ 0.2       , -0.42320508,  0.3330127 ])
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...         pi / 3.0, 'x')
>>> c1.difference_position(c2)
array([ 0.2, -0.5, -0.2])
```

`difference_rotation`(*coords*, *rotation_axis=True*)
Return differences in rotation of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **rotation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xx', 'yy', 'zz', 'xm', 'ym', 'zm', 'xy', 'yx', 'yz', 'zy', 'zx', 'xz', True or False(None).

Returns **dif_rot** – difference rotation of self coordinates and coords considering rotation_axis.

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates.math import rpy_matrix
>>> coord1 = Coordinates()
>>> coord2 = Coordinates(rot=rpy_matrix(pi / 2.0, pi / 3.0, pi / 5.0))
>>> coord1.difference_rotation(coord2)
array([-0.32855112,  1.17434985,  1.05738936])
>>> coord1.difference_rotation(coord2, rotation_axis=False)
array([0, 0, 0])
>>> coord1.difference_rotation(coord2, rotation_axis='x')
array([0.        , 1.36034952, 0.78539816])
>>> coord1.difference_rotation(coord2, rotation_axis='y')
array([0.35398131, 0.        , 0.97442695])
>>> coord1.difference_rotation(coord2, rotation_axis='z')
array([-0.88435715,  0.74192175,  0.        ])
```

Using mirror option ['xm', 'ym', 'zm'], you can allow differences of mirror direction.

```
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-2.99951957e-32,  0.00000000e+00,  0.00000000e+00])
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi / 2.0, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-1.57079633,  0.        ,  0.        ])
```

disable_hook()

dissoc(*child*)

find_joint_angle_limit_weight_from_union_link_list(*union_link_list*)

find_link_path(*src_link*, *target_link*)

Find paths of src_link to target_link

Parameters

- **src_link** (*skrobot.model.link.Link*) – source link.
- **target_link** (*skrobot.model.link.Link*) – target link.

Returns **ret** – If the links are connected, return Link list. Otherwise, return an empty list.

Return type List[skrobot.model.link.Link]

find_link_route(*to*, *frm=None*)

fix_leg_to_coords(*fix_coords*, *leg='both'*, *mid=0.5*)

Fix robot's legs to a coords

In the Following codes, leged robot is assumed.

Parameters

- **fix_coords** (Coordinates) – target coordinate
- **leg** (*string*) – ['both', 'rleg', 'rleg', 'left', 'right']
- **mid** (*float*) – ratio of legs coord.

get_transform()

Return Transform object

Returns **transform** – cornesponding Transform to this coordinates

Return type skrobot.coordinates.base.Transform

ik_convergence_check(*dif_pos*, *dif_rot*, *rotation_axis*, *translation_axis*, *thre*, *rthre*, *centroid_thre=None*, *target_centroid_pos=None*, *centroid_offset_func=None*, *cog_translation_axis=None*, *update_mass_properties=True*)

check ik convergence.

Parameters

- **dif_pos** (*list of np.ndarray*) –
- **dif_rot** (*list of np.ndarray*) –
- **translation_axis** (*list of axis*) –
- **rotation_axis** (*list of axis*) – see _wrap_axis

init_pose()

inverse_kinematics(*target_coords*, *move_target=None*, *link_list=None*, ***kwargs*)
Solve inverse kinematics.

solve inverse kinematics, move move-target to target-coords look-at- target suppots t, nil, float-vector, coords, list of float-vector, list of coords link-list is set by default based on move-target -> root link link-list.

inverse_kinematics_args(*union_link_list=None*, *rotation_axis=None*, *translation_axis=None*, *additional_jacobi_dimension=0*, ***kwargs*)

inverse_kinematics_loop(*dif_pos*, *dif_rot*, *move_target*, *link_list=None*, *target_coords=None*, ***kwargs*)
move move_target using dif_pos and dif_rot.

Parameters TODO –

Return type TODO

inverse_kinematics_loop_for_look_at(*move_target*, *look_at*, *link_list*, *rotation_axis='z'*, *translation_axis=False*, *rthre=0.001*, ***kwargs*)
Solve look at inverse kinematics

Parameters **look_at** (*list or np.ndarray or* Coordinates) –

inverse_kinematics_optimization(*target_coords*, *move_target=None*, *link_list=None*, *regularization_parameter=None*, *init_angle_vector=None*, *translation_axis=True*, *rotation_axis=True*, *stop=100*, *dt=0.005*, *inverse_kinematics_hook=[]*, *thre=0.001*, *rthre=0.017453292519943295*, **args*, ***kwargs*)

inverse_rotate_vector(*v*)

inverse_transform_vector(*v*)
Transform vector in world coordinates to local coordinates

Parameters **vec** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

inverse_transformation(*dest=None*)
Return a invese transformation of this coordinate system.

Create a new coordinate with inverse transformation of this coordinate system.

$$\begin{pmatrix} R^{-1} & -R^{-1}p \\ 0 & 1 \end{pmatrix}$$

Parameters **dest** (*None or* skrobot.coordinates.Coordinates) – If dest is given, the result of transformation is in-placed to dest.

Returns **dest** – result of inverse transformation.

Return type *skrobot.coordinates.Coordinates*

link_lists(*to*, *frm=None*)
Find link list from to link to frm link.

load_urdf(*urdf*)

load_urdf_file(*file_obj*)

look_at_hand(*coords*)

move_coords(*target_coords*, *local_coords*)
Transform this coordinate so that local_coords to target_coords.

Parameters

- **target_coords** (skrobot.coordinates.Coordinates) – target coords.
- **local_coords** (skrobot.coordinates.Coordinates) – local coords to be aligned.

Returns **self.worldcoords()** – world coordinates.

Return type *skrobot.coordinates.Coordinates*

move_end_pos(*pos*, *wrt='local'*, **args*, ***kwargs*)

move_end_rot(*angle*, *axis*, *wrt='local'*, **args*, ***kwargs*)

move_joints(*union_vel*, *union_link_list=None*, *periodic_time=0.05*, *joint_args=None*, *move_joints_hook=None*, **args*, ***kwargs*)

move_joints_avoidance(*union_vel*, *union_link_list=None*, *link_list=None*, *n_joint_dimension=None*, *weight=None*, *null_space=None*, *avoid_nspace_gain=0.01*, *avoid_weight_gain=1.0*, *avoid_collision_distance=200*, *avoid_collision_null_gain=1.0*, *avoid_collision_joint_gain=1.0*, *collision_avoidance_link_pair=None*, *cog_gain=0.0*, *target_centroid_pos=None*, *centroid_offset_func=None*, *cog_translation_axis='z'*, *cog_null_space=False*, *additional_weight_list=None*, *additional_nspace_list=None*, *jacobi=None*, *obstacles=None*, **args*, ***kwargs*)

newcoords(*c*, *pos=None*, *check_validity=True*)

Update this coordinates.

This function records that this CascadedCoords has changed and recursively records the change to descendants of this CascadedCoords.

Parameters

- **c** (skrobot.coordinates.Coordinates *or* *numpy.ndarray*) – If pos is *None*, *c* means new Coordinates. If pos is given, *c* means rotation matrix.
- **pos** (*numpy.ndarray or None*) – new translation.
- **check_validity** (*bool*) – If this value is *True*, check whether an input rotation and an input translation are valid.

open_hand(*default_angle=0.17453292519943295*, *av=None*)

orient_with_matrix(*rotation_matrix*, *wrt='world'*)

Force update this coordinate system's rotation.

Parameters

- **rotation_matrix** (*numpy.ndarray*) – 3x3 rotation matrix.
- **wrt** (*str or* skrobot.coordinates.Coordinates) – reference coordinates.

parent_orientation(*v*, *wrt*)

parentcoords()

reset_joint_angle_limit_weight(*union_link_list*)

reset_manip_pose()

reset_pose()

rotate(*theta*, *axis*, *wrt='local'*)

Rotate this coordinate.

Rotate this coordinate relative to axis by theta radians with respect to wrt.

Parameters

- **theta** (*float*) – radian
- **axis** (*str or numpy.ndarray*) – 'x', 'y', 'z' or vector
- **wrt** (*str or* Coordinates) –

Return type self

rotate_vector(*v*)

Rotate 3-dimensional vector using rotation of this coordinate

Parameters **v** (*numpy.ndarray*) – vector shape of (3,)

Returns **np.matmul(self.rotation, v)** – rotated vector

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from numpy import pi
>>> c = Coordinates().rotate(pi, 'z')
>>> c.rotate_vector([1, 2, 3])
array([-1., -2.,  3.])
```

rotate_with_matrix(*matrix*, *wrt*)

Rotate this coordinate by given rotation matrix.

This is a subroutine of self.rotate function.

Parameters

- **mat** (*numpy.ndarray*) – rotation matrix shape of (3, 3)
- **wrt** (*str or* skrobot.coordinates.Coordinates) – with respect to.

Returns self

Return type *skrobot.coordinates.Coordinates*

rpy_angle()

Return a pair of rpy angles of this coordinates.

Returns **rpy_angle(self.rotation)** – a pair of rpy angles. See also skrobot.coordinates.math.rpy_angle

Return type tuple(numpy.ndarray, numpy.ndarray)

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates().rotate(np.pi / 2.0, 'x').rotate(np.pi / 3.0, 'z')
>>> r.rpy_angle()
(array([ 3.84592537e-16, -1.04719755e+00,  1.57079633e+00]),
array([ 3.14159265, -2.0943951 , -1.57079633]))
```

self_collision_check()

Return collision link pair

Returns

- **is_collision** (*bool*) – True if a collision occurred between any pair of objects and False otherwise
- **names** (*set of 2-tuple*) – The set of pairwise collisions. Each tuple contains two names in alphabetical order indicating that the two corresponding objects are in collision.

transform(*c*, *wrt='local'*, *out=None*)

Transform this coordinates

Parameters

- **c** (skrobot.coordinates.Coordinates) – coordinates
- **wrt** (*str* or skrobot.coordinates.Coordinates) – transform this coordinates with respect to wrt. If wrt is 'local' or self, multiply c from the right. If wrt is 'parent' or self.parent, transform c with respect to parentcoords. (multiply c from the left.) If wrt is Coordinates, transform c with respect to c.
- **out** (*None* or skrobot.coordinates.Coordinates) – If the *out* is specified, set new coordinates to *out*. Note that if the *out* is given, these coordinates don't change.

Returns **self** – return self

Return type *skrobot.coordinates.CascadedCoords*

transform_vector(*v*)

"Return vector represented at world frame.

Vector v given in the local coords is converted to world representation.

Parameters **v** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

transformation(*c2*, *wrt='local'*)

translate(*vec*, *wrt='local'*)

Translate this coordinates.

Note that this function changes this coordinates self. So if you don't want to change this class, use copy_worldcoords()

Parameters

- **vec** (*list* or *numpy.ndarray*) – shape of (3,) translation vector. unit is [m] order.
- **wrt** (*str* or Coordinates *(optional)*) – translate with respect to wrt.

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.], dtype=float32)
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3], dtype=float32)
```

```
>>> c = Coordinates()
>>> c.copy_worldcoords().translate([0.1, 0.2, 0.3])
>>> c.translation
array([0., 0., 0.], dtype=float32)
```

```
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([ 0.3,  0.2, -0.1])
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3], 'world')
>>> c.translation
array([0.1, 0.2, 0.3])
```

update(*force=False*)

worldcoords()
Calculate rotation and position in the world.

worldpos()
Return translation of this coordinate

See also skrobot.coordinates.Coordinates.translation

Returns **self.translation** – translation of this coordinate

Return type numpy.ndarray

worldrot()
Return rotation of this coordinate

See also skrobot.coordinates.Coordinates.rotation

Returns **self.rotation** – rotation matrix of this coordinate

Return type numpy.ndarray

__eq__(*value*, */*)
Return self==value.

__ne__(*value*, */*)
Return self!=value.

__lt__(*value*, */*)
Return self<value.

__le__(*value*, */*)
Return self<=value.

__gt__(*value*, */*)
Return self>value.

__ge__(*value*, */*)
Return self>=value.

__mul__(*other_c*)
Return Transformed Coordinates.

Note that this function creates new Coordinates and does not change translation and rotation, unlike transform function.

Parameters **other_c** (`skrobot.coordinates.Coordinates`) – input coordinates.

Returns **out** – transformed coordinates multiplied other_c from the right. T = T_{self} T_{other_c}.

Return type *skrobot.coordinates.Coordinates*

__pow__(*exponent*)
Return exponential homogeneous matrix.

If exponent equals -1, return inverse transformation of this coords.

Parameters **exponent** (*numbers.Number*) – exponent value. If exponent equals -1, return inverse transformation of this coords. In current, support only -1 case.

Returns **out** – output.

Return type *skrobot.coordinates.Coordinates*

Attributes

default_urdf_path

descendants

dimension
Return dimension of this coordinate

Returns **len(self.translation)** – dimension of this coordinate

Return type int

dual_quaternion
Property of DualQuaternion

Return DualQuaternion representation of this coordinate.

Returns **DualQuaternion** – DualQuaternion representation of this coordinate

Return type *skrobot.coordinates.dual_quaternion.DualQuaternion*

interlocking_joint_pairs
Interlocking joint pairs.

pairs are [(joint0, joint1), . . .] If users want to use interlocking joints, please overwrite this method.

joint_max_angles

joint_min_angles

larm

lleg

name

Return this coordinate's name

Returns **self._name** – name of this coordinate

Return type str

parent

quaternion

Property of quaternion

Returns **q** – [w, x, y, z] quaternion

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.quaternion
array([1., 0., 0., 0.])
>>> c.rotate(pi / 3, 'y').rotate(pi / 5, 'z')
>>> c.quaternion
array([0.8236391 , 0.1545085 , 0.47552826, 0.26761657])
```

rarm

rleg

rotation

Return rotation matrix of this coordinates.

Returns **self._rotation** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.rotation
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> c.rotate(np.pi / 2.0, 'y')
>>> c.rotation
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16]])
```

translation

Return translation of this coordinates.

Returns **self._translation** – vector shape of (3,). unit is [m]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3])
```

x_axis
Return x axis vector of this coordinates.

Returns **axis** – x axis.

Return type numpy.ndarray

y_axis
Return y axis vector of this coordinates.

Returns **axis** – y axis.

Return type numpy.ndarray

z_axis
Return z axis vector of this coordinates.

Returns **axis** – z axis.

Return type numpy.ndarray

PR2

skrobot.models.pr2.PR2	PR2 Robot Model.

skrobot.models.pr2.PR2

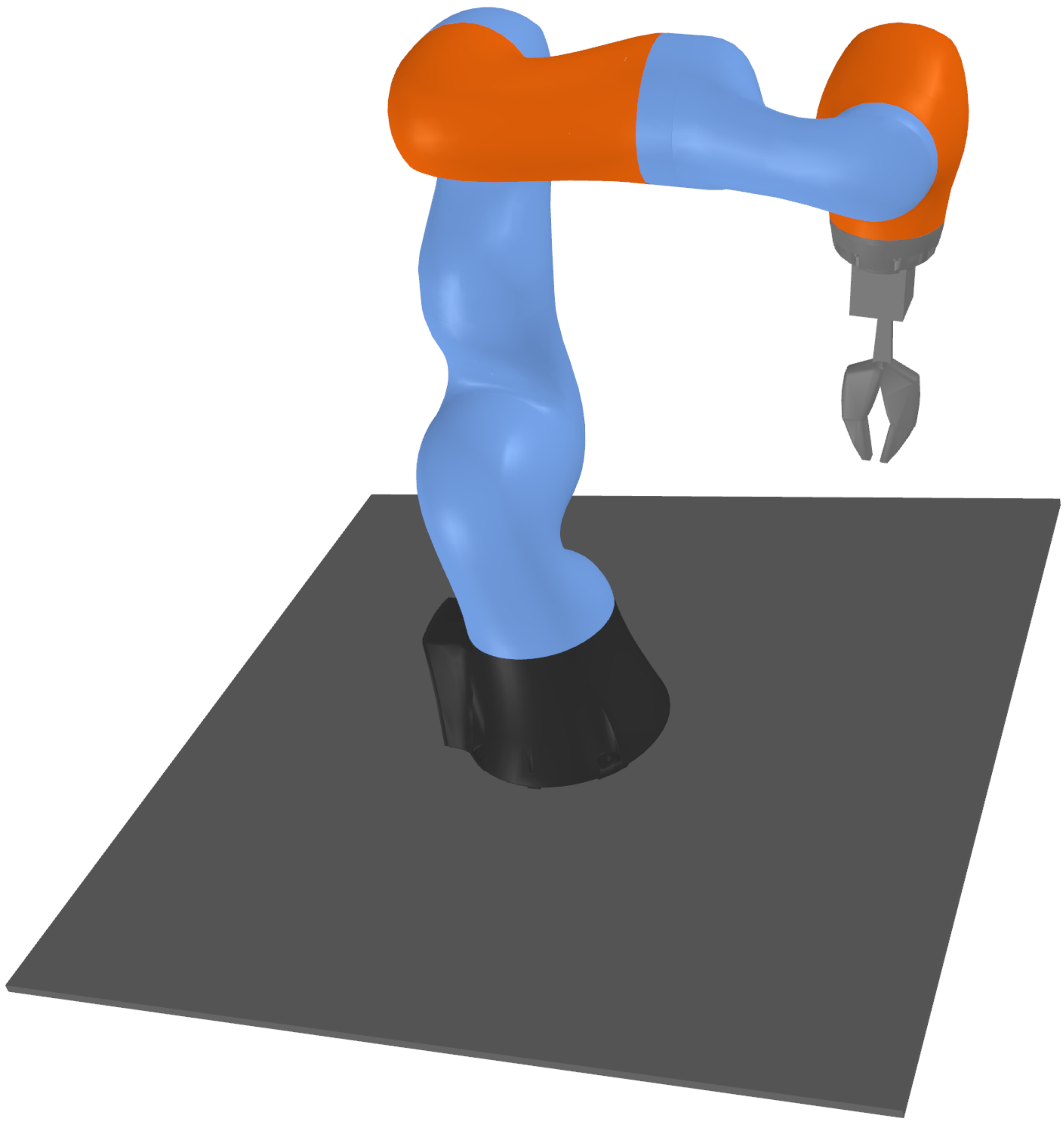
class skrobot.models.pr2.**PR2**(**args*, ***kwargs*)
PR2 Robot Model.

Methods

T()
Return 4x4 homogeneous transformation matrix.

Returns **matrix** – homogeneous transformation matrix shape of (4, 4)

Return type numpy.ndarray



Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.T()
array([[1., 0., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 0., 0., 1.]])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.rotate(pi / 2.0, 'y')
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00,
         1.00000000e-01],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00,
         2.00000000e-01],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16,
         3.00000000e-01],
       [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
         1.00000000e+00]])
```

angle_vector(*av=None*, *return_av=None*)
Returns angle vector

If av is given, it updates angles of all joint. If given av violate min/max range, the value is modified.

assoc(*child*, *relative_coords='world'*, *force=False*, ***kwargs*)
Associate child coords to this coordinate system.

If *relative_coords* is *None* or 'world', the translation and rotation of childcoords in the world coordinate system do not change. If *relative_coords* is specified, childcoords is assoced at translation and rotation of *relative_coords*. By default, if child is already assoced to some other coords, raise an exception. But if *force* is *True*, you can overwrite the existing assoc relation.

Parameters

- **child** (CascadedCoords) – child coordinates.
- **relative_coords** (*None or* Coordinates *or* *str*) – child coordinates' relative coordinates.
- **force** (*bool*) – predicate for overwriting the existing assoc-relation

Returns **child** – assoced child.

Return type *CascadedCoords*

Examples

```
>>> from skrobot.coordinates import CascadedCoords
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords)
#<CascadedCoords 0x7f1d30e29510 1.000 1.000 0.000 / 0.0 -0.0 0.0>
>>> child_coords.worldpos()
array([1., 1., 0.])
```

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(continued from previous page)

```
>>> child_coords.translation
array([0., 1., 0.])
```

None and 'world' have the same meaning.

```
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords, relative_coords='world')
#<CascadedCoords 0x7f1d30e29510 1.000 1.000 0.000 / 0.0 -0.0 0.0>
>>> child_coords.worldpos()
array([1., 1., 0.])
```

If *relative_coords* is 'local', *child* is associated at world translation and world rotation of *child* from this coordinate system.

```
>>> parent_coords = CascadedCoords(pos=[1, 0, 0])
>>> child_coords = CascadedCoords(pos=[1, 1, 0])
>>> parent_coords.assoc(child_coords, relative_coords='local')
>>> child_coords.worldpos()
array([2., 1., 0.])
>>> child_coords.translation
array([1., 1., 0.])
```

axis(*ax*)

calc_inverse_jacobian(*jacobi*, *manipulability_limit=0.1*, *manipulability_gain=0.001*, *weight=None*, **args*, ***kwargs*)

calc_inverse_kinematics_nspace_from_link_list(*link_list*, *avoid_nspace_gain=0.01*, *union_link_list=None*, *n_joint_dimension=None*, *null_space=None*, *additional_nspace_list=None*, *weight=None*)

calc_inverse_kinematics_weight_from_link_list(*link_list*, *avoid_weight_gain=1.0*, *union_link_list=None*, *n_joint_dimension=None*, *weight=None*, *additional_weight_list=[]*)

Calculate all weight from link list.

calc_jacobian_for_interlocking_joints(*link_list*, *interlocking_joint_pairs=None*)

calc_jacobian_from_link_list(*move_target*, *link_list=None*, *transform_coords=None*, *rotation_axis=None*, *translation_axis=None*, *col_offset=0*, *dim=None*, *jacobian=None*, *additional_jacobi_dimension=0*, *n_joint_dimension=None*, **args*, ***kwargs*)

calc_joint_angle_from_min_max_table(*index*, *j*, *av*)

calc_joint_angle_speed(*union_vel*, *angle_speed=None*, *angle_speed_blending=0.5*, *jacobi=None*, *j_sharp=None*, *null_space=None*, **args*, ***kwargs*)

calc_joint_angle_speed_gain(*union_link_list*, *dav*, *periodic_time*)

calc_nspace_from_joint_limit(*avoid_nspace_gain*, *union_link_list*, *weight*)

Calculate null-space according to joint limit.

calc_target_axis_dimension(*rotation_axis*, *translation_axis*)

rotation-axis, translation-axis -> both list and atom OK.

calc_target_joint_dimension(*link_list*)

calc_union_link_list(*link_list*)

calc_vel_for_interlocking_joints(*link_list*, *interlocking_joint_pairs=None*)
Calculate 0 velocity for keeping interlocking joint.

at the same joint angle.

calc_vel_from_pos(*dif_pos*, *translation_axis*, *p_limit=100.0*)
Calculate velocity from difference position

Parameters

- **dif_pos** (*np.ndarray*) – [m] order
- **translation_axis** (*str*) – see calc_dif_with_axis

Returns vel_p

Return type np.ndarray

calc_vel_from_rot(*dif_rot*, *rotation_axis*, *r_limit=0.5*)

calc_weight_from_joint_limit(*avoid_weight_gain*, *link_list*, *union_link_list*, *weight*, *n_joint_dimension=None*)
Calculate weight according to joint limit.

changed()
Return False

This is used for CascadedCoords compatibility

Returns **False** – always return False

Return type bool

collision_avoidance_link_pair_from_link_list(*link_list*, *obstacles=None*)

compute_qp_common(*target_coords*, *move_target*, *dt*, *link_list=None*, *gain=0.85*, *weight=1.0*, *translation_axis=True*, *rotation_axis=True*, *dof_limit_gain=0.5*)

compute_velocity(*target_coords*, *move_target*, *dt*, *link_list=None*, *gain=0.85*, *weight=1.0*, *translation_axis=True*, *rotation_axis=True*, *dof_limit_gain=0.5*, *fast=True*, *sym_proj=False*, *solver='cvxopt'*, **args*, ***kwargs*)

coords()
Return a deep copy of the Coordinates.

copy()
Return a deep copy of the Coordinates.

copy_coords()
Return a deep copy of the Coordinates.

copy_worldcoords()
Return a deep copy of the Coordinates.

difference_position(*coords*, *translation_axis=True*)
Return differences in positoin of given coords.

Parameters

- **coords** (*skrobot.coordinates.Coordinates*) – given coordinates
- **translation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xy', 'yz', 'zx', 'xx', 'yy', 'zz', True or False(None).

Returns **dif_pos** – difference position of self coordinates and coords considering translation_axis.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates import transform_coords
>>> from numpy import pi
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(
...           pi / 3.0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...           pi / 2.0, 'y')
>>> c1.difference_position(c2)
array([ 0.2       , -0.42320508,  0.3330127 ])
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...           pi / 3.0, 'x')
>>> c1.difference_position(c2)
array([ 0.2, -0.5, -0.2])
```

difference_rotation(*coords*, *rotation_axis=True*)
Return differences in rotation of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **rotation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xx', 'yy', 'zz', 'xm', 'ym', 'zm', 'xy', 'yx', 'yz', 'zy', 'zx', 'xz', True or False(None).

Returns **dif_rot** – difference rotation of self coordinates and coords considering rotation_axis.

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates.math import rpy_matrix
>>> coord1 = Coordinates()
>>> coord2 = Coordinates(rot=rpy_matrix(pi / 2.0, pi / 3.0, pi / 5.0))
>>> coord1.difference_rotation(coord2)
array([-0.32855112,  1.17434985,  1.05738936])
>>> coord1.difference_rotation(coord2, rotation_axis=False)
array([0, 0, 0])
>>> coord1.difference_rotation(coord2, rotation_axis='x')
array([0.        , 1.36034952, 0.78539816])
>>> coord1.difference_rotation(coord2, rotation_axis='y')
array([0.35398131, 0.        , 0.97442695])
>>> coord1.difference_rotation(coord2, rotation_axis='z')
array([-0.88435715,  0.74192175,  0.        ])
```

Using mirror option ['xm', 'ym', 'zm'], you can allow differences of mirror direction.

```
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-2.99951957e-32,  0.00000000e+00,  0.00000000e+00])
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi / 2.0, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-1.57079633,  0.        ,  0.        ])
```

disable_hook()

dissoc(*child*)

find_joint_angle_limit_weight_from_union_link_list(*union_link_list*)

find_link_path(*src_link*, *target_link*)
Find paths of src_link to target_link

Parameters

- **src_link** (*skrobot.model.link.Link*) – source link.
- **target_link** (*skrobot.model.link.Link*) – target link.

Returns **ret** – If the links are connected, return Link list. Otherwise, return an empty list.

Return type List[skrobot.model.link.Link]

find_link_route(*to*, *frm=None*)

fix_leg_to_coords(*fix_coords*, *leg='both'*, *mid=0.5*)
Fix robot's legs to a coords

In the Following codes, leged robot is assumed.

Parameters

- **fix_coords** (Coordinates) – target coordinate
- **leg** (*string*) – ['both', 'rleg', 'rleg', 'left', 'right']
- **mid** (*float*) – ratio of legs coord.

get_transform()
Return Transform object

Returns **transform** – corrensponding Transform to this coordinates

Return type skrobot.coordinates.base.Transform

gripper_distance(*dist=None*, *arm='arms'*)
Change gripper angle function

Parameters

- **dist** (*None or float*) – gripper distance. If dist is None, return gripper distance. If flaot value is given, change joint angle.
- **arm** (*str*) – Specify target arm. You can specify 'larm', 'rarm', 'arms'.

Returns **dist** – Result of gripper distance in meter.

Return type float

ik_convergence_check(*dif_pos*, *dif_rot*, *rotation_axis*, *translation_axis*, *thre*, *rthre*, *centroid_thre=None*, *target_centroid_pos=None*, *centroid_offset_func=None*, *cog_translation_axis=None*, *update_mass_properties=True*)

check ik convergence.

Parameters

- **dif_pos** (*list of np.ndarray*) –
- **dif_rot** (*list of np.ndarray*) –
- **translation_axis** (*list of axis*) –
- **rotation_axis** (*list of axis*) – see _wrap_axis

init_pose()

inverse_kinematics(*target_coords*, *move_target=None*, *link_list=None*, ***kwargs*)

Solve inverse kinematics.

solve inverse kinematics, move move-target to target-coords look-at- target suppots t, nil, float-vector, coords, list of float-vector, list of coords link-list is set by default based on move-target -> root link link-list.

inverse_kinematics_args(*union_link_list=None*, *rotation_axis=None*, *translation_axis=None*, *additional_jacobi_dimension=0*, ***kwargs*)

inverse_kinematics_loop(*dif_pos*, *dif_rot*, *move_target*, *link_list=None*, *target_coords=None*, ***kwargs*)

move move_target using dif_pos and dif_rot.

Parameters **TODO** –

Return type TODO

inverse_kinematics_loop_for_look_at(*move_target*, *look_at*, *link_list*, *rotation_axis='z'*, *translation_axis=False*, *rthre=0.001*, ***kwargs*)

Solve look at inverse kinematics

Parameters **look_at** (*list or np.ndarray or* Coordinates) –

inverse_kinematics_optimization(*target_coords*, *move_target=None*, *link_list=None*, *regularization_parameter=None*, *init_angle_vector=None*, *translation_axis=True*, *rotation_axis=True*, *stop=100*, *dt=0.005*, *inverse_kinematics_hook=[]*, *thre=0.001*, *rthre=0.017453292519943295*, **args*, ***kwargs*)

inverse_rotate_vector(*v*)

inverse_transform_vector(*v*)

Transform vector in world coordinates to local coordinates

Parameters **vec** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

inverse_transformation(*dest=None*)

Return a invese transformation of this coordinate system.

Create a new coordinate with inverse transformation of this coordinate system.

$$\begin{pmatrix} R^{-1} & -R^{-1}p \\ 0 & 1 \end{pmatrix}$$

Parameters **dest** (*None or* skrobot.coordinates.Coordinates) – If dest is given, the result of transformation is in-placed to dest.

Returns **dest** – result of inverse transformation.

Return type *skrobot.coordinates.Coordinates*

link_lists(*to*, *frm=None*)
Find link list from to link to frm link.

load_urdf(*urdf*)

load_urdf_file(*file_obj*)

look_at_hand(*coords*)

move_coords(*target_coords*, *local_coords*)
Transform this coordinate so that local_coords to target_coords.

Parameters

- **target_coords** (`skrobot.coordinates.Coordinates`) – target coords.
- **local_coords** (`skrobot.coordinates.Coordinates`) – local coords to be aligned.

Returns **self.worldcoords()** – world coordinates.

Return type *skrobot.coordinates.Coordinates*

move_end_pos(*pos*, *wrt='local'*, **args*, ***kwargs*)

move_end_rot(*angle*, *axis*, *wrt='local'*, **args*, ***kwargs*)

move_joints(*union_vel*, *union_link_list=None*, *periodic_time=0.05*, *joint_args=None*, *move_joints_hook=None*, **args*, ***kwargs*)

move_joints_avoidance(*union_vel*, *union_link_list=None*, *link_list=None*, *n_joint_dimension=None*, *weight=None*, *null_space=None*, *avoid_nspace_gain=0.01*, *avoid_weight_gain=1.0*, *avoid_collision_distance=200*, *avoid_collision_null_gain=1.0*, *avoid_collision_joint_gain=1.0*, *collision_avoidance_link_pair=None*, *cog_gain=0.0*, *target_centroid_pos=None*, *centroid_offset_func=None*, *cog_translation_axis='z'*, *cog_null_space=False*, *additional_weight_list=None*, *additional_nspace_list=None*, *jacobi=None*, *obstacles=None*, **args*, ***kwargs*)

newcoords(*c*, *pos=None*, *check_validity=True*)
Update this coordinates.

This function records that this CascadedCoords has changed and recursively records the change to descendants of this CascadedCoords.

Parameters

- **c** (`skrobot.coordinates.Coordinates` *or* `numpy.ndarray`) – If pos is *None*, *c* means new Coordinates. If pos is given, *c* means rotation matrix.
- **pos** (`numpy.ndarray` *or* *None*) – new translation.
- **check_validity** (`bool`) – If this value is *True*, check whether an input rotation and an input translation are valid.

orient_with_matrix(*rotation_matrix*, *wrt='world'*)
Force update this coordinate system's rotation.

Parameters

- **rotation_matrix** (`numpy.ndarray`) – 3x3 rotation matrix.
- **wrt** (`str` *or* `skrobot.coordinates.Coordinates`) – reference coordinates.

parent_orientation(*v*, *wrt*)

parentcoords()

reset_joint_angle_limit_weight(*union_link_list*)

reset_manip_pose()

reset_pose()

rotate(*theta*, *axis*, *wrt='local'*)

Rotate this coordinate.

Rotate this coordinate relative to axis by theta radians with respect to wrt.

Parameters

- **theta** (*float*) – radian
- **axis** (*str or numpy.ndarray*) – 'x', 'y', 'z' or vector
- **wrt** (*str or* Coordinates) –

Return type self

rotate_vector(*v*)

Rotate 3-dimensional vector using rotation of this coordinate

Parameters **v** (*numpy.ndarray*) – vector shape of (3,)

Returns **np.matmul(self.rotation, v)** – rotated vector

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from numpy import pi
>>> c = Coordinates().rotate(pi, 'z')
>>> c.rotate_vector([1, 2, 3])
array([-1., -2.,  3.])
```

rotate_with_matrix(*matrix*, *wrt*)

Rotate this coordinate by given rotation matrix.

This is a subroutine of self.rotate function.

Parameters

- **mat** (*numpy.ndarray*) – rotation matrix shape of (3, 3)
- **wrt** (*str or* skrobot.coordinates.Coordinates) – with respect to.

Returns **self**

Return type *skrobot.coordinates.Coordinates*

rpy_angle()

Return a pair of rpy angles of this coordinates.

Returns **rpy_angle(self.rotation)** – a pair of rpy angles. See also skrobot.coordinates.math.rpy_angle

Return type tuple(numpy.ndarray, numpy.ndarray)

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates().rotate(np.pi / 2.0, 'x').rotate(np.pi / 3.0, 'z')
>>> r.rpy_angle()
(array([ 3.84592537e-16, -1.04719755e+00,  1.57079633e+00]),
array([ 3.14159265, -2.0943951 , -1.57079633]))
```

self_collision_check()

Return collision link pair

Returns

- **is_collision** (*bool*) – True if a collision occurred between any pair of objects and False otherwise
- **names** (*set of 2-tuple*) – The set of pairwise collisions. Each tuple contains two names in alphabetical order indicating that the two corresponding objects are in collision.

transform(*c*, *wrt='local'*, *out=None*)

Transform this coordinates

Parameters

- **c** (`skrobot.coordinates.Coordinates`) – coordinates
- **wrt** (*str or* `skrobot.coordinates.Coordinates`) – transform this coordinates with respect to wrt. If wrt is 'local' or self, multiply c from the right. If wrt is 'parent' or self.parent, transform c with respect to parentcoords. (multiply c from the left.) If wrt is Coordinates, transform c with respect to c.
- **out** (*None or* `skrobot.coordinates.Coordinates`) – If the *out* is specified, set new coordinates to *out*. Note that if the *out* is given, these coordinates don't change.

Returns **self** – return self

Return type *skrobot.coordinates.CascadedCoords*

transform_vector(*v*)

"Return vector represented at world frame.

Vector v given in the local coords is converted to world representation.

Parameters **v** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

transformation(*c2*, *wrt='local'*)

translate(*vec*, *wrt='local'*)

Translate this coordinates.

Note that this function changes this coordinates self. So if you don't want to change this class, use copy_worldcoords()

Parameters

- **vec** (*list or numpy.ndarray*) – shape of (3,) translation vector. unit is [m] order.
- **wrt** (*str or* `Coordinates` *(optional)*) – translate with respect to wrt.

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.], dtype=float32)
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3], dtype=float32)
```

```
>>> c = Coordinates()
>>> c.copy_worldcoords().translate([0.1, 0.2, 0.3])
>>> c.translation
array([0., 0., 0.], dtype=float32)
```

```
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([ 0.3,  0.2, -0.1])
>>> c = Coordinates().rotate(np.pi / 2.0, 'y')
>>> c.translate([0.1, 0.2, 0.3], 'world')
>>> c.translation
array([0.1, 0.2, 0.3])
```

update(*force=False*)

worldcoords()

Calculate rotation and position in the world.

worldpos()

Return translation of this coordinate

See also skrobot.coordinates.Coordinates.translation

Returns **self.translation** – translation of this coordinate

Return type numpy.ndarray

worldrot()

Return rotation of this coordinate

See also skrobot.coordinates.Coordinates.rotation

Returns **self.rotation** – rotation matrix of this coordinate

Return type numpy.ndarray

__eq__(*value*, */*)

Return self==value.

__ne__(*value*, */*)

Return self!=value.

__lt__(*value*, */*)

Return self<value.

__le__(*value*, */*)

Return self<=value.

`__gt__`(*value*, */*)
Return self>value.

`__ge__`(*value*, */*)
Return self>=value.

`__mul__`(*other_c*)
Return Transformed Coordinates.

Note that this function creates new Coordinates and does not change translation and rotation, unlike transform function.

Parameters **other_c** (`skrobot.coordinates.Coordinates`) – input coordinates.

Returns **out** – transformed coordinates multiplied other_c from the right. T = T_{self} T_{other_c}.

Return type *skrobot.coordinates.Coordinates*

`__pow__`(*exponent*)
Return exponential homogeneous matrix.

If exponent equals -1, return inverse transformation of this coords.

Parameters **exponent** (*numbers.Number*) – exponent value. If exponent equals -1, return inverse transformation of this coords. In current, support only -1 case.

Returns **out** – output.

Return type *skrobot.coordinates.Coordinates*

Attributes

`default_urdf_path`

`descendants`

`dimension`
Return dimension of this coordinate

Returns **len(self.translation)** – dimension of this coordinate

Return type int

`dual_quaternion`
Property of DualQuaternion

Return DualQuaternion representation of this coordinate.

Returns **DualQuaternion** – DualQuaternion representation of this coordinate

Return type *skrobot.coordinates.dual_quaternion.DualQuaternion*

`head`

`interlocking_joint_pairs`
Interlocking joint pairs.

pairs are [(joint0, joint1), . . .] If users want to use interlocking joints, please overwrite this method.

`joint_max_angles`

`joint_min_angles`

`larm`

lleg

name

Return this coordinate's name

Returns **self._name** – name of this coordinate

Return type str

parent

quaternion

Property of quaternion

Returns **q** – [w, x, y, z] quaternion

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.quaternion
array([1., 0., 0., 0.])
>>> c.rotate(pi / 3, 'y').rotate(pi / 5, 'z')
>>> c.quaternion
array([0.8236391 , 0.1545085 , 0.47552826, 0.26761657])
```

rarm

rleg

rotation

Return rotation matrix of this coordinates.

Returns **self._rotation** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.rotation
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> c.rotate(np.pi / 2.0, 'y')
>>> c.rotation
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16]])
```

translation

Return translation of this coordinates.

Returns **self._translation** – vector shape of (3,). unit is [m]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3])
```

x_axis
Return x axis vector of this coordinates.

Returns **axis** – x axis.

Return type numpy.ndarray

y_axis
Return y axis vector of this coordinates.

Returns **axis** – y axis.

Return type numpy.ndarray

z_axis
Return z axis vector of this coordinates.

Returns **axis** – z axis.

Return type numpy.ndarray

3.3 Functions

3.3.1 Utilities functions

skrobot.coordinates.math._wrap_axis	Convert axis to float vector.
skrobot.coordinates.math._check_valid_rotation	Checks that the given rotation matrix is valid.
skrobot.coordinates.math._check_valid_translation	Checks that the translation vector is valid.
skrobot.coordinates.math.triple_product	Returns Triple Product
skrobot.coordinates.math.inverse_rodrigues	Inverse Rodrigues formula Convert Rotation-Matirx to Axis-Angle.
skrobot.coordinates.math.rotation_angle	Inverse Rodrigues formula Convert Rotation-Matirx to Axis-Angle.
skrobot.coordinates.math.make_matrix	Wrapper of numpy array.
skrobot.coordinates.math.random_rotation	Generates a random 3x3 rotation matrix.
skrobot.coordinates.math.random_translation	Generates a random translation vector.

continues on next page

Table 8 – continued from previous page

skrobot.coordinates.math.midpoint	Return midpoint
skrobot.coordinates.math.midrot	Returns mid (or p) rotation matrix of given two matrix r1 and r2.
skrobot.coordinates.math.transform	Return transform m v
skrobot.coordinates.math.rotation_matrix	Return the rotation matrix.
skrobot.coordinates.math.rotate_vector	Rotate vector.
skrobot.coordinates.math.rotate_matrix	
skrobot.coordinates.math.rpy_matrix	Return rotation matrix from yaw-pitch-roll
skrobot.coordinates.math.rpy_angle	Decomposing a rotation matrix to yaw-pitch-roll.
skrobot.coordinates.math.normalize_vector	Return normalized vector
skrobot.coordinates.math.matrix_log	Returns matrix log of given rotation matrix, it returns [-pi, pi]
skrobot.coordinates.math.matrix_exponent	Returns exponent of given omega.
skrobot.coordinates.math.outer_product_matrix	Returns outer product matrix of given v.
skrobot.coordinates.math.rotation_matrix_from_rpy	Returns Rotation matrix from yaw-pitch-roll angles.
skrobot.coordinates.math.rotation_matrix_from_axis	Return rotation matrix orienting first_axis
skrobot.coordinates.math.rodrigues	Rodrigues formula.
skrobot.coordinates.math.rotation_angle	Inverse Rodrigues formula Convert Rotation-Matirx to Axis-Angle.
skrobot.coordinates.math.rotation_distance	Return the distance of rotation matrixes.
skrobot.coordinates.math.axis_angle_from_matrix	Converts the rotation of a matrix into axis-angle representation.
skrobot.coordinates.math.angle_between_vectors	Returns the smallest angle in radians between two vectors.

skrobot.coordinates.math._wrap_axis

skrobot.coordinates.math.**_wrap_axis**(*axis*)

Convert axis to float vector.

Parameters **axis** (*list or numpy.ndarray or str or bool or None*) – rotation axis indicated by number or string.

Returns **axis** – conveted axis

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import _wrap_axis
>>> _wrap_axis('x')
array([1, 0, 0])
>>> _wrap_axis('y')
array([0, 1, 0])
>>> _wrap_axis('z')
array([0, 0, 1])
>>> _wrap_axis('xy')
```

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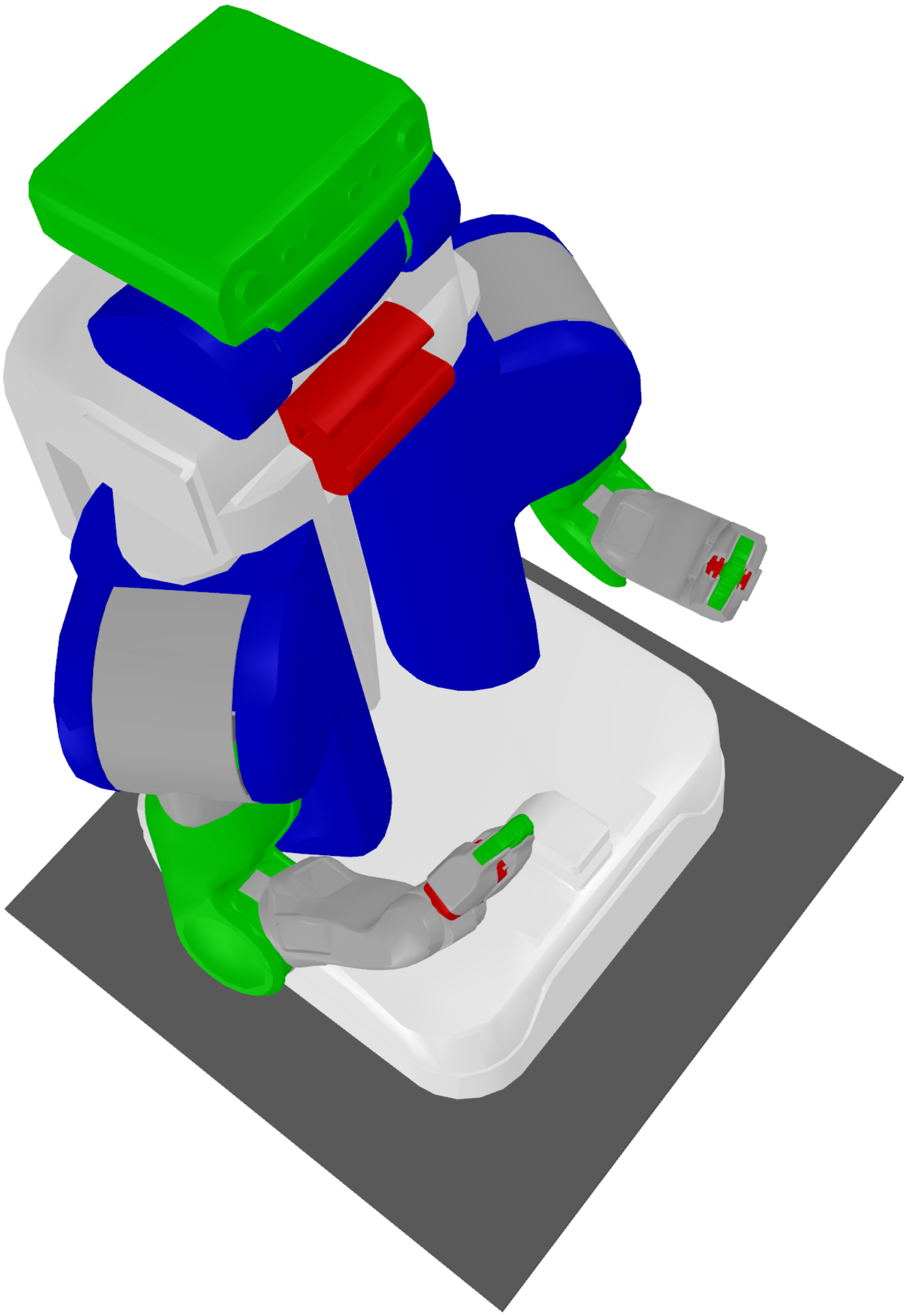

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```
array([1, 1, 0])
>>> _wrap_axis([1, 1, 1])
array([1, 1, 1])
>>> _wrap_axis(True)
array([0, 0, 0])
>>> _wrap_axis(False)
array([1, 1, 1])
```

skrobot.coordinates.math._check_valid_rotation

skrobot.coordinates.math.**_check_valid_rotation**(*rotation*)
Checks that the given rotation matrix is valid.

skrobot.coordinates.math._check_valid_translation

skrobot.coordinates.math.**_check_valid_translation**(*translation*)
Checks that the translation vector is valid.

skrobot.coordinates.math.triple_product

skrobot.coordinates.math.**triple_product**(*a*, *b*, *c*)
Returns Triple Product

See https://en.wikipedia.org/wiki/Triple_product.

Geometrically, the scalar triple product

$a \cdot (b \times c)$

is the (signed) volume of the parallelepiped defined by the three vectors given.

Parameters

- **a** (*numpy.ndarray*) – vector a
- **b** (*numpy.ndarray*) – vector b
- **c** (*numpy.ndarray*) – vector c

Returns **triple product** – calculated triple product

Return type float

Examples

```
>>> from skrobot.math import triple_product
>>> triple_product([1, 1, 1], [1, 1, 1], [1, 1, 1])
0
>>> triple_product([1, 0, 0], [0, 1, 0], [0, 0, 1])
1
```

skrobot.coordinates.math.inverse_rodrigues

skrobot.coordinates.math.**inverse_rodrigues**(*mat*)

Inverse Rodrigues formula Convert Rotation-Matirx to Axis-Angle.

Return theta and axis. If given unit matrix, return None.

Parameters **mat** (*numpy.ndarray*) – rotation matrix, shape (3, 3)

Returns **theta, axis** – rotation angle in radian and rotation axis

Return type tuple(float, numpy.ndarray)

Examples

```
>>> import numpy
>>> from skrobot.coordinates.math import rotation_angle
>>> rotation_angle(numpy.eye(3)) is None
True
>>> rotation_angle(numpy.array([[0, 0, 1], [0, 1, 0], [-1, 0, 0]]))
(1.5707963267948966, array([0., 1., 0.]))
```

skrobot.coordinates.math.rotation_angle

skrobot.coordinates.math.**rotation_angle**(*mat*)

Inverse Rodrigues formula Convert Rotation-Matirx to Axis-Angle.

Return theta and axis. If given unit matrix, return None.

Parameters **mat** (*numpy.ndarray*) – rotation matrix, shape (3, 3)

Returns **theta, axis** – rotation angle in radian and rotation axis

Return type tuple(float, numpy.ndarray)

Examples

```
>>> import numpy
>>> from skrobot.coordinates.math import rotation_angle
>>> rotation_angle(numpy.eye(3)) is None
True
>>> rotation_angle(numpy.array([[0, 0, 1], [0, 1, 0], [-1, 0, 0]]))
(1.5707963267948966, array([0., 1., 0.]))
```

skrobot.coordinates.math.make_matrix

skrobot.coordinates.math.**make_matrix**(*r*, *c*)

Wrapper of numpy array.

Parameters

- **r** (*int*) – row of matrix
- **c** (*int*) – column of matrix

Returns **np.zeros((r, c), 'f')** – matrix

Return type numpy.ndarray

skrobot.coordinates.math.random_rotation

`skrobot.coordinates.math.`**`random_rotation`**`()`

Generates a random 3x3 rotation matrix.

Returns **rot** – randomly generated 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import random_rotation
>>> random_rotation()
array([[-0.00933428, -0.90465681, -0.42603865],
       [-0.50305571, -0.36396787,  0.78387648],
       [-0.86420358,  0.2216381 , -0.4516954 ]])
>>> random_rotation()
array([[-0.6549113 ,  0.09499001, -0.749712  ],
       [-0.47962794, -0.81889635,  0.31522342],
       [-0.58399334,  0.5660262 ,  0.58186434]])
```

skrobot.coordinates.math.random_translation

`skrobot.coordinates.math.`**`random_translation`**`()`

Generates a random translation vector.

Returns **translation** – A 3-entry random translation vector.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import random_translation
>>> random_translation()
array([0.03299473, 0.81481471, 0.57782565])
>>> random_translation()
array([0.10835455, 0.46549158, 0.73277675])
```

skrobot.coordinates.math.midpoint

`skrobot.coordinates.math.midpoint(p, a, b)`

Return midpoint

Parameters

- **p** (*float*) – ratio of a:b
- **a** (*numpy.ndarray*) – vector
- **b** (*numpy.ndarray*) – vector

Returns **midpoint** – midpoint

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates.math import midpoint
>>> midpoint(0.5, np.ones(3), np.zeros(3))
>>> array([0.5, 0.5, 0.5])
```

skrobot.coordinates.math.midrot

`skrobot.coordinates.math.midrot(p, r1, r2)`

Returns mid (or p) rotation matrix of given two matrix r1 and r2.

Parameters

- **p** (*float*) – ratio of r1:r2
- **r1** (*numpy.ndarray*) – 3x3 rotation matrix
- **r2** (*numpy.ndarray*) – 3x3 rotation matrix

Returns **r** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates.math import midrot
>>> midrot(0.5,
        np.eye(3),
        np.array([[0, 0, 1], [0, 1, 0], [-1, 0, 0]]))
array([[ 0.70710678,  0.        ,  0.70710678],
       [ 0.        ,  1.        ,  0.        ],
       [-0.70710678,  0.        ,  0.70710678]])
>>> from skrobot.coordinates.math import rpy_angle
>>> np.rad2deg(rpy_angle(midrot(0.5,
              np.eye(3),
              np.array([[0, 0, 1], [0, 1, 0], [-1, 0, 0]])))[0])
array([ 0., 45.,  0.])
```

skrobot.coordinates.math.transform

`skrobot.coordinates.math.`**`transform`**(*m*, *v*)

Return transform m v

Parameters

- **m** (*numpy.ndarray*) – 3 x 3 rotation matrix.
- **v** (*numpy.ndarray or list*) – input vector.

Returns **np.matmul(m, v)** – transformed vector.

Return type numpy.ndarray

skrobot.coordinates.math.rotation_matrix

`skrobot.coordinates.math.`**`rotation_matrix`**(*theta*, *axis*)

Return the rotation matrix.

Return the rotation matrix associated with counterclockwise rotation about the given axis by theta radians.

Parameters

- **theta** (*float*) – radian
- **axis** (*str or list or numpy.ndarray*) – rotation axis such that 'x', 'y', 'z' [0, 0, 1], [0, 1, 0], [1, 0, 0]

Returns **rot** – rotation matrix about the given axis by theta radians.

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates.math import rotation_matrix
>>> rotation_matrix(np.pi / 2.0, [1, 0, 0])
array([[ 1.00000000e+00,  0.00000000e+00,  0.00000000e+00],
       [ 0.00000000e+00,  2.22044605e-16, -1.00000000e+00],
       [ 0.00000000e+00,  1.00000000e+00,  2.22044605e-16]])
>>> rotation_matrix(np.pi / 2.0, 'y')
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16]])
```

skrobot.coordinates.math.rotate_vector

`skrobot.coordinates.math.`**`rotate_vector`**(*vec*, *theta*, *axis*)

Rotate vector.

Rotate vec with respect to axis.

Parameters

- **vec** (*list or numpy.ndarray*) – target vector
- **theta** (*float*) – rotation angle

- **axis** (*list or numpy.ndarray or str*) – axis of rotation.

Returns **rotated_vec** – rotated vector.

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates.math import rotate_vector
>>> rotate_vector([1, 0, 0], pi / 6.0, [1, 0, 0])
array([1., 0., 0.])
>>> rotate_vector([1, 0, 0], pi / 6.0, [0, 1, 0])
array([ 0.8660254,  0.       , -0.5      ])
>>> rotate_vector([1, 0, 0], pi / 6.0, [0, 0, 1])
array([0.8660254, 0.5      , 0.       ])
```

skrobot.coordinates.math.rotate_matrix

skrobot.coordinates.math.**rotate_matrix**(*matrix*, *theta*, *axis*, *world=None*)

skrobot.coordinates.math.rpy_matrix

skrobot.coordinates.math.**rpy_matrix**(*az*, *ay*, *ax*)

Return rotation matrix from yaw-pitch-roll

This function creates a new rotation matrix which has been rotated ax radian around x-axis in WORLD, ay radian around y-axis in WORLD, and az radian around z axis in WORLD, in this order. These angles can be extracted by the rpy function.

Parameters

- **az** (*float*) – rotated around z-axis(yaw) in radian.
- **ay** (*float*) – rotated around y-axis(pitch) in radian.
- **ax** (*float*) – rotated around x-axis(roll) in radian.

Returns **r** – rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates.math import rpy_matrix
>>> yaw = np.pi / 2.0
>>> pitch = np.pi / 3.0
>>> roll = np.pi / 6.0
>>> rpy_matrix(yaw, pitch, roll)
array([[ 1.11022302e-16, -8.66025404e-01,  5.00000000e-01],
       [ 5.00000000e-01,  4.33012702e-01,  7.50000000e-01],
       [-8.66025404e-01,  2.50000000e-01,  4.33012702e-01]])
```

skrobot.coordinates.math.rpy_angle

skrobot.coordinates.math.**rpy_angle**(*matrix*)

Decomposing a rotation matrix to yaw-pitch-roll.

Parameters **matrix** (*list or numpy.ndarray*) – 3x3 rotation matrix

Returns **rpy** – pair of rpy in yaw-pitch-roll order.

Return type tuple(numpy.ndarray, numpy.ndarray)

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates.math import rpy_matrix
>>> from skrobot.coordinates.math import rpy_angle
>>> yaw = np.pi / 2.0
>>> pitch = np.pi / 3.0
>>> roll = np.pi / 6.0
>>> rot = rpy_matrix(yaw, pitch, roll)
>>> rpy_angle(rot)
(array([1.57079633, 1.04719755, 0.52359878]),
 array([ 4.71238898,  2.0943951 , -2.61799388]))
```

skrobot.coordinates.math.normalize_vector

skrobot.coordinates.math.**normalize_vector**(*v*, *ord=2*)

Return normalized vector

Parameters

- **v** (*list or numpy.ndarray*) – vector
- **ord** (*int (optional)*) – ord of np.linalg.norm

Returns **v** – normalized vector

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import normalize_vector
>>> normalize_vector([1, 1, 1])
array([0.57735027, 0.57735027, 0.57735027])
>>> normalize_vector([0, 0, 0])
array([0., 0., 0.])
```

skrobot.coordinates.math.matrix_log

skrobot.coordinates.math.**matrix_log**(*m*)

Returns matrix log of given rotation matrix, it returns [-pi, pi]

Parameters **m** (*list or numpy.ndarray*) – 3x3 rotation matrix

Returns **matrixlog** – vector of shape (3,)

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates.math import matrix_log
>>> matrix_log(np.eye(3))
array([0., 0., 0.])
```

skrobot.coordinates.math.matrix_exponent

skrobot.coordinates.math.**matrix_exponent**(*omega*, *p=1.0*)

Returns exponent of given omega.

This function is similar to cv2.Rodrigues. Convert rvec (which is log quaternion) to rotation matrix.

Parameters **omega** (*list or numpy.ndarray*) – vector of shape (3,)

Returns **rot** – exponential matrix of given omega

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates.math import matrix_exponent
>>> matrix_exponent([1, 1, 1])
array([[ 0.22629564, -0.18300792,  0.95671228],
       [ 0.95671228,  0.22629564, -0.18300792],
       [-0.18300792,  0.95671228,  0.22629564]])
>>> matrix_exponent([1, 0, 0])
array([[ 1.        ,  0.        ,  0.        ],
       [ 0.        ,  0.54030231, -0.84147098],
       [ 0.        ,  0.84147098,  0.54030231]])
```

skrobot.coordinates.math.outer_product_matrix

skrobot.coordinates.math.**outer_product_matrix**(*v*)

Returns outer product matrix of given v.

Returns following outer product matrix.

$$\begin{pmatrix} 0 & -v_2 & v_1 \\ v_2 & 0 & -v_0 \\ -v_1 & v_0 & 0 \end{pmatrix}$$

Parameters **v** (*numpy.ndarray or list*) – [x, y, z]

Returns **matrix** – 3x3 rotation matrix.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import outer_product_matrix
>>> outer_product_matrix([1, 2, 3])
array([[ 0, -3,  2],
       [ 3,  0, -1],
       [-2,  1,  0]])
```

skrobot.coordinates.math.rotation_matrix_from_rpy

skrobot.coordinates.math.**rotation_matrix_from_rpy**(*rpy*)

Returns Rotation matrix from yaw-pitch-roll angles.

Parameters **rpy** (*numpy.ndarray or list*) – Vector of yaw-pitch-roll angles in radian.

Returns **rot** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates.math import rotation_matrix_from_rpy
>>> rotation_matrix_from_rpy([0, np.pi / 3, 0])
array([[ 0.5      ,  0.       ,  0.8660254],
       [ 0.       ,  1.       ,  0.       ],
       [-0.8660254,  0.       ,  0.5      ]])
```

skrobot.coordinates.math.rotation_matrix_from_axis

skrobot.coordinates.math.**rotation_matrix_from_axis**(*first_axis=(1, 0, 0)*, *second_axis=(0, 1, 0)*, *axes='xy'*)

Return rotation matrix orienting first_axis

Parameters

- **first_axis** (*list or tuple or numpy.ndarray*) – direction of first axis
- **second_axis** (*list or tuple or numpy.ndarray*) – direction of second axis. This input axis is normalized using Gram-Schmidt.
- **axes** (*str*) – valid inputs are 'xy', 'yx', 'xz', 'zx', 'yz', 'zy'. first index indicates first_axis's axis.

Returns **rotation_matrix** – Rotation matrix

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import rotation_matrix_from_axis
>>> rotation_matrix_from_axis((1, 0, 0), (0, 1, 0))
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> rotation_matrix_from_axis((1, 1, 1), (0, 1, 0))
array([[ 0.57735027, -0.40824829, -0.70710678],
       [ 0.57735027,  0.81649658,  0.        ],
       [ 0.57735027, -0.40824829,  0.70710678]])
```

skrobot.coordinates.math.rodrigues

skrobot.coordinates.math.**rodrigues**(*axis*, *theta=None*)

Rodrigues formula.

See: Rodrigues' rotation formula - Wikipedia.

See: Axis-angle representation - Wikipedia.

Parameters

- **axis** (*numpy.ndarray or list*) – [x, y, z] vector. You can give axis-angle representation to *axis* if *theta* is None.
- **theta** (*float or None (optional)*) – radian. If None is given, calculate theta from axis.

Returns **mat** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy
>>> from skrobot.coordinates.math import rodrigues
>>> rodrigues([1, 0, 0], 0)
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> rodrigues([1, 1, 1], numpy.pi)
array([[-0.33333333,  0.66666667,  0.66666667],
       [ 0.66666667, -0.33333333,  0.66666667],
       [ 0.66666667,  0.66666667, -0.33333333]])
```

skrobot.coordinates.math.rotation_distance

`skrobot.coordinates.math.`**`rotation_distance`**(*mat1*, *mat2*)

Return the distance of rotation matrixes.

Parameters

- **mat1** (*list or numpy.ndarray*) –
- **mat2** (*list or numpy.ndarray*) – 3x3 matrix

Returns **diff_theta** – distance of rotation matrixes in radian.

Return type float

Examples

```
>>> import numpy
>>> from skrobot.coordinates.math import rotation_distance
>>> rotation_distance(numpy.eye(3), numpy.eye(3))
0.0
>>> rotation_distance(
        numpy.eye(3),
        numpy.array([[0, 0, 1], [0, 1, 0], [-1, 0, 0]]))
1.5707963267948966
```

skrobot.coordinates.math.axis_angle_from_matrix

`skrobot.coordinates.math.`**`axis_angle_from_matrix`**(*rotation*)

Converts the rotation of a matrix into axis-angle representation.

Parameters **rotation** (*numpy.ndarray*) – 3x3 rotation matrix

Returns **axis_angle** – axis-angle representation of vector

Return type numpy.ndarray

Examples

```
>>> import numpy
>>> from skrobot.coordinates.math import axis_angle_from_matrix
>>> axis_angle_from_matrix(numpy.eye(3))
array([0, 0, 0])
>>> axis_angle_from_matrix(
    numpy.array([[0, 0, 1], [0, 1, 0], [-1, 0, 0]]))
array([0.        , 1.57079633, 0.        ])
```

skrobot.coordinates.math.angle_between_vectors

skrobot.coordinates.math.**angle_between_vectors**(*v1*, *v2*, *normalize=True*, *directed=True*)
Returns the smallest angle in radians between two vectors.

Parameters

- **v1** (*numpy.ndarray, list[float] or tuple(float)*) – input vector.
- **v2** (*numpy.ndarray, list[float] or tuple(float)*) – input vector.
- **normalize** (*bool*) – If normalize is True, normalize v1 and v2.
- **directed** (*bool*) – If directed is *False*, the input vectors are interpreted as undirected axes.

Returns **theta** – smallest angle between v1 and v2.

Return type float

3.3.2 Jacobian Functions

skrobot.coordinates.math.sr_inverse	Returns SR-inverse of given Jacobian.
skrobot.coordinates.math.sr_inverse_org	Return SR-inverse of given J
skrobot.coordinates.math.manipulability	Return manipulability of given matrix.

skrobot.coordinates.math.sr_inverse

skrobot.coordinates.math.**sr_inverse**(*J*, *k=1.0*, *weight_vector=None*)
Returns SR-inverse of given Jacobian.

Calculate Singularity-Robust Inverse See: *Inverse Kinematic Solutions With Singularity Robustness for Robot Manipulator Control*

Parameters

- **J** (*numpy.ndarray*) – jacobian
- **k** (*float*) – coefficients
- **weight_vector** (*None or numpy.ndarray*) – weight vector

Returns **ret** – result of SR-inverse

Return type numpy.ndarray

skrobot.coordinates.math.sr_inverse_org

skrobot.coordinates.math.**sr_inverse_org**(*J*, *k=1.0*)

Return SR-inverse of given J

Definition of SR-inverse is following.

$J^* = J^T(JJ^T + kI_m)^{-1}$

Parameters

- **J** (*numpy.ndarray*) – jacobian
- **k** (*float*) – coefficients

Returns **sr_inverse** – calculated SR-inverse

Return type numpy.ndarray

skrobot.coordinates.math.manipulability

skrobot.coordinates.math.**manipulability**(*J*)

Return manipulability of given matrix.

Definition of manipulability is following.

$w = \sqrt{\det J(\theta)J^T(\theta)}$

Parameters **J** (*numpy.ndarray*) – jacobian

Returns **w** – manipulability

Return type float

3.3.3 Quaternion Functions

skrobot.coordinates.math.xyzw2wxyz	Convert quaternion [x, y, z, w] to [w, x, y, z] order.
skrobot.coordinates.math.wxyz2xyzw	Convert quaternion [w, x, y, z] to [x, y, z, w] order.
skrobot.coordinates.math.random_quaternion	Generate uniform random unit quaternion.
skrobot.coordinates.math.quaternion_multiply	Return multiplication of two quaternions.
skrobot.coordinates.math.quaternion_conjugate	Return conjugate of quaternion.
skrobot.coordinates.math.quaternion_inverse	Return inverse of quaternion.
skrobot.coordinates.math.quaternion_slerp	Return spherical linear interpolation between two quaternions.
skrobot.coordinates.math.quaternion_distance	Return the distance of quaternion.
skrobot.coordinates.math.quaternion_absolute_distance	Return the absolute distance of quaternion.
skrobot.coordinates.math.quaternion_norm	Return the norm of quaternion.
skrobot.coordinates.math.quaternion_normalize	Return the normalized quaternion.
skrobot.coordinates.math.matrix2quaternion	Returns quaternion of given rotation matrix.
skrobot.coordinates.math.quaternion2matrix	Returns matrix of given quaternion.

continues on next page

Table 10 – continued from previous page

skrobot.coordinates.math.quaternion2rpy	Returns Roll-pitch-yaw angles of a given quaternion.
skrobot.coordinates.math.rpy2quaternion	Return Quaternion from yaw-pitch-roll angles.
skrobot.coordinates.math.rpy_from_quat	Returns Roll-pitch-yaw angles of a given quaternion.
skrobot.coordinates.math.quat_from_rotation_matrix	Returns quaternion of given rotation matrix.
skrobot.coordinates.math.quat_from_rpy	Return Quaternion from yaw-pitch-roll angles.
skrobot.coordinates.math.rotation_matrix_from_quat	Returns matrix of given quaternion.
skrobot.coordinates.math.quaternion_from_axis_angle	Return the quaternion from axis angle
skrobot.coordinates.math.axis_angle_from_quaternion	Converts a quaternion into the axis-angle representation.

skrobot.coordinates.math.xyzw2wxyz

skrobot.coordinates.math.**xyzw2wxyz**(*quat*)

Convert quaternion [x, y, z, w] to [w, x, y, z] order.

Parameters **quat** (*list or numpy.ndarray*) – quaternion [x, y, z, w]

Returns **quaternion** – quaternion [w, x, y, z]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import xyzw2wxyz
>>> xyzw2wxyz([1, 2, 3, 4])
array([4, 1, 2, 3])
```

skrobot.coordinates.math.wxyz2xyzw

skrobot.coordinates.math.**wxyz2xyzw**(*quat*)

Convert quaternion [w, x, y, z] to [x, y, z, w] order.

Parameters **quat** (*list or numpy.ndarray*) – quaternion [w, x, y, z]

Returns **quaternion** – quaternion [x, y, z, w]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import wxyz2xyzw
>>> wxyz2xyzw([1, 2, 3, 4])
array([2, 3, 4, 1])
```

skrobot.coordinates.math.random_quaternion

`skrobot.coordinates.math.random_quaternion()`

Generate uniform random unit quaternion.

Returns **quaternion** – generated random unit quaternion [w, x, y, z]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import random_quaternion
>>> random_quaternion()
array([-0.02156994,  0.5404561 , -0.72781116, -0.42158374])
>>> random_quaternion()
array([-0.47302116,  0.020306  , -0.37539238,  0.79681818])
>>> from skrobot.coordinates.math import quaternion_norm
>>> q = random_quaternion()
>>> numpy.allclose(1.0, quaternion_norm(q))
True
>>> q.shape
(4,)
```

skrobot.coordinates.math.quaternion_multiply

`skrobot.coordinates.math.quaternion_multiply(`*quaternion1*, *quaternion0*`)`

Return multiplication of two quaternions.

Parameters

- **quaternion0** (*list or numpy.ndarray*) – [w, x, y, z]
- **quaternion1** (*list or numpy.ndarray*) – [w, x, y, z]

Returns **quaternion** – [w, x, y, z]

Return type numpy.ndarray

Examples

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

skrobot.coordinates.math.quaternion_conjugate

skrobot.coordinates.math.**quaternion_conjugate**(*quaternion*)

Return conjugate of quaternion.

Parameters **quaternion** (*list or numpy.ndarray*) – quaternion [w, x, y, z]

Returns **conjugate of quaternion** – [w, x, y, z]

Return type numpy.ndarray

Examples

```
>>> q0 = random_quaternion()
>>> q1 = quaternion_conjugate(q0)
>>> np.allclose(quaternion_multiply(q0, q1), [1.0, 0, 0, 0])
True
```

skrobot.coordinates.math.quaternion_inverse

skrobot.coordinates.math.**quaternion_inverse**(*quaternion*)

Return inverse of quaternion.

Parameters **quaternion** (*list or numpy.ndarray*) – [w, x, y, z]

Returns **inverse of quaternion** – [w, x, y, z]

Return type numpy.ndarray

Examples

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

skrobot.coordinates.math.quaternion_slerp

skrobot.coordinates.math.**quaternion_slerp**(*q0*, *q1*, *fraction*, *spin=0*, *shortestpath=True*)

Return spherical linear interpolation between two quaternions.

Parameters

- **q0** (*list or numpy.ndarray*) – start quaternion
- **q1** (*list or numpy.ndarray*) – end quaternion
- **fraction** (*float*) – ratio
- **spin** (*int*) – TODO
- **shortestpath** (*bool*) – TODO

Returns **quaternion** – spherical linear interpolated quaternion

Return type numpy.ndarray

Examples

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

skrobot.coordinates.math.quaternion_distance

skrobot.coordinates.math.**quaternion_distance**(*q1*, *q2*, *absolute=False*)

Return the distance of quaternion.

Parameters

- **q1** (*list or numpy.ndarray*) –
- **q2** (*list or numpy.ndarray*) – [w, x, y, z] order
- **absolute** (*bool*) – if True, return distance accounting for the sign ambiguity.

Returns **diff_theta** – distance of q1 and q2 in radian.

Return type float

Examples

```
>>> from skrobot.coordinates.math import quaternion_distance
>>> quaternion_distance([1, 0, 0, 0], [1, 0, 0, 0])
0.0
>>> quaternion_distance([1, 0, 0, 0], [0, 1, 0, 0])
3.141592653589793
>>> distance = quaternion_distance(
        [1, 0, 0, 0],
        [0.8660254, 0, 0.5, 0])
>>> np.rad2deg(distance)
60.00000021683236
```

skrobot.coordinates.math.quaternion_absolute_distance

skrobot.coordinates.math.**quaternion_absolute_distance**(*q1*, *q2*)

Return the absolute distance of quaternion.

Parameters

- **q1** (*list or numpy.ndarray*) –
- **q2** (*list or numpy.ndarray*) – [w, x, y, z] order

Returns **diff_theta** – absolute distance of q1 and q2 in radian.

Return type float

Examples

```
>>> from skrobot.coordinates.math import quaternion_absolute_distance
>>> quaternion_absolute_distance([1, 0, 0, 0], [1, 0, 0, 0])
0.0
>>> quaternion_absolute_distance(
        [1, 0, 0, 0],
        [0, 0.7071067811865476, 0, 0.7071067811865476])
3.141592653589793
>>> quaternion_absolute_distance(
        [-1, 0, 0, 0],
        [0, 0.7071067811865476, 0, 0.7071067811865476])
```

skrobot.coordinates.math.quaternion_norm

skrobot.coordinates.math.**quaternion_norm**(*q*)

Return the norm of quaternion.

Parameters **q** (*list or numpy.ndarray*) – [w, x, y, z] order

Returns **norm_q** – quaternion norm of q

Return type float

Examples

```
>>> from skrobot.coordinates.math import quaternion_norm
>>> q = [1, 1, 1, 1]
>>> quaternion_norm(q)
2.0
>>> q = [0, 0.7071067811865476, 0, 0.7071067811865476]
>>> quaternion_norm(q)
1.0
```

skrobot.coordinates.math.quaternion_normalize

skrobot.coordinates.math.**quaternion_normalize**(*q*)

Return the normalized quaternion.

Parameters **q** (*list or numpy.ndarray*) – [w, x, y, z] order

Returns **normalized_q** – normalized quaternion

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import quaternion_normalize
>>> from skrobot.coordinates.math import quaternion_norm
>>> q = quaternion_normalize([1, 1, 1, 1])
>>> quaternion_norm(q)
1.0
```

skrobot.coordinates.math.matrix2quaternion

skrobot.coordinates.math.**matrix2quaternion**(*m*)

Returns quaternion of given rotation matrix.

Parameters **m** (*list or numpy.ndarray*) – 3x3 rotation matrix

Returns **quaternion** – quaternion [w, x, y, z] order

Return type numpy.ndarray

Examples

```
>>> import numpy
>>> from skrobot.coordinates.math import matrix2quaternion
>>> matrix2quaternion(np.eye(3))
array([1., 0., 0., 0.])
```

skrobot.coordinates.math.quaternion2matrix

skrobot.coordinates.math.**quaternion2matrix**(*q*, *normalize=False*)

Returns matrix of given quaternion.

Parameters

- **quaternion** (*list or numpy.ndarray*) – quaternion [w, x, y, z] order
- **normalize** (*bool*) – if normalize is True, input quaternion is normalized.

Returns **rot** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy
>>> from skrobot.coordinates.math import quaternion2matrix
>>> quaternion2matrix([1, 0, 0, 0])
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
```

skrobot.coordinates.math.quaternion2rpy

skrobot.coordinates.math.**quaternion2rpy**(*q*)

Returns Roll-pitch-yaw angles of a given quaternion.

Parameters **q** (*numpy.ndarray or list*) – Quaternion in [w x y z] format.

Returns **rpy** – Array of yaw-pitch-roll angles, in radian.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import quaternion2rpy
>>> quaternion2rpy([1, 0, 0, 0])
(array([ 0., -0.,  0.]), array([3.14159265, 3.14159265, 3.14159265]))
>>> quaternion2rpy([0, 1, 0, 0])
(array([ 0.        , -0.        ,  3.14159265]),
 array([3.14159265, 3.14159265, 0.        ]))
```

skrobot.coordinates.math.rpy2quaternion

skrobot.coordinates.math.**rpy2quaternion**(*rpy*)

Return Quaternion from yaw-pitch-roll angles.

Parameters **rpy** (*numpy.ndarray or list*) – Vector of yaw-pitch-roll angles in radian.

Returns **quat** – Quaternion in [w x y z] format.

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates.math import rpy2quaternion
>>> rpy2quaternion([0, 0, 0])
array([1., 0., 0., 0.])
>>> yaw = np.pi / 3.0
>>> rpy2quaternion([yaw, 0, 0])
array([0.8660254, 0.       , 0.       , 0.5      ])
>>> rpy2quaternion([np.pi * 2 - yaw, 0, 0])
array([-0.8660254, -0.       ,  0.       ,  0.5      ])
```

skrobot.coordinates.math.rpy_from_quat

skrobot.coordinates.math.**rpy_from_quat**(*q*)

Returns Roll-pitch-yaw angles of a given quaternion.

Parameters **q** (*numpy.ndarray or list*) – Quaternion in [w x y z] format.

Returns **rpy** – Array of yaw-pitch-roll angles, in radian.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import quaternion2rpy
>>> quaternion2rpy([1, 0, 0, 0])
(array([ 0., -0.,  0.]), array([3.14159265, 3.14159265, 3.14159265]))
>>> quaternion2rpy([0, 1, 0, 0])
(array([ 0.        , -0.        ,  3.14159265]),
 array([3.14159265, 3.14159265, 0.        ]))
```

skrobot.coordinates.math.quat_from_rotation_matrix

skrobot.coordinates.math.**quat_from_rotation_matrix**(*m*)

Returns quaternion of given rotation matrix.

Parameters **m** (*list or numpy.ndarray*) – 3x3 rotation matrix

Returns **quaternion** – quaternion [w, x, y, z] order

Return type numpy.ndarray

Examples

```
>>> import numpy
>>> from skrobot.coordinates.math import matrix2quaternion
>>> matrix2quaternion(np.eye(3))
array([1., 0., 0., 0.])
```

skrobot.coordinates.math.quat_from_rpy

skrobot.coordinates.math.**quat_from_rpy**(*rpy*)

Return Quaternion from yaw-pitch-roll angles.

Parameters **rpy** (*numpy.ndarray or list*) – Vector of yaw-pitch-roll angles in radian.

Returns **quat** – Quaternion in [w x y z] format.

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates.math import rpy2quaternion
>>> rpy2quaternion([0, 0, 0])
array([1., 0., 0., 0.])
>>> yaw = np.pi / 3.0
>>> rpy2quaternion([yaw, 0, 0])
array([0.8660254, 0.        , 0.        , 0.5       ])
>>> rpy2quaternion([np.pi * 2 - yaw, 0, 0])
array([-0.8660254, -0.        ,  0.        ,  0.5       ])
```

skrobot.coordinates.math.rotation_matrix_from_quat

`skrobot.coordinates.math.`**`rotation_matrix_from_quat`**(*q*, *normalize=False*)

Returns matrix of given quaternion.

Parameters

- **quaternion** (*list or numpy.ndarray*) – quaternion [w, x, y, z] order
- **normalize** (*bool*) – if normalize is True, input quaternion is normalized.

Returns **rot** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy
>>> from skrobot.coordinates.math import quaternion2matrix
>>> quaternion2matrix([1, 0, 0, 0])
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
```

skrobot.coordinates.math.quaternion_from_axis_angle

`skrobot.coordinates.math.`**`quaternion_from_axis_angle`**(*theta*, *axis*)

Return the quaternion from axis angle

This function returns quaternion associated with counterclockwise rotation about the given axis by theta radians.

Parameters

- **theta** (*float*) – radian
- **axis** (*list or numpy.ndarray*) – length is 3. Automatically normalize in this function

Returns **quaternion** – [w, x, y, z] order

Return type numpy.ndarray

Examples

```
>>> import numpy
>>> from skrobot.coordinates.math import quaternion_from_axis_angle
>>> quaternion_from_axis_angle(0.1, [1, 0, 0])
array([0.99875026, 0.04997917, 0.        , 0.        ])
>>> quaternion_from_axis_angle(numpy.pi, [1, 0, 0])
array([6.123234e-17, 1.000000e+00, 0.000000e+00, 0.000000e+00])
>>> quaternion_from_axis_angle(0, [1, 0, 0])
array([1., 0., 0., 0.])
>>> quaternion_from_axis_angle(numpy.pi, [1, 0, 1])
array([6.12323400e-17, 7.07106781e-01, 0.00000000e+00, 7.07106781e-01])
```

skrobot.coordinates.math.axis_angle_from_quaternion

skrobot.coordinates.math.**axis_angle_from_quaternion**(*quat*)

Converts a quaternion into the axis-angle representation.

Parameters **quat** (*numpy.ndarray*) – quaternion [w, x, y, z]

Returns **axis_angle** – axis-angle representation of vector

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates.math import axis_angle_from_quaternion
>>> axis_angle_from_quaternion([1, 0, 0, 0])
array([0, 0, 0])
>>> axis_angle_from_quaternion([0, 7.07106781e-01, 0, 7.07106781e-01])
array([2.22144147, 0.        , 2.22144147])
```

3.3.4 Geometry functions

skrobot.coordinates.geo.rotate_points	Rotate given points based on a starting and ending vector.

skrobot.coordinates.geo.rotate_points

skrobot.coordinates.geo.**rotate_points**(*points*, *a*, *b*)

Rotate given points based on a starting and ending vector.

Axis vector k is calculated from the any two nonzero vectors a and b. Rotated points are calculated from following Rodrigues rotation formula.

$$`P_{rot} = P\cos\theta + (k \times P)\sin\theta + k(k \cdot P)(1 - \cos\theta)`$$

Parameters

- **points** (*numpy.ndarray*) – Input points. The shape should be (3,) or (N, 3).
- **a** (*numpy.ndarray*) – nonzero vector.

- **b** (*numpy.ndarray*) – nonzero vector.

Returns **points_rot** – rotated points.

Return type numpy.ndarray

3.4 Interfaces

3.4.1 Pybullet Interface

You can use a Pybullet interface using skrobot.

skrobot.interfaces._pybullet.PybulletRobotInterface	Pybullet Interface Class

skrobot.interfaces._pybullet.PybulletRobotInterface

class skrobot.interfaces._pybullet.**PybulletRobotInterface**(*robot*, *urdf_path=None*, *use_fixed_base=False*, *connect=1*, **args*, ***kwargs*)

Pybullet Interface Class

Parameters

- **robot** (skrobot.model.RobotModel) – robot model
- **urdf_path** (*None or str*) – urdf path. If this value is *None*, get *urdf_path* from *robot.urdf_path*.
- **use_fixed_base** (*bool*) – If this value is *True*, robot in pybullet simulator will be fixed.
- **connect** (*int*) – pybullet's connection mode. If you have already connected to pybullet physics server, specify the server id. The default value is 1 (pybullet.GUI).

Examples

```
>>> from skrobot.models import PR2
>>> from skrobot.interfaces import PybulletRobotInterface
>>> robot_model = PR2()
>>> interface = PybulletRobotInterface(robot_model)
```

If you have already connected to pybullet physics server

```
>>> import pybullet
>>> client_id = pybullet.connect(pybullet.GUI)
>>> robot_model = PR2()
>>> interface = PybulletRobotInterface(robot_model, connect=client_id)
```

Methods

T()

Return 4x4 homogeneous transformation matrix.

Returns **matrix** – homogeneous transformation matrix shape of (4, 4)

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.T()
array([[1., 0., 0., 0.],
       [0., 1., 0., 0.],
       [0., 0., 1., 0.],
       [0., 0., 0., 1.]])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.rotate(pi / 2.0, 'y')
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00,
         1.00000000e-01],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00,
         2.00000000e-01],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16,
         3.00000000e-01],
       [ 0.00000000e+00,  0.00000000e+00,  0.00000000e+00,
         1.00000000e+00]])
```

angle_vector(*angle_vector=None*, *realtime_simulation=None*)

Send a angle vector to pybullet's phsyics engine.

Parameters

- **angle_vector** (*None or numpy.ndarray*) – angle vector. If *None*, send self.robot.angle_vector()
- **realtime_simulation** (*None or bool*) – If this value is *True*, send angle_vector by pybullet.setJointMotorControl2.

Returns **angle_vector** – return sent angle vector.

Return type numpy.ndarray

static available()

Check Pybullet is available.

Returns **_available** – If *False*, pybullet is not available.

Return type bool

axis(*ax*)

changed()

Return False

This is used for CascadedCoords compatibility

Returns **False** – always return False

Return type bool

coords()
Return a deep copy of the Coordinates.

copy()
Return a deep copy of the Coordinates.

copy_coords()
Return a deep copy of the Coordinates.

copy_worldcoords()
Return a deep copy of the Coordinates.

difference_position(*coords*, *translation_axis=True*)
Return differences in positoin of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **translation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xy', 'yz', 'zx', 'xx', 'yy', 'zz', True or False(None).

Returns dif_pos – difference position of self coordinates and coords considering translation_axis.

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates import transform_coords
>>> from numpy import pi
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(
...          pi / 3.0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...          pi / 2.0, 'y')
>>> c1.difference_position(c2)
array([ 0.2       , -0.42320508,  0.3330127 ])
>>> c1 = Coordinates().translate([0.1, 0.2, 0.3]).rotate(0, 'x')
>>> c2 = Coordinates().translate([0.3, -0.3, 0.1]).rotate(
...          pi / 3.0, 'x')
>>> c1.difference_position(c2)
array([ 0.2, -0.5, -0.2])
```

difference_rotation(*coords*, *rotation_axis=True*)
Return differences in rotation of given coords.

Parameters

- **coords** (skrobot.coordinates.Coordinates) – given coordinates
- **rotation_axis** (*str or bool or None (optional)*) – we can take 'x', 'y', 'z', 'xx', 'yy', 'zz', 'xm', 'ym', 'zm', 'xy', 'yx', 'yz', 'zy', 'zx', 'xz', True or False(None).

Returns dif_rot – difference rotation of self coordinates and coords considering rotation_axis.

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import Coordinates
>>> from skrobot.coordinates.math import rpy_matrix
>>> coord1 = Coordinates()
>>> coord2 = Coordinates(rot=rpy_matrix(pi / 2.0, pi / 3.0, pi / 5.0))
>>> coord1.difference_rotation(coord2)
array([-0.32855112,  1.17434985,  1.05738936])
>>> coord1.difference_rotation(coord2, rotation_axis=False)
array([0, 0, 0])
>>> coord1.difference_rotation(coord2, rotation_axis='x')
array([0.        , 1.36034952, 0.78539816])
>>> coord1.difference_rotation(coord2, rotation_axis='y')
array([0.35398131, 0.        , 0.97442695])
>>> coord1.difference_rotation(coord2, rotation_axis='z')
array([-0.88435715,  0.74192175,  0.        ])
```

Using mirror option [‘xm’, ‘ym’, ‘zm’], you can allow differences of mirror direction.

```
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-2.99951957e-32,  0.00000000e+00,  0.00000000e+00])
>>> coord1 = Coordinates()
>>> coord2 = Coordinates().rotate(pi / 2.0, 'x')
>>> coord1.difference_rotation(coord2, 'xm')
array([-1.57079633,  0.        ,  0.        ])
```

disable_hook()

get_transform()

Return Transform object

Returns **transform** – corrensponding Transform to this coordinates

Return type skrobot.coordinates.base.Transform

inverse_rotate_vector(*v*)

inverse_transform_vector(*vec*)

Transform vector in world coordinates to local coordinates

Parameters **vec** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

inverse_transformation(*dest=None*)

Return a invese transformation of this coordinate system.

Create a new coordinate with inverse transformation of this coordinate system.

$$\begin{pmatrix} R^{-1} & -R^{-1}p \\ 0 & 1 \end{pmatrix}$$

Parameters **dest** (*None or* skrobot.coordinates.Coordinates) – If dest is given, the result of transformation is in-placed to dest.

Returns **dest** – result of inverse transformation.

Return type *skrobot.coordinates.Coordinates*

`load_bullet()`
Load bullet configurations.

This function internally called.

`move_coords`(*target_coords*, *local_coords*)
Transform this coordinate so that local_coords to target_coords.

Parameters

- **target_coords** (`skrobot.coordinates.Coordinates`) – target coords.
- **local_coords** (`skrobot.coordinates.Coordinates`) – local coords to be aligned.

Returns **self.worldcoords()** – world coordinates.

Return type *skrobot.coordinates.Coordinates*

`newcoords`(*c*, *pos=None*)
Update of position and orientation.

`orient_with_matrix`(*rotation_matrix*, *wrt='world'*)
Force update this coordinate system's rotation.

Parameters

- **rotation_matrix** (*numpy.ndarray*) – 3x3 rotation matrix.
- **wrt** (*str or* `skrobot.coordinates.Coordinates`) – reference coordinates.

`parent_orientation`(*v*, *wrt*)

`rotate`(*theta*, *axis=None*, *wrt='local'*)
Rotate this robot by given theta and axis.

For more detail, please see docs of skrobot.coordinates.Coordinates.rotate. The difference between the rotate, this function internally call pybullet.resetBasePositionAndOrientation.

Parameters

- **theta** (*float*) – radian
- **wrt** (*string or* `skrobot.coordinates.Coordinates`) –

`rotate_vector`(*v*)
Rotate 3-dimensional vector using rotation of this coordinate

Parameters **v** (*numpy.ndarray*) – vector shape of (3,)

Returns **np.matmul(self.rotation, v)** – rotated vector

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> from numpy import pi
>>> c = Coordinates().rotate(pi, 'z')
>>> c.rotate_vector([1, 2, 3])
array([-1., -2.,  3.])
```

rotate_with_matrix(*mat*, *wrt='local'*)

Rotate this coordinate by given rotation matrix.

This is a subroutine of self.rotate function.

Parameters

- **mat** (*numpy.ndarray*) – rotation matrix shape of (3, 3)
- **wrt** (*str or* skrobot.coordinates.Coordinates) – with respect to.

Returns self

Return type *skrobot.coordinates.Coordinates*

rpy_angle()

Return a pair of rpy angles of this coordinates.

Returns **rpy_angle(self.rotation)** – a pair of rpy angles. See also skrobot.coordinates.math.rpy_angle

Return type tuple(numpy.ndarray, numpy.ndarray)

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates().rotate(np.pi / 2.0, 'x').rotate(np.pi / 3.0, 'z')
>>> r.rpy_angle()
(array([ 3.84592537e-16, -1.04719755e+00,  1.57079633e+00]),
array([ 3.14159265, -2.0943951 , -1.57079633]))
```

sync()

Synchronize pybullet pose to robot_model.

transform(*c*, *wrt='local'*)

Transform this coordinate by coords based on wrt

For more detail, please see docs of skrobot.coordinates.Coordinates.transform. The difference between the transform, this function internally call pybullet.resetBasePositionAndOrientation.

Parameters

- **c** (skrobot.coordinates.Coordinates) – coordinate
- **wrt** (*string or* skrobot.coordinates.Coordinates) – If wrt is 'local' or self, multiply c from the right. If wrt is 'world' or 'parent' or self.parent, transform c with respect to worldcoord. If wrt is Coordinates, transform c with respect to c.

transform_vector(*v*)

"Return vector represented at world frame.

Vector v given in the local coords is converted to world representation.

Parameters **v** (*numpy.ndarray*) – 3d vector. We can take batch of vector like (batch_size, 3)

Returns **transformed_point** – transformed point

Return type numpy.ndarray

transformation(*c2*, *wrt='local'*)

translate(*vec*, *wrt='local'*)

Translate robot in simulator.

For more detail, please see docs of skrobot.coordinates.Coordinates.translate. The difference between the translate, this function internally call pybullet.resetBasePositionAndOrientation.

Parameters

- **vec** (*list or np.ndarray*) – shape of (3,) translation vector. unit is [m] order.
- **wrt** (*string or Coordinates (optional)*) – translate with respect to wrt.

wait_interpolation(*thresh=0.05*, *timeout=60.0*)

Wait robot movement.

This function usually called after self.angle_vector. Wait while the robot joints are moving or until time of timeout. This function called internally pybullet.stepSimulation().

Parameters

- **thresh** (*float*) – velocity threshold for detecting movement stop.
- **timeout** (*float*) – maximum time of timeout.

worldcoords()

Return thisself

worldpos()

Return translation of this coordinate

See also skrobot.coordinates.Coordinates.translation

Returns **self.translation** – translation of this coordinate

Return type numpy.ndarray

worldrot()

Return rotation of this coordinate

See also skrobot.coordinates.Coordinates.rotation

Returns **self.rotation** – rotation matrix of this coordinate

Return type numpy.ndarray

__eq__(*value*, */*)

Return self==value.

__ne__(*value*, */*)

Return self!=value.

__lt__(*value*, */*)

Return self<value.

__le__(*value*, */*)

Return self<=value.

__gt__(*value*, */*)

Return self>value.

`__ge__`(*value*, */*)
Return self>=value.

`__mul__`(*other_c*)
Return Transformed Coordinates.

Note that this function creates new Coordinates and does not change translation and rotation, unlike transform function.

Parameters `other_c` (`skrobot.coordinates.Coordinates`) – input coordinates.

Returns **out** – transformed coordinates multiplied other_c from the right. T = T_{self} T_{other_c}.

Return type *skrobot.coordinates.Coordinates*

`__pow__`(*exponent*)
Return exponential homogeneous matrix.

If exponent equals -1, return inverse transformation of this coords.

Parameters `exponent` (*numbers.Number*) – exponent value. If exponent equals -1, return inverse transformation of this coords. In current, support only -1 case.

Returns **out** – output.

Return type *skrobot.coordinates.Coordinates*

Attributes

`dimension`
Return dimension of this coordinate

Returns **len(self.translation)** – dimension of this coordinate

Return type int

`dual_quaternion`
Property of DualQuaternion

Return DualQuaternion representation of this coordinate.

Returns **DualQuaternion** – DualQuaternion representation of this coordinate

Return type *skrobot.coordinates.dual_quaternion.DualQuaternion*

`name`
Return this coordinate's name

Returns **self._name** – name of this coordinate

Return type str

`pose`
Getter of Pose in pybullet phsyics simulator.

Wrapper of pybullet.getBasePositionAndOrientation.

Returns **pose** – pose of this robot in the phsyics simulator.

Return type *skrobot.coordinates.Coordinates*

`quaternion`
Property of quaternion

Returns **q** – [w, x, y, z] quaternion

Return type numpy.ndarray

Examples

```
>>> from numpy import pi
>>> from skrobot.coordinates import make_coords
>>> c = make_coords()
>>> c.quaternion
array([1., 0., 0., 0.])
>>> c.rotate(pi / 3, 'y').rotate(pi / 5, 'z')
>>> c.quaternion
array([0.8236391 , 0.1545085 , 0.47552826, 0.26761657])
```

rotation

Return rotation matrix of this coordinates.

Returns **self._rotation** – 3x3 rotation matrix

Return type numpy.ndarray

Examples

```
>>> import numpy as np
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.rotation
array([[1., 0., 0.],
       [0., 1., 0.],
       [0., 0., 1.]])
>>> c.rotate(np.pi / 2.0, 'y')
>>> c.rotation
array([[ 2.22044605e-16,  0.00000000e+00,  1.00000000e+00],
       [ 0.00000000e+00,  1.00000000e+00,  0.00000000e+00],
       [-1.00000000e+00,  0.00000000e+00,  2.22044605e-16]])
```

translation

Return translation of this coordinates.

Returns **self._translation** – vector shape of (3,). unit is [m]

Return type numpy.ndarray

Examples

```
>>> from skrobot.coordinates import Coordinates
>>> c = Coordinates()
>>> c.translation
array([0., 0., 0.])
>>> c.translate([0.1, 0.2, 0.3])
>>> c.translation
array([0.1, 0.2, 0.3])
```

x_axis

Return x axis vector of this coordinates.

Returns **axis** – x axis.

Return type numpy.ndarray

y_axis

Return y axis vector of this coordinates.

Returns **axis** – y axis.

Return type numpy.ndarray

z_axis

Return z axis vector of this coordinates.

Returns **axis** – z axis.

Return type numpy.ndarray

```
>>> from skrobot.models import PR2
>>> from skrobot.interfaces import PybulletRobotInterface
>>> import pybullet
>>> client_id = pybullet.connect(pybullet.GUI)
>>> robot_model = PR2()
>>> interface = PybulletRobotInterface(robot_model, connect=client_id)
>>> interface.angle_vector(robot_model.reset_pose())
```

3.5 Signed distance function (SDF)

3.5.1 SDF classes

skrobot.sdf.SignedDistanceFunction	A base class for signed distance functions (SDFs).
skrobot.sdf.UnionSDF	One can concat multiple SDFs *sdf_list* by using this class.
skrobot.sdf.BoxSDF	SDF for a box specified by *origin* and *width*.
skrobot.sdf.GridSDF	SDF using precopmuted signed distances for gridded points.
skrobot.sdf.CylinderSDF	SDF for a cylinder specified by *origin*,`radius` and *height*
skrobot.sdf.SphereSDF	SDF for a sphere specified by *origin* and *radius*.

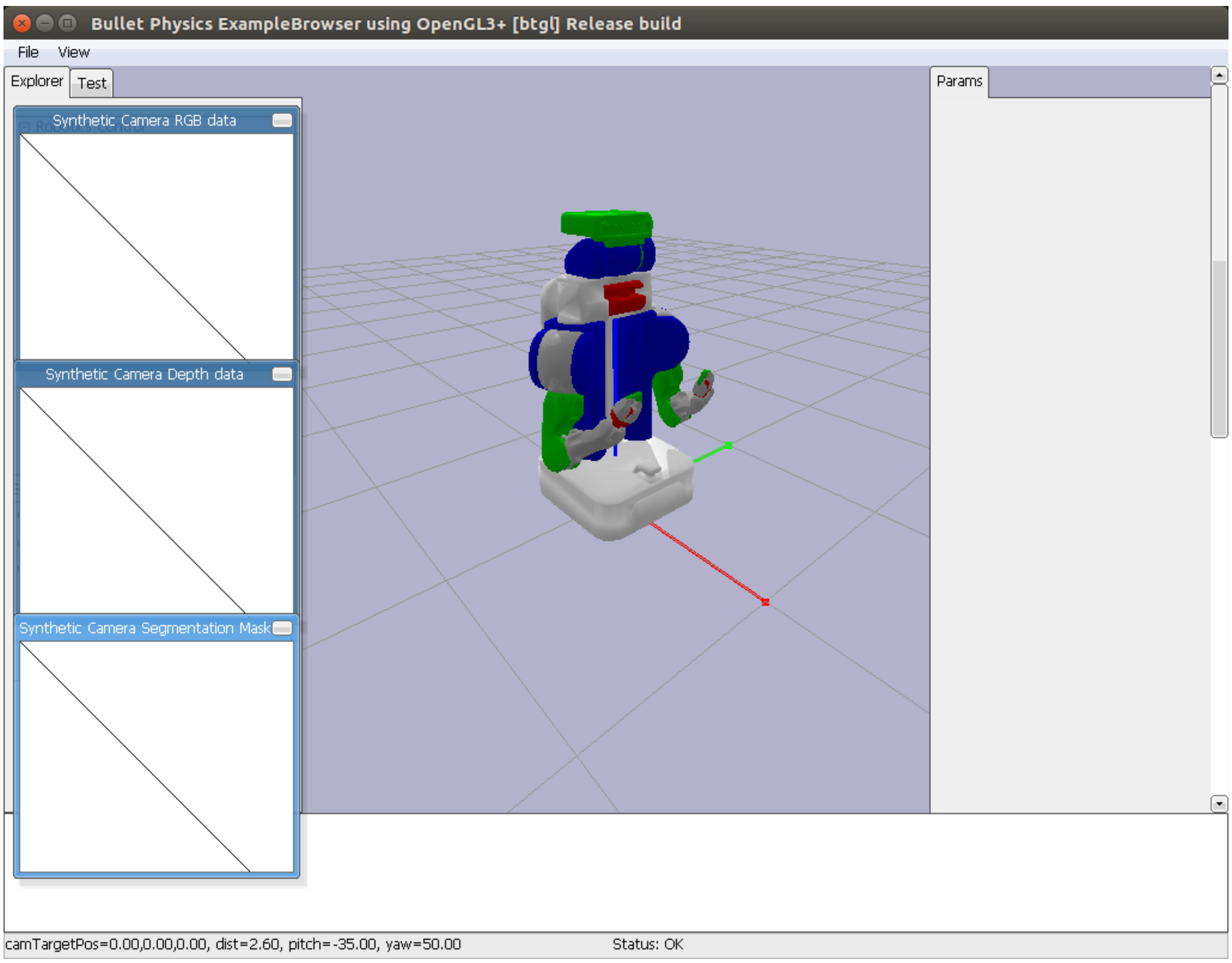
skrobot.sdf.SignedDistanceFunction

class skrobot.sdf.**SignedDistanceFunction**(*origin*, *coords=None*, *use_abs=False*)

A base class for signed distance functions (SDFs).

Suffixes *_obj* and *_sdf* (e.g. in points_sdf) indicate that points are expressed in the sdf's object coordinate (*self.coords*) and sdf-specfic coordinate respectively. Each SDF performs the signed-distance computation in its own sdf-specific coordinate. For example, the origin of GridSDF's sdf-specific coordinate is the tip of the precomputed-gridded-box.

Usually, a child class implements the computation in the sdf-specific coordinates and SignedDistanceFunction wraps them so that the user can pass and get points and values expressed in an object coordinate. Thus, it is less


Bullet Physics ExampleBrowser using OpenGL3+ [btgl] Release build
File View
Explorer Test
Synthetic Camera RGB data
Synthetic Camera Depth data
Synthetic Camera Segmentation Mask
Params
camTargetPos=0.00,0.00,0.00, dist=2.60, pitch=-35.00, yaw=50.00
Status: OK

likely that a user directly calls a method in a child class.

Methods

`__call__`(*points_obj*)

Compute signed distances of input points to the implicit surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. object coordinate.

Returns **signed_distances** – 1 dim (n_point,) array of signed distance.

Return type numpy.ndarray[float]

`on_surface`(*points_obj*)

Check if points are on the surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. an object coordinate.

Returns

- **logicals** (*numpy.ndarray[bool](n_point,)*) – boolean vector of the on-surface predicate for *points_obj*.
- **sd_vals** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to *logicals*.

`surface_points`(*n_sample=1000*)

Sample points from the implicit surface of the sdf.

Parameters **n_sample** (*int*) – number of sample points.

Returns

- **points_obj** (*numpy.ndarray[float](n_point, 3)*) – sampled points w.r.t object coordinate.
- **dists** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to points_obj.

`__eq__`(*value*, /)

Return self==value.

`__ne__`(*value*, /)

Return self!=value.

`__lt__`(*value*, /)

Return self<value.

`__le__`(*value*, /)

Return self<=value.

`__gt__`(*value*, /)

Return self>value.

`__ge__`(*value*, /)

Return self>=value.

skrobot.sdf.UnionSDF

class skrobot.sdf.**UnionSDF**(*sdf_list*, *coords=None*)

One can concat multiple SDFs *sdf_list* by using this class.

For consistency in the concatenation, it is required that the all SDFs to be concated are with *use_abs=False*.

Methods

__call__(*points_obj*)

Compute signed distances of input points to the implicit surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. object coordinate.

Returns **signed_distances** – 1 dim (n_point,) array of signed distance.

Return type numpy.ndarray[float]

classmethod from_robot_model(*robot_model*, *dim_grid=50*)

Create union sdf from a robot model

Parameters **robot_model** (skrobot.model.RobotModel) – Using the links of the robot_model this creates the UnionSDF instance.

Returns **union_sdf** – union sdf of robot_model

Return type *skrobot.sdf.UnionSDF*

on_surface(*points_obj*)

Check if points are on the surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. an object coordinate.

Returns

- **logicals** (*numpy.ndarray[bool](n_point,)*) – boolean vector of the on-surface predicate for *points_obj*.
- **sd_vals** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to *logicals*.

surface_points(*n_sample=1000*)

Sample points from the implicit surface of the sdf.

Parameters **n_sample** (*int*) – number of sample points.

Returns

- **points_obj** (*numpy.ndarray[float](n_point, 3)*) – sampled points w.r.t object coordinate.
- **dists** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to points_obj.

__eq__(*value*, */*)

Return self==value.

__ne__(*value*, */*)

Return self!=value.

__lt__(*value*, */*)

Return self<value.

__le__(*value*, */*)

Return self<=value.

`__gt__`(*value*, */*)
Return self>value.

`__ge__`(*value*, */*)
Return self>=value.

skrobot.sdf.BoxSDF

class `skrobot.sdf.BoxSDF`(*origin*, *width*, *coords=None*, *use_abs=False*)
SDF for a box specified by *origin* and *width*.

Methods

`__call__`(*points_obj*)
Compute signed distances of input points to the implicit surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. object coordinate.

Returns **signed_distances** – 1 dim (n_point,) array of signed distance.

Return type numpy.ndarray[float]

`on_surface`(*points_obj*)
Check if points are on the surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. an object coordinate.

Returns

- **logicals** (*numpy.ndarray[bool](n_point,)*) – boolean vector of the on-surface predicate for *points_obj*.
- **sd_vals** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to *logicals*.

`surface_points`(*n_sample=1000*)
Sample points from the implicit surface of the sdf.

Parameters **n_sample** (*int*) – number of sample points.

Returns

- **points_obj** (*numpy.ndarray[float](n_point, 3)*) – sampled points w.r.t object coordinate.
- **dists** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to points_obj.

`__eq__`(*value*, */*)
Return self==value.

`__ne__`(*value*, */*)
Return self!=value.

`__lt__`(*value*, */*)
Return self<value.

`__le__`(*value*, */*)
Return self<=value.

`__gt__`(*value*, */*)
Return self>value.

`__ge__`(*value*, */*)
Return self>=value.

skrobot.sdf.GridSDF

class skrobot.sdf.**GridSDF**(*sdf_data*, *origin*, *resolution*, *fill_value=inf*, *coords=None*, *use_abs=False*)
SDF using precopmuted signed distances for gridded points.

Methods

`__call__`(*points_obj*)
Compute signed distances of input points to the implicit surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. object coordinate.

Returns **signed_distances** – 1 dim (n_point,) array of signed distance.

Return type numpy.ndarray[float]

static **from_file**(*filepath*)
Return GridSDF instance from a .sdf file.

Parameters **filepath** (*str or pathlib.Path*) – path of .sdf file

Returns **sdf_instance** – instance of sdf

Return type skrobot.esdf.GridSDF

static **from_objfile**(*obj_filepath*, *dim_grid=100*, *padding_grid=5*)
Return GridSDF instance from an .obj file.

In the initial call of this method for an .obj file, the pre-process takes some time to converting it to a .sdf file. However, because a cache of .sdf file is created in the initial call, there is no overhead from the next call for the same .obj file.

Parameters

- **obj_filepath** (*str or pathlib.Path*) – path of objfile
- **dim_grid** (*int*) – dim of sdf
- **padding_grid** (*int*) – number of padding

Returns **sdf_instance** – instance of sdf

Return type *skrobot.sdf.GridSDF*

is_out_of_bounds(*points_obj*)
check if the the input points is out of bounds

This method checks if the the input points is out of bounds of RegularGridInterpolator.

Parameters **points_obj** (*numpy.ndarray[float](n_points, 3)*) – points w.r.t. object to be checked.

Returns **is_out_arr** – If points is out of the interpolator's boundary, the correspoinding element of is_out_arr is True

Return type numpy.ndarray[bool](n_points,)

on_surface(*points_obj*)
Check if points are on the surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. an object coordinate.

Returns

- **logicals** (*numpy.ndarray[bool](n_point,)*) – boolean vector of the on-surface predicate for *points_obj*.
- **sd_vals** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to *logicals*.

surface_points(*n_sample=1000*)

Sample points from the implicit surface of the sdf.

Parameters **n_sample** (*int*) – number of sample points.

Returns

- **points_obj** (*numpy.ndarray[float](n_point, 3)*) – sampled points w.r.t object coordinate.
- **dists** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to points_obj.

__eq__(*value*, */*)

Return self==value.

__ne__(*value*, */*)

Return self!=value.

__lt__(*value*, */*)

Return self<value.

__le__(*value*, */*)

Return self<=value.

__gt__(*value*, */*)

Return self>value.

__ge__(*value*, */*)

Return self>=value.

skrobot.sdf.CylinderSDF

class skrobot.sdf.**CylinderSDF**(*origin*, *height*, *radius*, *coords=None*, *use_abs=False*)

SDF for a cylinder specified by *origin*,`radius` and *height*

Methods

__call__(*points_obj*)

Compute signed distances of input points to the implicit surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. object coordinate.

Returns **signed_distances** – 1 dim (n_point,) array of signed distance.

Return type numpy.ndarray[float]

on_surface(*points_obj*)

Check if points are on the surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. an object coordinate.

Returns

- **logicals** (*numpy.ndarray[bool](n_point,)*) – boolean vector of the on-surface predicate for *points_obj*.
- **sd_vals** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to *logicals*.

`surface_points`(*n_sample=1000*)
Sample points from the implicit surface of the sdf.

Parameters **n_sample** (*int*) – number of sample points.

Returns

- **points_obj** (*numpy.ndarray[float](n_point, 3)*) – sampled points w.r.t object coordinate.
- **dists** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to points_obj.

`__eq__`(*value*, */*)
Return self==value.

`__ne__`(*value*, */*)
Return self!=value.

`__lt__`(*value*, */*)
Return self<value.

`__le__`(*value*, */*)
Return self<=value.

`__gt__`(*value*, */*)
Return self>value.

`__ge__`(*value*, */*)
Return self>=value.

skrobot.sdf.SphereSDF

`class skrobot.sdf.SphereSDF`(*origin*, *radius*, *coords=None*, *use_abs=False*)
SDF for a sphere specified by *origin* and *radius*.

Methods

`__call__`(*points_obj*)
Compute signed distances of input points to the implicit surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. object coordinate.

Returns **signed_distances** – 1 dim (n_point,) array of signed distance.

Return type numpy.ndarray[float]

`on_surface`(*points_obj*)
Check if points are on the surface.

Parameters **points_obj** (*numpy.ndarray[float](n_point, 3)*) – 2 dim point array w.r.t. an object coordinate.

Returns

- **logicals** (*numpy.ndarray[bool](n_point,)*) – boolean vector of the on-surface predicate for *points_obj*.
- **sd_vals** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to *logicals*.

surface_points(*n_sample=1000*)
Sample points from the implicit surface of the sdf.

Parameters **n_sample** (*int*) – number of sample points.

Returns

- **points_obj** (*numpy.ndarray[float](n_point, 3)*) – sampled points w.r.t object coordinate.
- **dists** (*numpy.ndarray[float](n_point,)*) – signed distances corresponding to points_obj.

__eq__(*value*, */*)
Return self==value.

__ne__(*value*, */*)
Return self!=value.

__lt__(*value*, */*)
Return self<value.

__le__(*value*, */*)
Return self<=value.

__gt__(*value*, */*)
Return self>value.

__ge__(*value*, */*)
Return self>=value.

3.5.2 SDF utilities

skrobot.sdf.signed_distance_function.trimesh2sdf	Convert trimesh to signed distance function.
skrobot.sdf.signed_distance_function.link2sdf	Convert Link to corresponding sdf

skrobot.sdf.signed_distance_function.trimesh2sdf

skrobot.sdf.signed_distance_function.**trimesh2sdf**(*mesh*, *dim_grid=100*, *padding_grid=5*)
Convert trimesh to signed distance function.

Parameters

- **mesh** (*trimesh.base.Trimesh*) – mesh object.
- **dim_grid** (*int*) – dimension of the GridSDF. This value is used for a not primitive mesh.
- **padding_grid** (*int*) – number of padding.

Returns **sdf** – converted signed distance function.

Return type *skrobot.sdf.SignedDistanceFunction*

skrobot.sdf.signed_distance_function.link2sdf

skrobot.sdf.signed_distance_function.**link2sdf**(*link*, *urdf_path*, *dim_grid=30*)
Convert Link to corresponding sdf

Parameters

- **link** (*skrobot.model.Link*) – link object
- **urdf_path** (*str*) – urdf path of the robot model that the link belongs to
- **dim_grid** (*int*) – dimension of the GridSDF

Returns **sdf** – corresponding signed distance function to the link type. e.g. if Link has geometry of urdf.Box, then BoxSDF is created.

Return type *skrobot.sdf.SignedDistanceFunction*

3.6 Planning

3.6.1 Sdf-swept-sphere-based collision checker

skrobot.planner.SweptSphereSdfCollisionChecker	Collision checker between swept spheres and sdf

skrobot.planner.SweptSphereSdfCollisionChecker

class skrobot.planner.**SweptSphereSdfCollisionChecker**(*sdf*, *robot_model*)
Collision checker between swept spheres and sdf

Methods

add_coll_spheres_to_viewer(*viewer*)
Add collision sheres to viewer

Parameters **viewer** (*skrobot.viewers._trimesh.TrimeshSceneViewer*) – viewer

add_collision_link(*coll_link*)
Add link for which collision with sdf is checked

The given *coll_link* will be approximated by swept-spheres and these spheres will be added to collision sphere's list.

Parameters **coll_link** (*skrobot.model.Link*) – link for which collision with sdf is checked

add_collision_links(*coll_links*)
Add links for which collisions with SDF is checked.

The given *coll_links* will be approximated by swept-spheres and these spheres will be added to collision sphere's list.

Parameters **coll_links** (*list[skrobot.model.Link]*) – link list for which collisions with sdf is checked.

collision_check()
Check collision between links and collision spheres.

Returns **is_collision** – *True* if a collision occurred between any pair of links and collision spheres and *False* otherwise.

Return type bool

`compute_batch_sd_vals`(*joint_list*, *angle_vector_seq*, *with_base=False*, *with_jacobian=False*)

Compute sd signed distances of collision spheres

This method is the core of this class. We assume that this method is mainly called from a trajecotyr optimizer or path planner.

Let n_{wp} be the number of way-points of a trajectory. Let n_f be the number of collision feature points on the robot links.

Let $f_{i,j} : \mathbb{R}^{n_{dof}} \ni q \mapsto x \in \mathbb{R}^3$ be the forward kinematics of collision features point j at waypoint i where q is the angle vector and n_{dof} is the dimension of the angle vector.

Let $c : \mathbb{R}^3 \ni x \mapsto sd \in \mathbb{R}$ be the signd distance function.

Then, this fucntion is defined as $F : \mathbb{R}^{n_{wp}n_{dof}} \ni \xi \mapsto [[f_{1,1}(q_1), \ldots, f_{1,n_f}(q_1)]^T, \ldots, [f_{n_{wp},1}(q_{n_{wp}}), \ldots, f_{n_{wp},n_f}(q_{n_{wp}})]^T]^T \in \mathbb{R}^{n_{wp}n_f}$ where $\xi = [q_1^T, \ldots, q_{n_{wp}}^T]^T$ be the angle vector sequence of the trajectory. The corresponding jacobian is defined as $\frac{\partial F}{\partial \xi}$.

Parameters

- **joint_list** (`list[skrobot.model.Joint]`) – joint list to be set
- **angle_vector_seq** (`numpy.ndarray[float](n_wp, n_dof)`) – angle vector sequence.
- **with_base** (`bool`) – hoge
- **with_jacobian** (`bool`) – if *True*, jacobian is copmuted at the same time.

Returns

- **sd_vals** (*numpy.ndarray[float](n_wp * n_feature,)*) – signed distnaces for all feature points through the trajectory
- **sd_vals_jacobi** (*numpy.ndarray[float](n_wp * n_feature, n_wp * n_dof)*) – jacobain of sd_vals with respect to DOF (i.e. n_wp * n_dof) of the trajectory

`delete_coll_spheres_from_viewer`(*viewer*)

Delete collision sheres from viewer

Parameters **viewer** (`skrobot.viewers._trimesh.TrimeshSceneViewer`) – viewer

`update_color`()

Update the color of links under collision

This method checks the collision between the collision spheres and registered sdf. If collision spheres are found to be under collision, the color of the spheres will be changed to *color_collision_sphere*.

Returns **dists** – array of the signed distances for each sphere against sdf.

Return type numpy.ndarray(n_sphere,)

`__eq__`(*value*, */*)

Return self==value.

`__ne__`(*value*, */*)

Return self!=value.

`__lt__`(*value*, */*)

Return self<value.

__le__(*value*, /)
Return self<=value.

__gt__(*value*, /)
Return self>value.

__ge__(*value*, /)
Return self>=value.

Attributes

n_feature
Return number of collision sphere.

Returns **n_feature** – number of collision spheres.

Return type int

3.6.2 SQP-based trajectory planner

skrobot.planner.sqp_plan_trajectory	Gradient based trajectory optimization using scipy's SLSQP.

skrobot.planner.sqp_plan_trajectory

skrobot.planner.**sqp_plan_trajectory**(*collision_checker*, *av_start*, *av_goal*, *joint_list*, *n_wp*, *safety_margin=0.01*, *with_base=False*, *weights=None*, *initial_trajectory=None*, *slsqp_option=None*)

Gradient based trajectory optimization using scipy's SLSQP.

Collision constraint is considered in an inequality constraits. Terminal constraint (start and end) is considered as an equality constraint.

Parameters

- **av_start** (*numpy.ndarray(n_dof,)*) – joint angle vector at start point
- **joint_list** (*list[skrobot.model.Link]*) – link list to be controlled (similar to inverse_kinematics function)
- **n_wp** (*int*) – number of waypoints
- **safety_margin** (*float*) – safety margin in collision checking
- **with_base** (*bool*) – If *with_base=False*, *n_dof* is the number of joints *n_joint*, but if *with_base=True*, *n_dof = len(joint_list) + 3*.
- **weights** (*numpy.ndarray(n_dof,) or None*) – cost to move of each joint. For example, if you set weights=numpy.ndarray([1.0, 0.1, 0.1]) for a 3 DOF manipulator, moving the first joint is with high cost compared to others. If set to *None* it's automatically determined.
- **initial_trajectory** (*numpy.ndarray(n_wp, n_dof) or None*) – initial solution in the trajectory optimization specifeid by a angle vector sequence. If None, initial trajectory is automatically generated.
- **slsqp_option** (*dict or None*) – option of slsqp. Please see *options* in https://docs.scipy.org/doc/scipy/reference/optimize.minimize-slsqp.html for the detail. If set to *None*, a default values is used.

Returns **planned_trajectory** – planned trajectory.

Return type numpy.ndarray(n_wp, n_dof)

3.6.3 Swept sphere generater

skrobot.planner.swept_sphere.compute_swept_sphere	Compute swept spheres approximating a mesh

skrobot.planner.swept_sphere.compute_swept_sphere

skrobot.planner.swept_sphere.**compute_swept_sphere**(*collision_mesh*, *n_sphere=None*, *tol=0.1*)

Compute swept spheres approximating a mesh

Parameters

- **collision_mesh** (*trimesh.Trimesh*) – mesh which swept spheres are computed for
- **n_sphere** (*int or None*) – number of sphere to approximate the mesh. If it's set to *None*, the number of sphere is automatically determined.
- **tol** (*float*) – tolerance determins how much mesh jutting-out from the swept-spheres are accepted. Let *max_jut* be the maximum jut-distance. Then the setting *tol* enforces *max_jut / radius* < *max_jut*. If some integer is set to *n_sphere*, *tol* does not affects the result.

Returns

- **centers_original_space** (*numpy.ndarray[float](n_sphere, 3)*) – center of the approximating spheres in the space where the mesh vertices are defined.
- **radius** (*float*) – radius of approximating sphers.

3.6.4 Planner utils

skrobot.planner.utils.scipinize	Scipinize a function returning both f and jac
skrobot.planner.utils.set_robot_config	A utility function for setting robot state
skrobot.planner.utils.get_robot_config	A utility function for getting robot state
skrobot.planner.utils.forward_kinematics_multi	Compute fk for multiple feature points

skrobot.planner.utils.scipinize

skrobot.planner.utils.**scipinize**(*fun*)

Scipinize a function returning both f and jac

For the detail this issue may help: https://github.com/scipy/scipy/issues/12692

Parameters **fun** (*function*) – function maps numpy.ndarray(n_dim,) to tuple[numpy.ndarray(m_dim,), numpy.ndarray(m_dim, n_dim)], where the returned tuples is composed of function value(vector) and the corresponding jacobian.

Returns

- **fun_scipinized** (*function*) – function maps numpy.ndarray(n_dim,) to a value numpy.ndarray(m_dim,).

- **fun_scipinized_jac** (*function*) – function maps numpy.ndarray(n_dim,) to jacobian numpy.ndarray(m_dim, n_dim).

skrobot.planner.utils.set_robot_config

`skrobot.planner.utils.set_robot_config`(*robot_model*, *joint_list*, *av*, *with_base=False*)

A utility function for setting robot state

Parameters

- **robot_model** (*skrobot.model.CascadedLink*) – robot model
- **joint_list** (*list[skrobot.model.Joint]*) – joint list to be set
- **av** (*numpy.ndarray[float](n_dof,)*) – angle vector which has n_dof dims.
- **with_base** (*bool*) – If *with_base=False*, *n_dof* is the number of joints *n_joint*, but if *with_base=True*, *n_dof = n_joint + 3*.

skrobot.planner.utils.get_robot_config

`skrobot.planner.utils.get_robot_config`(*robot_model*, *joint_list*, *with_base=False*)

A utility function for getting robot state

Parameters

- **robot_model** (*skrobot.model.CascadedLink*) – robot model
- **joint_list** (*list[Joint]*) – joint list of which you want to know the angles
- **with_base** (*bool*) – If set to *True*, base position is also computed.

Returns **av_whole (or av_joint)** – angle vector. If *with_base=False*, *n_dof* is the number of joints *n_joint*, but if *with_base=True*, *n_dof = n_joint + 3*.

Return type numpy.ndarray(n_dof,)

skrobot.planner.utils.forward_kinematics_multi

`skrobot.planner.utils.forward_kinematics_multi`(*robot_model*, *joint_list*, *av*, *move_target_list*, *with_rot*, *with_base*, *with_jacobian*)

Compute fk for multiple feature points

Parameters

- **robot_model** (*skrobot.model.CascadedLink*) – robot model.
- **joint_list** (*list[skrobot.model.Joint]*) – joint to be controlled
- **av** (*numpy.ndarray(n_dof,)*) – angle vector.
- **move_target_list** (*list[skrobot.coordinates.CascadedCoords]*) – the list has *n_feature* elements. Each element is the coordinate of the features points.
- **with_rot** (*bool*) – If set to *True*, 7(3 + 4) dim pose-fk is also computed. Otherwise, 3 dim point-fk is computed.
- **with_base** (*bool*) – If *with_base=False*, *n_dof* is the number of joints *n_joint*, but if *with_base=True*, *n_dof = n_joint + 3*.

Returns

- **pose_arr** (*numpy.ndarray(n_feature, dim_pose)*) – array of pose of each feature points. *dim_pose=7' if `with_rot=True*. Otherwise, *dim_pose=3*.
- **jac_arr** (*numpy.ndarray(n_feature, dim_pose, n_dof)*) – array of jacobian of each feature points.

CHAPTER

FOUR

DEVELOPMENT GUIDE

Read this guide before doing development in `skrobot`.

4.1 Setting Up

To set up the tools you'll need for developing, you'll need to install `skrobot` in development mode. Start by installing the development dependencies:

```
git clone https://github.com/iory/scikit-robot.git
cd scikit-robot
pip install -e .
```

4.2 Running Code Style Checks

We follow PEP 8 and partially OpenStack Style Guidelines as basic style guidelines. Any contributions in terms of code are expected to follow these guidelines.

You can use the `autopep8`, `isort` and the `flake8` commands to check whether or not your code follows the guidelines. In order to avoid confusion from using different tool versions, we pin the versions of those tools. Install them with the following command (from within the top directory of the Chainer repository):

```
$ pip install hacking pytest autopep8 isort
```

And check your code with:

```
$ autopep8 path/to/your/code.py
$ flake8 path/to/your/code.py
```

`autopep8` can automatically correct Python code to conform to the PEP 8 style guide:

```
$ autopep8 --in-place path/to/your/code.py
```

`isort` can automatically correct `import order`:

```
$ cd scikit-robot && isort path/to/your/code.py
```

For more information, please see the flake8 documentation.

4.3 Running Tests

This project uses pytest, the standard Python testing framework. Their website has tons of useful details, but here are the basics.

To run the testing suite, simply navigate to the top-level folder in `scikit-robot` and run the following command:

```
pytest -v tests
```

You should see the testing suite run. There are a few useful command line options that are good to know:

- `-s` - Shows the output of `stdout`. By default, this output is masked.
- `--pdb` - Instead of crashing, opens a debugger at the first fault.
- `--lf` - Instead of running all tests, just run the ones that failed last.
- `--trace` - Open a debugger at the start of each test.

You can see all of the other command-line options here.

By default, `pytest` will look in the `tests` folder recursively. It will run any function that starts with `test_` in any file that starts with `test_`. You can run `pytest` on a directory or on a particular file by specifying the file path:

```
pytest -v tests/skrobot_tests/coordinates_tests/test_math.py
```

4.4 Building Documentation

To build `scikit-robot`'s documentation, go to the `docs` directory and run `make` with the appropriate target. For example,

```
cd docs/
make html
```

will generate HTML-based docs, which are probably the easiest to read. The resulting index page is at `docs/build/html/index.html`. If the docs get stale, just run `make clean` to remove all build files.

CHAPTER

FIVE

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PYTHON MODULE INDEX

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