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Geometry3D is a simple python computational geographics library written in python. This library focuses on the functions and lacks efficiency which might be improved in future version.

1.1 Core Features

- Simple Object like Cubic, Sphere, Cylinder, Cone, Rectangle, Parallepiped, Parallogram and Circle.
- Basic Attributes Of Geometries: length, area, volume.
- Basic Relationships And Operations Between Geometries: move, angle, parallel, orthogonal, intersection.
- Overload Build-In Functions Such As `__contains__`, `__hash__`, `__eq__`, `__neg__`.
- A Naive Renderer Using matplotlib.

1.2 Resources

- Documentations
- PDF_Documentations
- Code: https://github.com/GouMinghao/Geometry3D
2.1 Prerequisites

It is assumed that you already have Python 3 installed. If you want graphic support, you need to manually install matplotlib.

2.2 System wide installation

You can install Geometry3D via pip:

```bash
$ pip install Geometry3D
```

Alternatively, you can install Geometry3D from source:

```bash
$ git clone http://github.com/GouMinghao/Geometry3D
$ cd Geometry3D/
$ sudo pip install .
# Alternative:
$ sudo python setup.py install
```

Note that the Python (or pip) version you use to install Geometry3D must match the version you want to use Geometry3D with.

2.3 Virtualenv installation

Geometry3D can be installed inside a virtualenv just like any other python package, though I suggest the use of virtualenvwrapper.
CHAPTER THREE

FIRST EXAMPLE

3.1 Steinmetz solid

This part shows how to use Geometry3D to calculate the volume and area of a Steinmetz solid. Simply run the code below after installation:

```python
>>> from Geometry3D import *
>>> import copy
>>> radius=5
>>> s1 = Cylinder(Point(-2 * radius,0,0),radius,4*radius * x_unit_vector(),n=40)
>>> s2 = Cylinder(Point(0,-2 * radius,0),radius,4*radius * y_unit_vector(),n=40)
>>> s3 = intersection(s1,s2)
>>> r = Renderer()
>>> r.add((s1,'r',1))
>>> r.add((s2,'b',1))
>>> r.add((s3,'y',5))
>>> r.show()

>>> r2 = Renderer()
>>> r2.add((s3,'y',1))
>>> r2.show()

>>> import math

>>> v_real = 16 / 3 * math.pow(radius,3)
>>> a_real = 16 * math.pow(radius,2)

>>> print('Ground truth volume of the Steinmetz solid is:{}, Calculated value is:{}'.format(v_real,s3.volume()))
Ground truth volume of the Steinmetz solid is:666.6666666666666, Calculated value is:662.5627801983807

>>> print('Ground truth surface area of the Steinmetz solid is:{}, Calculated value is:{}'.format(a_real,s3.area()))
Ground truth surface area of the Steinmetz solid is:400.0, Calculated value is:398.76693349325194
```
3.1. Steinmetz solid
4.1 Creating Geometries

4.1.1 Creating Point

Creating a Point using three coordinates:

```python
>>> from Geometry3D import *
>>> pa = Point(1,2,3)
>>> pa
Point(1, 2, 3)
```

Creating a Point using a list of coordinates:

```python
>>> pb = Point([2,4,3])
>>> pb
Point(2, 4, 3)
```

Specifically, special Point can be created using class function:

```python
>>> o = origin()
>>> o
Point(0, 0, 0)
```

4.1.2 Creating Vector

Creating a Vector using three coordinates:

```python
>>> from Geometry3D import *
>>> va = Vector(1,2,3)
>>> va
Vector(1, 2, 3)
```

Creating a Vector using two Points:

```python
>>> pa = Point(1,2,3)
>>> pb = Point(2,3,1)
>>> vb = Vector(pa,pb)
>>> vb
Vector(1, 1, -2)
```

Creating a Vector using a list of coordinates:
>>> vc = Vector([1,2,4])
>>> vc
Vector(1, 2, 4)

Specifically, special Vectors can be created using class functions:

>>> x_unit_vector()
Vector(1, 0, 0)
>>> y_unit_vector()
Vector(0, 1, 0)
>>> z_unit_vector()
Vector(0, 0, 1)

### 4.1.3 Creating Line

Creating Line using two Points:

```python
>>> from Geometry3D import *
>>> pa = Point(1,2,3)
>>> pb = Point(2,3,1)
>>> l = Line(pa,pb)
>>> l
Line(sv=Vector(1, 2, 3),dv=Vector(1, 1, -2))
```

Creating Line using two Vectors:

```python
>>> va = Vector(1,2,3)
>>> vb = Vector(-1,-2,-1)
>>> l = Line(va,vb)
>>> l
Line(sv=Vector(1, 2, 3),dv=Vector(-1, -2, -1))
```

Creating Line using a Point and a Vector:

```python
Line(sv=Vector(1, 2, 3),dv=Vector(-1, -2, -1))
>>> pa = Point(2,6,-2)
>>> v = Vector(2,0,4)
>>> l = Line(pa,v)
>>> l
Line(sv=Vector(2, 6, -2),dv=Vector(2, 0, 4))
```

Specifically, special Lines can be created using class functions:

```python
>>> x_axis()
Line(sv=Vector(0, 0, 0),dv=Vector(1, 0, 0))
>>> y_axis()
Line(sv=Vector(0, 0, 0),dv=Vector(0, 1, 0))
>>> z_axis()
Line(sv=Vector(0, 0, 0),dv=Vector(0, 0, 1))
```
4.1.4 Creating Plane

Creating Plane using three Points:
```python
>>> from Geometry3D import *
>>> p1 = origin()
>>> p2 = Point(1,0,0)
>>> p3 = Point(0,1,0)
>>> p = Plane(p1,p2,p3)
>>> p
Plane(Point(0, 0, 0), Vector(0, 0, 1))
```

Creating Plane using a Point and two Vectors:
```python
>>> p1 = origin()
>>> v1 = x_unit_vector()
>>> v2 = z_unit_vector()
>>> p = Plane(p1,v1,v2)
>>> p
Plane(Point(0, 0, 0), Vector(0, -1, 0))
```

Creating Plane using a Point and a Vector:
```python
>>> p1 = origin()
>>> p = Plane(p1,Vector(1,1,1))
>>> p
Plane(Point(0, 0, 0), Vector(1, 1, 1))
```

Creating Plane using four parameters:
```python
# Plane(a, b, c, d):
# Initialise a plane given by the equation
# ax1 + bx2 + cx3 = d (general form).
>>> p = Plane(1,2,3,4)
>>> p
Plane(Point(-1.0, 1.0, 1.0), Vector(1, 2, 3))
```

Specifically, special Planes can be created using class functions:
```python
>>> xy_plane()
Plane(Point(0, 0, 0), Vector(0, 0, 1))
>>> yz_plane()
Plane(Point(0, 0, 0), Vector(1, 0, 0))
>>> xz_plane()
Plane(Point(0, 0, 0), Vector(0, 1, 0))
```

4.1.5 Creating Segment

Creating Segment using two Points:
```python
>>> from Geometry3D import *
>>> p1 = Point(0,0,2)
>>> p2 = Point(-1,2,0)
>>> s = Segment(p1,p2)
>>> s
Segment(Point(0, 0, 2), Point(-1, 2, 0))
```
4.1.6 Creating ConvexPolygon

Creating ConvexPolygon using a tuple of points:

```python
>>> from Geometry3D import *
>>> pa = origin()
>>> pb = Point(1,1,0)
>>> pc = Point(1,0,0)
>>> pd = Point(0,1,0)
>>> cpg = ConvexPolygon((pa,pb,pc,pd))
>>> cpg
ConvexPolygon((Point(0, 0, 0), Point(1, 1, 0), Point(1, 0, 0), Point(0, 1, 0)))
```

Specifically, Parallelogram can be created using one Point and two Vectors:

```python
>>> pa = origin()
>>> cpg = Parallelogram(pa,x_unit_vector(),y_unit_vector())
>>> cpg
ConvexPolygon((Point(0, 0, 0), Point(1, 0, 0), Point(1, 1, 0), Point(0, 1, 0)))
```

4.1.7 Creating ConvexPolyhedron

Creating ConvexPolyhedron using a tuple of ConvexPolygons:

```python
>>> from Geometry3D import *
>>> a = Point(1,1,1)
>>> b = Point(-1,1,1)
>>> c = Point(-1,-1,1)
>>> d = Point(1,-1,1)
>>> e = Point(1,1,-1)
>>> f = Point(-1,1,-1)
>>> g = Point(-1,-1,-1)
>>> h = Point(1,-1,-1)
>>> cpg0 = ConvexPolygon((a,d,h,e))
>>> cpg1 = ConvexPolygon((a,e,f,b))
>>> cpg2 = ConvexPolygon((c,b,f,g))
>>> cpg3 = ConvexPolygon((c,g,h,d))
>>> cpg4 = ConvexPolygon((a,b,c,d))
>>> cpg5 = ConvexPolygon((e,h,g,f))
>>> cph0 = ConvexPolyhedron((cpg0,cpg1,cpg2,cpg3,cpg4,cpg5))
>>> cph0
ConvexPolyhedron
pyramid set:{Pyramid(ConvexPolygon((Point(1, 1, -1), Point(1, -1, -1), Point(-1, -1, -1), Point(-1, 1, -1))), Point(0.0, 0.0, 0.0)), Pyramid(ConvexPolygon((Point(1, 1, -1), Point(1, -1, -1), Point(-1, 1, -1), Point(-1, -1, -1))), Point(0.0, 0.0, 0.0)), Pyramid(ConvexPolygon((Point(-1, -1, 1), Point(-1, 1, 1), Point(-1, 1, -1), Point(-1, -1, -1))), Point(0.0, 0.0, 0.0)), Pyramid(ConvexPolygon((Point(-1, -1, 1), Point(-1, -1, -1), Point(1, -1, -1), Point(1, -1, 1))), Point(0.0, 0.0, 0.0)), Pyramid(ConvexPolygon((Point(1, 1, 1), Point(1, -1, 1), Point(1, -1, -1), Point(1, 1, -1))), Point(0.0, 0.0, 0.0))}
(continues on next page)
Specifically, Parallelepiped can be created using a Point and Three Vectors:

```python
>>> cph = Parallelepiped(origin(), x_unit_vector(), y_unit_vector(), z_unit_vector())
>>> cph
ConvexPolyhedron
```

4.1.8 Creating HalfLine

Creating HalfLine using two Points or a Point and a Vector:

```python
>>> from Geometry3D import *
>>> HalfLine(origin(),Point(1,0,0))
HalfLine(Point(0, 0, 0), Vector(1, 0, 0))
>>> HalfLine(origin(),y_unit_vector())
HalfLine(Point(0, 0, 0), Vector(0, 1, 0))
```

4.1.9 Other Geometries

Inscribed convex polygon and convex polyhedron of circle, cylinder, sphere, cone are also available:

```python
>>> from Geometry3D import *
>>> import copy

>>> b = Circle(origin(),y_unit_vector(),10,20)
>>> a = Circle(origin(),x_unit_vector(),10,20)
>>> c = Circle(origin(),z_unit_vector(),10,20)
>>> r = Renderer()
>>> r.add((a,'g',3))
>>> r.add((b,'b',3))
>>> r.add((c,'r',3))

>>> s1 = Sphere(Point(20,0,0),10,n1=12,n2=5)
>>> s2 = copy.deepcopy(s1).move(Vector(10,2,-3.9))
>>> s3 = intersection(s1,s2)

>>> r.add((s1,'r',1))
>>> r.add((s2,'b',1))
>>> r.add((s3,'y',3))
```
4.2 Renderer Examples

4.2.1 Creating Geometries

```python
>>> a = Point(1,2,1)
>>> c = Point(-1,-1,1)
>>> d = Point(1,-1,1)
>>> e = Point(1,1,-1)
>>> h = Point(1,-1,-1)

>>> s = Segment(a,c)

>>> cpg = ConvexPolygon((a,d,h,e))

>>> cph = Parallelepiped(Point(-1.5,-1.5,-1.5),Vector(2,0,0),Vector(0,2,0),Vector(0,0,-2))
```
4.2.2 Getting a Renderer

```python
>>> r = Renderer(backend='matplotlib')
```

4.2.3 Adding Geometries

```python
>>> r.add((a,'r',10),normal_length=0)
>>> r.add((d,'r',10),normal_length=0)
>>> r.add((s,'g',3),normal_length=0)
>>> r.add((cpg,'b',2),normal_length=0)
>>> r.add((cph,'y',1),normal_length=1)
```

4.2.4 Displaying Geometries

```python
>>> r.show()
```
4.3 Getting Attributes

4.3.1 Creating Geometries

```python
>>> a = Point(1,1,1)
>>> d = Point(1,-1,1)
>>> c = Point(-1,-1,1)
>>> e = Point(1,1,-1)
>>> h = Point(1,-1,-1)

>>> s = Segment(a,c)

>>> cpg = ConvexPolygon((a,d,h,e))

>>> cph = Parallelepiped(Point(-1,-1,-1),Vector(2,0,0),Vector(0,2,0),Vector(0,0,2))
```

4.3.2 Calculating the length

```python
>>> s.length() # 2 * sqrt(2)
2.8284271247461903

>>> cpg.length() # 8
8.0

>>> cph.length() # 24
24.0
```

4.3.3 Calculating the area

```python
>>> cph.area() # 24
23.999999999999993

>>> cpg.area() # 4
3.999999999999982

>>> # Floating point calculation error
```
4.3.4 Calculating the volume

```python
>>> cph.volume()  # 8
7.999999999999995
>>> volume(cph0)  # 8
7.999999999999995
```

4.4 Operations Examples

4.4.1 move

Move a Point:

```python
>>> a = Point(1,2,1)
>>> print('a before move:{}'.format(a))
a before move:Point(1, 2, 1)
>>> a.move(x_unit_vector())
Point(2, 2, 1)
>>> print('a after move:{}'.format(a))
a after move:Point(2, 2, 1)
```

Move a Segment:

```python
>>> b = origin()
>>> c = Point(1,2,3)
>>> s = Segment(b,c)
>>> s
Segment(Point(0, 0, 0), Point(1, 2, 3))
>>> s.move(Vector(-1,-2,-3))
Segment(Point(-1, -2, -3), Point(0, 0, 0))
```

Move a ConvexPolygon Without Changing the Original Object:

```python
>>> import copy

>>> cpg0 = Parallelogram(origin(),x_unit_vector(),y_unit_vector())
>>> cpg0
ConvexPolygon((Point(0, 0, 0), Point(1, 0, 0), Point(1, 1, 0), Point(0, 1, 0)))
>>> cpg1 = copy.deepcopy(cpg0).move(Vector(0,0,1))
>>> cpg1
ConvexPolygon((Point(0, 0, 1), Point(1, 0, 1), Point(1, 1, 1), Point(0, 1, 1)))
```
4.4.2 Intersection

The operation of intersection is very complex. There are a total of 21 situations.

<table>
<thead>
<tr>
<th>obj1</th>
<th>obj2</th>
<th>output obj</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point</td>
<td>Point</td>
<td>None, Point</td>
</tr>
<tr>
<td>Point</td>
<td>Line</td>
<td>None, Point</td>
</tr>
<tr>
<td>Point</td>
<td>Plane</td>
<td>None, Point</td>
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<tr>
<td>Point</td>
<td>Segment</td>
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<tr>
<td>Point</td>
<td>ConvexPolygon</td>
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<td>Point</td>
<td>ConvexPolyhedron</td>
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<tr>
<td>Point</td>
<td>HalfLine</td>
<td>None, Point</td>
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<tr>
<td>Line</td>
<td>Line</td>
<td>None, Point, Line</td>
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<td>Line</td>
<td>Plane</td>
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<tr>
<td>Line</td>
<td>Segment</td>
<td>None, Point, Segment</td>
</tr>
<tr>
<td>Line</td>
<td>ConvexPolygon</td>
<td>None, Point, Segment</td>
</tr>
<tr>
<td>Line</td>
<td>ConvexPolyhedron</td>
<td>None, Point, Segment</td>
</tr>
<tr>
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<td>Plane</td>
<td>None, Line, Plane</td>
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<td>Plane</td>
<td>Segment</td>
<td>None, Point, Segment</td>
</tr>
<tr>
<td>Plane</td>
<td>ConvexPolygon</td>
<td>None, Point, Segment, ConvexPolygon</td>
</tr>
<tr>
<td>Plane</td>
<td>ConvexPolyhedron</td>
<td>None, Point, Segment, ConvexPolygon</td>
</tr>
<tr>
<td>Plane</td>
<td>HalfLine</td>
<td>None, Point, HalfLine</td>
</tr>
<tr>
<td>Segment</td>
<td>Segment</td>
<td>None, Point, Segment</td>
</tr>
<tr>
<td>Segment</td>
<td>ConvexPolygon</td>
<td>None, Point, Segment</td>
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<tr>
<td>Segment</td>
<td>ConvexPolyhedron</td>
<td>None, Point, Segment</td>
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<td>HalfLine</td>
<td>None, Point, Segment</td>
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<tr>
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<td>ConvexPolygon</td>
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</tr>
<tr>
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<td>ConvexPolyhedron</td>
<td>None, Point, Segment, ConvexPolygon, ConvexPolyhedron</td>
</tr>
<tr>
<td>ConvexPolyhedron</td>
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<td>None, Point, Segment</td>
</tr>
<tr>
<td>HalfLine</td>
<td>HalfLine</td>
<td>None, Point, Segment, HalfLine</td>
</tr>
</tbody>
</table>

All of the situations above are implemented. The documentation shows some examples.

Example 1:

```python
>>> po = origin()
>>> l1 = x_axis()
>>> l2 = y_axis()
>>> intersection(po, l1)
Point(0, 0, 0)
>>> intersection(l1, l2)
Point(0.0, 0.0, 0.0)
>>> s1 = Segment(Point(1,0,1), Point(0,1,1))
>>> s2 = Segment(Point(0,0,1), Point(1,1,1))
>>> s3 = Segment(Point(0.5,0.5,1), Point(-0.5,1.5,1))
>>> intersection(s1, s2)
Point(0.5, 0.5, 1.0)
>>> intersection(s1, s3)
Segment(Point(0.5, 0.5, 1.0), Point(0, 1, 1))
>>> intersection(l1, s1) is None
True
```
```python
>>> cph0 = Parallelepiped(origin(), x_unit_vector(), y_unit_vector(), z_unit_vector())
>>> p = Plane(Point(0.5, 0.5, 0.5), Vector(1, 1, 1))
>>> cpg = intersection(cph0, p)
>>> r = Renderer()
>>> r.add((cph0, 'r', 1), normal_length = 0)
>>> r.add((cpg, 'b', 1), normal_length=0)
>>> r.show()
```

Example 2:

```python
>>> from Geometry3D import *
>>> import copy

>>> r = Renderer()

>>> cph0 = Parallelepiped(origin(), x_unit_vector(), y_unit_vector(), z_unit_vector())
>>> cph6 = Parallelepiped(origin(), 2 * x_unit_vector(), 2 * y_unit_vector(), 2 * z_unit_vector())

>>> r.add((cph0, 'b', 1), normal_length = 0.5)
>>> r.add((cph6, 'r', 1), normal_length = 0.5)
>>> r.add((intersection(cph6, cph0), 'g', 2))

>>> print(intersection(cph0, cph6))
ConvexPolyhedron
pyramid set:{Pyramid(ConvexPolygon((Point(1, 1, 1), Point(0, 1, 1), Point(0.0, 0.0, 1.0), Point(1, 0, 1))), Point(0.5, 0.5, 0.5)), Pyramid(ConvexPolygon((Point(1.0, 0.0, 0.0), Point(1, 0, 1), Point(1, 1, 1), Point(1, 1, 0))), Point(0.5, 0.5, 0.5)), Pyramid(ConvexPolygon((Point(1, 1, 0), Point(1, 1, 1), Point(0, 1, 1), Point(0.0, 1.0, 0.0))), Point(0.5, 0.5, 0.5)), Pyramid(ConvexPolygon((Point(0, 0, 1), Point(0, 0, 0), Point(0, 1, 0), Point(0, 1, 1))), Point(0.5, 0.5, 0.5)), Pyramid(ConvexPolygon((Point(1, 0, 0), Point(1, 0, 1), Point(0, 0, 1), Point(0, 0, 0))), Point(0.5, 0.5, 0.5))
```
Example 3:

```python
>>> from Geometry3D import *

>>> a = Point(1,1,1)
>>> b = Point(-1,1,1)
>>> c = Point(-1,-1,1)
>>> d = Point(1,-1,1)
>>> e = Point(1,1,-1)
>>> f = Point(-1,1,-1)
>>> g = Point(-1,-1,-1)
>>> h = Point(1,-1,-1)

>>> cph0 = Parallelepiped(Point(-1,-1,-1), Vector(2,0,0), Vector(0,2,0), Vector(0,0,2))
>>> cpgl2 = ConvexPolygon((e,c,h))
>>> cpgl3 = ConvexPolygon((e,f,c))
>>> cpgl4 = ConvexPolygon((c,f,g))
>>> cpgl5 = ConvexPolygon((h,c,g))
>>> cpgl6 = ConvexPolygon((h,g,f,e))

>>> cph1 = ConvexPolyhedron((cpgl2, cpgl3, cpgl4, cpgl5, cpgl6))
>>> a1 = Point(1.5,1.5,1.5)
```
Geometry3D, Release 0.2.4

>>> b1 = Point(-0.5,1.5,1.5)
>>> c1 = Point(-0.5,-0.5,1.5)
>>> d1 = Point(1.5,-0.5,1.5)
>>> e1 = Point(1.5,1.5,-0.5)
>>> f1 = Point(-0.2,1.5,-0.5)
>>> g1 = Point(-0.2,-0.5,-0.5)
>>> h1 = Point(1.5,-0.5,-0.5)

>>> cpg6 = ConvexPolygon((a1,d1,h1,e1))
>>> cpg7 = ConvexPolygon((a1,e1,f1,b1))
>>> cpg8 = ConvexPolygon((c1,b1,f1,g1))
>>> cpg9 = ConvexPolygon((c1,g1,h1,d1))
>>> cpg10 = ConvexPolygon((a1,b1,c1,d1))
>>> cpg11 = ConvexPolygon((e1,h1,g1,f1))
>>> cph2 = ConvexPolyhedron((cpg6,cpg7,cpg8,cpg9,cpg10,cpg11))
>>> cph3 = intersection(cph0,cph2)

>>> cph4 = intersection(cph1,cph2)
>>> r = Renderer()
>>> r.add((cph0,'r',1),normal_length = 0)
>>> r.add((cph1,'r',1),normal_length = 0)
>>> r.add((cph2,'g',1),normal_length = 0)
>>> r.add((cph3,'b',3),normal_length = 0.5)
>>> r.add((cph4,'y',3),normal_length = 0.5)
>>> r.show()
4.5 Build-In Functions

4.5.1 `__contains__`

`__contains__` is used in build-in operator `in`, here are some examples:

```python
>>> a = origin()
>>> b = Point(0.5, 0, 0)
>>> c = Point(1.5, 0, 0)
>>> d = Point(1, 0, 0)
>>> e = Point(0.5, 0.5, 0)
>>> s1 = Segment(origin(), d)
>>> s2 = Segment(e, c)
>>> a in s1
True
>>> b in s1
True
>>> c in s1
False
>>> a in s2
False
>>> b in s2
False
>>> c in s2
True
>>> cpg = Parallelogram(origin(), x_unit_vector(), y_unit_vector())
>>> a in cpg
True
>>> b in cpg
True
>>> c in cpg
False
>>> s1 in cpg
True
>>> s2 in cpg
False
>>> r=Renderer()
>>> r.add((a, 'r', 10))
>>> r.add((b, 'r', 10))
>>> r.add((c, 'r', 10))
>>> r.add((d, 'r', 10))
>>> r.add((e, 'r', 10))
>>> r.add((s1, 'b', 5))
>>> r.add((s2, 'b', 5))
>>> r.add((cpg, 'g', 2))
>>> r.show()
```
4.5.2 __hash__

__hash__ is used in set, here are some examples:

```python
>>> a = set()
>>> a.add(origin())
>>> a
{Point(0, 0, 0)}
>>> a.add(Point(0,0,0))
>>> a
{Point(0, 0, 0)}
>>> a.add(Point(0,0,0.01))
>>> a
{Point(0, 0, 0), Point(0.0, 0.0, 0.01)}
>>> b = set()
>>> b.add(Segment(origin(),Point(1,0,0)))
>>> b
{Segment(Point(0, 0, 0), Point(1, 0, 0))}
>>> b.add(Segment(Point(1.0,0,0),Point(0,0,0)))
>>> b
{Segment(Point(0, 0, 0), Point(1, 0, 0))}
>>> b.add(Segment(Point(0,0,0),Point(0,1,1)))
>>> b
{Segment(Point(0, 0, 0), Point(0, 1, 1))}
```
4.5.3 __eq__

__eq__ is the build-in operator ==, here are some examples:

```python
>>> a = origin()
>>> b = Point(1,0,0)
>>> c = Point(0,0,0)
>>> d = Point(2,0,0)
>>> a == b
False
>>> a == c
True
>>> s1 = Segment(a,b)
>>> s2 = Segment(a,b)
>>> s3 = Segment(b,a)
>>> s4 = Segment(a,d)
>>> s1 == s2
True
>>> s1 == s3
True
>>> s1 == s4
False
```  

```python
>>> cpg0 = ConvexPolygon((origin(),Point(1,0,0),Point(0,1,0),Point(1,1,0)))
>>> cpg1 = Parallelogram(origin(),x_unit_vector(),y_unit_vector())
>>> cpg0 == cpg1
True
```  

4.5.4 __neg__

__neg__ is the build-in operator -, here are some examples:

```python
>>> p = Plane(origin(),z_unit_vector())
>>> p
Plane(Point(0, 0, 0), Vector(0, 0, 1))
>>> -p
Plane(Point(0, 0, 0), Vector(0, 0, -1))
```  

4.6 Dealing With Floating Numbers

There will be some errors in floating numbers computations. So identical objects may be deemed different. To tackle with this problem, this library believe two objects equal if their difference is smaller that a small number `eps`. Another value is named significant number has the relationship with eps:

\[
\text{significant number} = -\log(\epsilon)
\]

The default value of `eps` is 1e-10. You can access and change the value as follows:
4.7 Logger Settings

4.7.1 Set Log Level

Set the log level by calling `set_log_level` function:

```python
>>> set_log_level('WARNING')
```

Details are introduced in the Python API part.
5.1 Geometry3D.calc package

5.1.1 Submodules

5.1.2 Geometry3D.calc.acute module

Acute Module
Geometry3D.calc.acute.acute(rad)

Input:
- rad: A angle in rad.

Output:
If the given angle is >90 (pi/2), return the opposite angle.
Return the angle else.

5.1.3 Geometry3D.calc.angle module

Angle Module
Geometry3D.calc.angle.angle(a, b)

Input:
- a: Line/Plane/Plane/Vector
- b: Line/Line/Plane/Vector

Output:
The angle (in radians) between
- Line/Line
- Plane/Line
- Plane/Plane
- Vector/Vector

Geometry3D.calc.angle.parallel(a, b)

Input:
- a: Line/Plane/Plane/Vector
• b:Line/Line/Plane/Vector

Output:
A boolean of whether the two objects are parallel. This can check
• Line/Line
• Plane/Line
• Plane/Plane
• Vector/Vector

Geometry3D.calc.angle.orthogonal(a, b)

Input:
• a:Line/Plane/Plane/Vector
• b:Line/Line/Plane/Vector

Output:
A boolean of whether the two objects are orthogonal. This can check
• Line/Line
• Plane/Line
• Plane/Plane
• Vector/Vector

5.1.4 Geometry3D.calc.aux_calc module

Auxilary Calculation Module.
Auxilary calculation functions for calculating intersection

Geometry3D.calc.aux_calc.get_projection_length(v1, v2)

Input:
• v1: Vector
• v2: Vector

Output:
The length of vector that v1 projected on v2

Geometry3D.calc.aux_calc.get_relative_projection_length(v1, v2)

Input:
• v1: Vector
• v2: Vector

Output:
The ratio of length of vector that v1 projected on v2 and the length of v2

Geometry3D.calc.aux_calc.get_segment_from_point_list(point_list)

Input:
• point_list: a list of Points
Output:

The longest segment between the points

Geometry3D.calc.aux_calc.get_segment_convexpolyhedron_intersection_point_set \( (s, cph) \)

Input:

- \( s \): Segment
- \( cph \): ConvexPolyhedron

Output:

A set of intersection points

Geometry3D.calc.aux_calc.get_segment_convexpolygon_intersection_point_set \( (s, cpg) \)

Input:

- \( s \): Segment
- \( cpg \): ConvexPolygon

Output:

A set of intersection points

Geometry3D.calc.aux_calc.get_halfline_convexpolyhedron_intersection_point_set \( (h, cph) \)

Input:

- \( h \): HalfLine
- \( cph \): ConvexPolyhedron

Output:

A set of intersection points

Geometry3D.calc.aux_calc.points_in_a_line \( (points) \)

Input:

- \( points \): Tuple or list of Points

Output:

A set of intersection points

5.1.5 Geometry3D.calc.distance module

Distance Module

Geometry3D.calc.distance.distance \( (a, b) \)

Input:

- \( a \): Point/Line/Plane
- \( b \): Point/Line/Point

Output:

Returns the distance between two objects. This includes

- Point
- Line/Point

• Line/Line
• Plane/Point
• Plane/Line

5.1.6 Geometry3D.calc.intersection module

Intersection Module

Geometry3D.calc.intersection.intersection(a, b)

Input:
• a: GeoBody or None
• b: GeoBody or None

Output:
The Intersection.
Maybe None or GeoBody

5.1.7 Geometry3D.calc.volume module

Volume module

Geometry3D.calc.volume.volume(arg)

Input:
• arg: Pyramid or ConvexPolyhedron

Output:
Returns the object volume. This includes
• Pyramid
• ConvexPolyhedron

5.1.8 Module contents

Geometry3D.calc.distance(a, b)

Input:
• a: Point/Line/Line/Plane/Plane
• b: Point/Point/Line/Point/Line

Output:
Returns the distance between two objects. This includes
• Point/Point
• Line/Point
• Line/Line
• Plane/Point
• Plane/Line
Geometry3D.calc.intersection\((a, b)\)

**Input:**
- a: GeoBody or None
- b: GeoBody or None

**Output:**
The Intersection.
Maybe None or GeoBody

Geometry3D.calc.parallel\((a, b)\)

**Input:**
- a:Line/Plane/Plane/Vector
- b:Line/Line/Plane/Vector

**Output:**
A boolean of whether the two objects are parallel. This can check
- Line/Line
- Plane/Line
- Plane/Plane
- Vector/Vector

Geometry3D.calc.angle\((a, b)\)

**Input:**
- a: Line/Plane/Plane/Vector
- b: Line/Line/Plane/Vector

**Output:**
The angle (in radians) between
- Line/Line
- Plane/Line
- Plane/Plane
- Vector/Vector

Geometry3D.calc.orthogonal\((a, b)\)

**Input:**
- a:Line/Plane/Plane/Vector
- b:Line/Line/Plane/Vector

**Output:**
A boolean of whether the two objects are orthogonal. This can check
- Line/Line
- Plane/Line
- Plane/Plane
- Vector/Vector
Geometry3D, Release 0.2.4

Geometry3D.calc.\texttt{volume}(\texttt{arg})

\textbf{Input:}
- \texttt{arg}: Pyramid or ConvexPolyhedron

\textbf{Output:}
Returns the object volume. This includes
- Pyramid
- ConvexPolyhedron

Geometry3D.calc.\texttt{get_projection_length}(\texttt{v1}, \texttt{v2})

\textbf{Input:}
- \texttt{v1}: Vector
- \texttt{v2}: Vector

\textbf{Output:}
The length of vector that \texttt{v1} projected on \texttt{v2}

Geometry3D.calc.\texttt{get_relative_projection_length}(\texttt{v1}, \texttt{v2})

\textbf{Input:}
- \texttt{v1}: Vector
- \texttt{v2}: Vector

\textbf{Output:}
The ratio of length of vector that \texttt{v1} projected on \texttt{v2} and the length of \texttt{v2}

Geometry3D.calc.\texttt{get_segment_from_point_list}(\texttt{point\_list})

\textbf{Input:}
- \texttt{point\_list}: a list of Points

\textbf{Output:}
The longest segment between the points

Geometry3D.calc.\texttt{get_segment_convexpolyhedron_intersection_point_set}(\texttt{s}, \texttt{cph})

\textbf{Input:}
- \texttt{s}: Segment
- \texttt{cph}: ConvexPolyhedren

\textbf{Output:}
A set of intersection points

Geometry3D.calc.\texttt{get_segment_convexpolygon_intersection_point_set}(\texttt{s}, \texttt{cpg})

\textbf{Input:}
- \texttt{s}: Segment
- \texttt{cpg}: ConvexPolygon

\textbf{Output:}
A set of intersection points

Geometry3D.calc.\texttt{get_halfline_convexpolyhedron_intersection_point_set}(\texttt{h}, \texttt{cph})

\textbf{Input:}
• h: HalfLine
• cph: ConvexPolyhedron

Output:
A set of intersection points

Geometry3D.calc.points_in_a_line(points)

Input:
• points: Tuple or list of Points

Output:
A set of intersection points

5.2 Geometry3D.geometry package

5.2.1 Submodules

5.2.2 Geometry3D.geometry.body module

Geobody module
class Geometry3D.geometry.body.GeoBody
    Bases: object
    A base class for geometric objects that provides some common methods to work with. In the end, everything is dispatched to Geometry3D.calc.calc.* anyway, but it sometimes feels nicer to write it like L1.intersection(L2) instead of intersection(L1, L2)

    angle(other)
        return the angle between self and other

distance(other)
    return the distance between self and other

intersection(other)
    return the intersection between self and other

orthogonal(other)
    return if self and other are orthogonal to each other

parallel(other)
    return if self and other are parallel to each other

5.2.3 Geometry3D.geometry.halfline module

HalfLine Module
class Geometry3D.geometry.halfline.HalfLine(a, b)
    Bases: Geometry3D.geometry.body.GeoBody

Input:
• HalfLine(Point,Point)
• HalfLine(Point,Vector)
class_level = 6

in_(other)
    other can be plane or line

move(v)
    Return the HalfLine that you get when you move self by vector v, self is also moved

parametric()
    Returns (point, vector) so that you can build the information for the halfline

5.2.4 Geometry3D.geometry.line module

Line Module

class Geometry3D.geometry.line.Line(a, b)
    Bases: Geometry3D.geometry.body.GeoBody

    • Line(Point, Point):
        A Line going through both given points.
    • Line(Point, Vector):
        A Line going through the given point, in the direction pointed by the given Vector.
    • Line(Vector, Vector):
        The same as Line(Point, Vector), but with instead of the point only the position vector of the point is given.

class_level = 1

move(v)
    Return the line that you get when you move self by vector v, self is also moved

parametric()
    Returns (s, u) so that you can build the equation for the line

    g: x = s + ru ; r e R

classmethod x_axis()
    return x axis which is a Line

classmethod y_axis()
    return y axis which is a Line

classmethod z_axis()
    return z axis which is a Line

Geometry3D.geometry.line.x_axis()
    return x axis which is a Line

Geometry3D.geometry.line.y_axis()
    return y axis which is a Line

Geometry3D.geometry.line.z_axis()
    return z axis which is a Line
5.2.5 Geometry3D.geometry.plane module

Plane module

class Geometry3D.geometry.plane.Plane(*args)
    Bases: Geometry3D.geometry.body.GeoBody

    • Plane(Point, Point, Point):
      Initialise a plane going through the three given points.
    • Plane(Point, Vector, Vector):
      Initialise a plane given by a point and two vectors lying on the plane.
    • Plane(Point, Vector):
      Initialise a plane given by a point and a normal vector (point normal form)
    • Plane(a, b, c, d):
      Initialise a plane given by the equation ax1 + bx2 + cx3 = d (general form).

class_level = 2

general_form()
    Returns (a, b, c, d) so that you can build the equation
    E: ax1 + bx2 + cx3 = d
    to describe the plane.

move(v)
    Return the plane that you get when you move self by vector v, self is also moved

parametric()
    Returns (u, v, w) so that you can build the equation
    E: x = u + rv + sw ; (r, s) e R
    to describe the plane (a point and two vectors).

point_normal()
    Returns (p, n) so that you can build the equation
    E: (x - p) n = 0
    to describe the plane.

classmethod xy_plane()
    return xy plane which is a Plane

classmethod xz_plane()
    return xz plane which is a Plane

classmethod yz_plane()
    return yz plane which is a Plane

Geometry3D.geometry.plane.xy_plane()
    return xy plane which is a Plane

Geometry3D.geometry.plane.yz_plane()
    return yz plane which is a Plane

Geometry3D.geometry.plane.xz_plane()
    return xz plane which is a Plane
5.2.6 Geometry3D.geometry.point module

Point Module

class Geometry3D.geometry.point.Point(*args)
    Bases: object
    • Point(a, b, c)
    • Point([a, b, c]):
      The point with coordinates (a | b | c)
    • Point(Vector):
      The point that you get when you move the origin by the given vector. If the vector has coordinates (a | b | c), the
      point will have the coordinates (a | b | c) (as easy as pi).

class_level = 0
distance(other)
    Return the distance between self and other

move(v)
    Return the point that you get when you move self by vector v, self is also moved

classmethod origin()
    Returns the Point (0 | 0 | 0)

pv()
    Return the position vector of the point.

Geometry3D.geometry.point.origin()
    Returns the Point (0 | 0 | 0)

5.2.7 Geometry3D.geometry.polygon module

Polygon Module

class Geometry3D.geometry.polygon.ConvexPolygon(pts,
    reverse=False,
    check_convex=False)
    Bases: Geometry3D.geometry.body.GeoBody
    • ConvexPolygons(points)
      points: a tuple of points.
      The points needn’t to be in order.
      The convexity should be guaranteed. This function will not check the convexity. If the Polygon is not convex, there
      might be errors.

classmethod Circle(center, normal, radius, n=10)
    A special function for creating an inscribed convex polygon of a circle
    Input:
    • Center: The center point of the circle
    • normal: The normal vector of the circle
    • radius: The radius of the circle
    • n=10: The number of Points of the ConvexPolygon
Output:
• An inscribed convex polygon of a circle.

classmethod Parallelogram(base_point, v1, v2)
A special function for creating Parallelogram

Input:
• base_point: a Point
• v1, v2: two Vectors

Output:
• A parallelogram which is a ConvexPolygon instance.

area()
Input:
• self

Output:
• The area of the convex polygon

class_level = 4

eq_with_normal(other)
return whether self equals with other considering the normal

hash_with_normal()
return the hash value considering the normal

in_(other)
Input:
• self: ConvexPolygon
• other: Plane

Output:
• whether self in other

length()
return the total length of ConvexPolygon

move(v)
Return the ConvexPolygon that you get when you move self by vector v, self is also moved

segments()
Input:
• self

Output:
• iterator of segments

Geometry3D.geometry.polygon.Parallelogram(base_point, v1, v2)
A special function for creating Parallelogram

Input:
• base_point: a Point
• v1, v2: two Vectors
Output:

- A parallelogram which is a ConvexPolygon instance.

`Geometry3D.geometry.polygon.get_circle_point_list(center, normal, radius, n=10)`

`Geometry3D.geometry.polygon.Circle(center, normal, radius, n=10)`

A special function for creating an inscribed convex polygon of a circle

Input:

- Center: The center point of the circle
- normal: The normal vector of the circle
- radius: The radius of the circle
- n=10: The number of Points of the ConvexPolygon

Output:

- An inscribed convex polygon of a circle.

### 5.2.8 Geometry3D.geometry.polyhedron module

Polyhedron Module

```python
class Geometry3D.geometry.polyhedron.ConvexPolyhedron(convex_polygons)
    Bases: Geometry3D.geometry.body.GeoBody

classmethod Cone(circle_center, radius, height_vector, n=10)
    A special function for creating the inscribed polyhedron of a sphere

    Input:
    - circle_center: The center of the bottom circle
    - radius: The radius of the bottom circle
    - height_vector: The Vector from the bottom circle center to the top circle center
    - n=10: The number of Points on the bottom circle

    Output:
    - An inscribed polyhedron of the given cone.

classmethod Cylinder(circle_center, radius, height_vector, n=10)
    A special function for creating the inscribed polyhedron of a sphere

    Input:
    - circle_center: The center of the bottom circle
    - radius: The radius of the bottom circle
    - height_vector: The Vector from the bottom circle center to the top circle center
    - n=10: The number of Points on the bottom circle

    Output:
    - An inscribed polyhedron of the given cylinder.

classmethod Parallelepiped(base_point, v1, v2, v3)
    A special function for creating Parallelepiped

    Input:
```
• base_point: a Point
• v1, v2, v3: three Vectors

Output:
• A parallelepiped which is a ConvexPolyhedron instance.

classmethod Sphere(center, radius, n1=10, n2=3)
A special function for creating the inscribed polyhedron of a sphere

Input:
• center: The center of the sphere
• radius: The radius of the sphere
• n1=10: The number of Points on a longitude circle
• n2=3: The number sections of a quarter latitude circle

Output:
• An inscribed polyhedron of the given sphere.

area()
return the total area of the polyhedron

class_level = 5

Input:
• convexPolygons: tuple of ConvexPolygons

Output:
• ConvexPolyhedron
• The correctness of convexPolygons are checked According to Euler’s formula.
• The normal of the convex polygons are checked and corrected which should be toward the outer direction

length()
return the total length of the polyhedron

move(v)
Return the ConvexPolyhedron that you get when you move self by vector v, self is also moved

volume()
return the total volume of the polyhedron

Geometry3D.geometry.polyhedron.Parallelepiped(base_point, v1, v2, v3)
A special function for creating Parallelepiped

Input:
• base_point: a Point
• v1, v2, v3: three Vectors

Output:
• A parallelepiped which is a ConvexPolyhedron instance.

Geometry3D.geometry.polyhedron.Cone(circle_center, radius, height_vector, n=10)
A special function for creating the inscribed polyhedron of a sphere

Input:
• `circle_center`: The center of the bottom circle
• `radius`: The radius of the bottom circle
• `height_vector`: The Vector from the bottom circle center to the top circle center
• `n=10`: The number of Points on the bottom circle

**Output:**

• An inscribed polyhedron of the given cone.

```python
Geometry3D.geometry.polyhedron.Sphere(center, radius, n1=10, n2=3)
```

A special function for creating the inscribed polyhedron of a sphere

**Input:**

• `center`: The center of the sphere
• `radius`: The radius of the sphere
• `n1=10`: The number of Points on a longitude circle
• `n2=3`: The number sections of a quarter latitude circle

**Output:**

• An inscribed polyhedron of the given sphere.

```python
Geometry3D.geometry.polyhedron.Cylinder(circle_center, radius, height_vector, n=10)
```

A special function for creating the inscribed polyhedron of a sphere

**Input:**

• `circle_center`: The center of the bottom circle
• `radius`: The radius of the bottom circle
• `height_vector`: The Vector from the bottom circle center to the top circle center
• `n=10`: The number of Points on the bottom circle

**Output:**

• An inscribed polyhedron of the given cylinder.

### 5.2.9 Geometry3D.geometry.pyramid module

**Pyramid Module**

```python
class Geometry3D.geometry.pyramid.Pyramid(cp, p, direct_call=True)
    Bases: Geometry3D.geometry.body.GeoBody
```

**Input:**

• `cp`: a ConvexPolygon
• `p`: a Point

```python
height()
```

return the height of the pyramid

```python
volume()
```

return the volume of the pyramid
5.2.10 Geometry3D.geometry.segment module

Segment Module

class Geometry3D.geometry.segment.Segment (a, b)  
Bases: Geometry3D.geometry.body.GeoBody

Input:
- Segment(Point,Point)
- Segment(Point,Vector)

class_level = 3

in_ (other)  
other can be plane or line

length ()  
return the length of the segment

move (v)  
Return the Segment that you get when you move self by vector v, self is also moved

parametric ()  
Returns (start_point, end_point) so that you can build the information for the segment

5.2.11 Module contents

class Geometry3D.geometry.ConvexPolyhedron (convex_polygons)  
Bases: Geometry3D.geometry.body.GeoBody

classmethod Cone (circle_center, radius, height_vector, n=10)  
A special function for creating the inscribed polyhedron of a sphere

Input:
- circle_center: The center of the bottom circle
- radius: The radius of the bottom circle
- height_vector: The Vector from the bottom circle center to the top circle center
- n=10: The number of Points on the bottom circle

Output:
- An inscribed polyhedron of the given cone.

classmethod Cylinder (circle_center, radius, height_vector, n=10)  
A special function for creating the inscribed polyhedron of a sphere

Input:
- circle_center: The center of the bottom circle
- radius: The radius of the bottom circle
- height_vector: The Vector from the bottom circle center to the top circle center
- n=10: The number of Points on the bottom circle

Output:
- An inscribed polyhedron of the given cylinder.
class method Parallelepiped $(\text{base\_point}, v1, v2, v3)$
A special function for creating Parallelepiped

**Input:**
- base\_point: a Point
- v1, v2, v3: three Vectors

**Output:**
- A parallelepiped which is a ConvexPolyhedron instance.

class method Sphere $(\text{center}, \text{radius}, n1=10, n2=3)$
A special function for creating the inscribed polyhedron of a sphere

**Input:**
- center: The center of the sphere
- radius: The radius of the sphere
- n1=10: The number of Points on a longitude circle
- n2=3: The number sections of a quater latitude circle

**Output:**
- An inscribed polyhedron of the given sphere.

area ()
return the total area of the polyhedron

class level = 5

**Input:**
- convex\_polygons: tuple of ConvexPolygons

**Output:**
- ConvexPolyhedron
- The correctness of convex\_polygons are checked According to Euler’s formula.
- The normal of the convex polygons are checked and corrected which should be toward the outer direction

length ()
return the total length of the polyhedron

move $(v)$
Return the ConvexPolyhedron that you get when you move self by vector v, self is also moved

volume ()
return the total volume of the polyhedron

Geometry3D.geometry.Parallelepiped $(\text{base\_point}, v1, v2, v3)$
A special function for creating Parallelepiped

**Input:**
- base\_point: a Point
- v1, v2, v3: three Vectors

**Output:**
- A parallelepiped which is a ConvexPolyhedron instance.
Geometry3D.geometry.Sphere(center, radius, n1=10, n2=3)
A special function for creating the inscribed polyhedron of a sphere

Input:

• center: The center of the sphere
• radius: The radius of the sphere
• n1=10: The number of Points on a longitude circle
• n2=3: The number sections of a quarter latitude circle

Output:

• An inscribed polyhedron of the given sphere.

Geometry3D.geometry.Cone(circle_center, radius, height_vector, n=10)
A special function for creating the inscribed polyhedron of a sphere

Input:

• circle_center: The center of the bottom circle
• radius: The radius of the bottom circle
• height_vector: The Vector from the bottom circle center to the top circle center
• n=10: The number of Points on the bottom circle

Output:

• An inscribed polyhedron of the given cone.

Geometry3D.geometry.Cylinder(circle_center, radius, height_vector, n=10)
A special function for creating the inscribed polyhedron of a sphere

Input:

• circle_center: The center of the bottom circle
• radius: The radius of the bottom circle
• height_vector: The Vector from the bottom circle center to the top circle center
• n=10: The number of Points on the bottom circle

Output:

• An inscribed polyhedron of the given cylinder.

class Geometry3D.geometry.ConvexPolygon(pts, reverse=False, check_convex=False)
Bases: Geometry3D.geometry.body.GeoBody

• ConvexPolygons(points)

points: a tuple of points.

The points needn’t to be in order.

The convexity should be guaranteed. This function will not check the convexity. If the Polygon is not convex, there might be errors.

classmethod Circle(center, normal, radius, n=10)
A special function for creating an inscribed convex polygon of a circle

Input:

• Center: The center point of the circle
- normal: The normal vector of the circle
- radius: The radius of the circle
- n=10: The number of Points of the ConvexPolygon

**Output:**
- An inscribed convex polygon of a circle.

**classmethod Parallelogram**(base_point, v1, v2)
A special function for creating Parallelogram

**Input:**
- base_point: a Point
- v1, v2: two Vectors

**Output:**
- A parallelogram which is a ConvexPolygon instance.

**area()**

**Input:**
- self

**Output:**
- The area of the convex polygon

**class_level = 4**

**eq_with_normal**(other)
return whether self equals with other considering the normal

**hash_with_normal()**
return the hash value considering the normal

**in_(other)**

**Input:**
- self: ConvexPolygon
- other: Plane

**Output:**
- whether self in other

**length()**
return the total length of ConvexPolygon

**move**(v)
Return the ConvexPolygon that you get when you move self by vector v, self is also moved

**segments()**

**Input:**
- self

**Output:**
- iterator of segments
Geometry3D.geometry.Parallelogram \((base\_point, v1, v2)\)

A special function for creating Parallelogram

**Input:**
- `base_point`: a Point
- `v1, v2`: two Vectors

**Output:**
- A parallelogram which is a ConvexPolygon instance.

Geometry3D.geometry.Circle \((center, normal, radius, n=10)\)

A special function for creating an inscribed convex polygon of a circle

**Input:**
- `Center`: The center point of the circle
- `normal`: The normal vector of the circle
- `radius`: The radius of the circle
- `n=10`: The number of Points of the ConvexPolygon

**Output:**
- An inscribed convex polygon of a circle.

```python
class Geometry3D.geometry.Pyramid(cp, p, direct_call=True):
   _bases: Geometry3D.geometry.body.GeoBody

    **Input:**
    - `cp`: a ConvexPolygon
    - `p`: a Point

    **height()**
    return the height of the pyramid

    **volume()**
    return the volume of the pyramid
```

```python
class Geometry3D.geometry.Segment(a, b):
    _bases: Geometry3D.geometry.body.GeoBody

    **Input:**
    - Segment(Point,Point)
    - Segment(Point,Vector)

    **class_level = 3**

    **in_(other)**
    other can be plane or line

    **length()**
    return the length of the segment

    **move(v)**
    Return the Segment that you get when you move self by vector v, self is also moved

    **parametric()**
    Returns (start_point, end_point) so that you can build the information for the segment
```

5.2. Geometry3D.geometry package
class Geometry3D.geometry.Line(a, b)
    Bases: Geometry3D.geometry.body.GeoBody

    • Line(Point, Point):
        A Line going through both given points.
    • Line(Point, Vector):
        A Line going through the given point, in the direction pointed by the given Vector.
    • Line(Vector, Vector):
        The same as Line(Point, Vector), but with instead of the point only the position vector of the point is given.

class_level = 1

move(v)
    Return the line that you get when you move self by vector v, self is also moved

parametric()
    Returns (s, u) so that you can build the equation for the line ___
    g: x = s + ru ; r e R

classmethod x_axis()
    return x axis which is a Line

classmethod y_axis()
    return y axis which is a Line

classmethod z_axis()
    return z axis which is a Line

class Geometry3D.geometry.Plane(*args)
    Bases: Geometry3D.geometry.body.GeoBody

    • Plane(Point, Point, Point):
        Initialise a plane going through the three given points.
    • Plane(Point, Vector, Vector):
        Initialise a plane given by a point and two vectors lying on the plane.
    • Plane(Point, Vector):
        Initialise a plane given by a point and a normal vector (point normal form)
    • Plane(a, b, c, d):
        Initialise a plane given by the equation ax1 + bx2 + cx3 = d (general form).

class_level = 2

general_form()
    Returns (a, b, c, d) so that you can build the equation
    E: ax1 + bx2 + cx3 = d
    to describe the plane.

move(v)
    Return the plane that you get when you move self by vector v, self is also moved

parametric()
    Returns (u, v, w) so that you can build the equation ___

\[ E: x = u + rv + sw : (r, s) \in \mathbb{R} \]
to describe the plane (a point and two vectors).

**point_normal()**

Returns \((p, n)\) so that you can build the equation

\[ E: (x - p) \cdot n = 0 \]
to describe the plane.

**classmethod xy_plane()**

return xy plane which is a Plane

**classmethod xz_plane()**

return xz plane which is a Plane

**classmethod yz_plane()**

return yz plane which is a Plane

---

```
5.2. Geometry3D.geometry package
```

**class Geometry3D.geometry.Point(*args)**

Bases: object

- Point(a, b, c)
- Point([a, b, c]):

The point with coordinates \((a | b | c)\)

- Point(Vector):

The point that you get when you move the origin by the given vector. If the vector has coordinates \((a | b | c)\), the point will have the coordinates \((a | b | c)\) (as easy as pi).

**class_level = 0**

**distance(other)**

Return the distance between self and other

**move(v)**

Return the point that you get when you move self by vector v, self is also moved

**classmethod origin()**

Returns the Point \((0 | 0 | 0)\)

**pv()**

Return the position vector of the point.

---

```
5.2. Geometry3D.geometry package
```

**class Geometry3D.geometry.HalfLine(a, b)**

Bases: Geometry3D.geometry.body.GeoBody

Input:

- HalfLine(Point,Point)
- HalfLine(Point,Vector)

**class_level = 6**

**in_(other)**

other can be plane or line

**move(v)**

Return the HalfLine that you get when you move self by vector v, self is also moved
parametric()
    Returns (point, vector) so that you can build the information for the halfline

Geometry3D.geometry.origin()
    Returns the Point (0 0 0)

Geometry3D.geometry.x_axis()
    return x axis which is a Line

Geometry3D.geometry.y_axis()
    return y axis which is a Line

Geometry3D.geometry.z_axis()
    return z axis which is a Line

Geometry3D.geometry.xy_plane()
    return xy plane which is a Plane

Geometry3D.geometry.yz_plane()
    return yz plane which is a Plane

Geometry3D.geometry.xz_plane()
    return xz plane which is a Plane

Geometry3D.geometry.get_circle_point_list(center, normal, radius, n=10)

5.3 Geometry3D.render package

5.3.1 Submodules

5.3.2 Geometry3D.render.arrow module

Arrow Module for Renderer

class Geometry3D.render.arrow.Arrow(x, y, z, u, v, w, length)
    Bases: object

    Arrow Class

    get_tuple()
        return the tuple expression of the arrow

5.3.3 Geometry3D.render.renderer module

Abstract Renderer Module

Geometry3D.render.renderer.Renderer(backend='matplotlib')

Input:
    • backend: the backend of the renderer

    Only matplotlib is supported till now
5.3.4 Geometry3D.render.renderer_matplotlib module

Matplotlib Renderer Module

class Geometry3D.render.renderer_matplotlib.MatplotlibRenderer
    Bases: object
    
    Renderer module to visualize geometries

    add(obj, normal_length=0)
        Input:
        - obj: a tuple (object, color, size)
        - normal_length: the length of normal arrows for ConvexPolyhedron.
        
        For other objects, normal_length should be zero. If you don’t want to show the normal arrows for a
        ConvexPolyhedron, you can set normal_length to 0.
        
        object can be Point, Segment, ConvexPolygon or ConvexPolyhedron

    show()
        Draw the image

5.3.5 Module contents

Geometry3D.render.Renderer (backend='matplotlib')
    Input:
    - backend: the backend of the renderer
      
      Only matplotlib is supported till now

5.4 Geometry3D.utils package

5.4.1 Submodules

5.4.2 Geometry3D.utils.constant module

Constant module

EPS and significant numbers for comparing float point numbers.

Two float numbers are deemed equal if they equal with each other within significant numbers.

Significant numbers = log(1 / eps) all the time

Geometry3D.utils.constant.set_eps (eps=1e-10)
    Input:
    - eps: floating number with 1e-10 the default

    Output:
    
    No output but set EPS to eps

    Significant numbers is also changed.
Geometry3D.utils.constant.get_eps()  
**Input:**  
no input  
**Output:**  
• current eps: float

Geometry3D.utils.constant.get_sig_figures()  
**Input:**  
no input  
**Output:**  
• current significant numbers: int

Geometry3D.utils.constant.set_sig_figures(sig_figures=10)  
**Input:**  
• sig_figures: int with 10 the default  
**Output:**  
No output but set significant numbers to sig_figures  
EPS is also changed.

### 5.4.3 Geometry3D.utils.logger module

**Logger Module**

Geometry3D.utils.logger.change_main_logger()  

Geometry3D.utils.logger.get_main_logger()  
**Input:**  
No Input  
**Output:**  
main_logger: The logger instance

Geometry3D.utils.logger.set_log_level(level='WARNING')  
**Input:**  
• level: a string of log level among 'DEBUG', 'INFO', 'WARNING', 'ERROR', 'CRITICAL'.  
  ‘WARNING’ is the default.  
**Output:**  
No output but setup the log level for the logger
5.4.4 Geometry3D.utils.solver module

Solver Module, An Auxiliary Module

class Geometry3D.utils.solver.Solution(s)
    Bases: object
    Holds a solution to a system of equations.

Geometry3D.utils.solver.count(f, l)

Geometry3D.utils.solver.find_pivot_row(m)

Geometry3D.utils.solver.first_nonzero(r)

Geometry3D.utils.solver.gaussian_elimination(m)
    Return the row echelon form of m by applying the gaussian elimination

Geometry3D.utils.solver.index(f, l)

Geometry3D.utils.solver.null(f)

Geometry3D.utils.solver.nullrow(r)

Geometry3D.utils.solver.shape(m)

Geometry3D.utils.solver.solve(matrix)

5.4.5 Geometry3D.utils.util module

Util Module

Geometry3D.utils.util.unify_types(items)
    Promote all items to the same type. The resulting type is the “most valuable” that an item already has as defined by the list (top = least valuable):
    • int
    • float
    • decimal.Decimal
    • fractions.Fraction
    • user defined

5.4.6 Geometry3D.utils.vector module

Vector Module

class Geometry3D.utils.vector.Vector(*args)
    Bases: object
    Vector Class

    angle(other)
    Returns the angle (in radians) enclosed by both vectors.

    cross(other)
    Calculates the cross product of two vectors, defined as _ _ / x2y3 - x3y2 x x y = l x3y1 - x1y3 l
    x1y2 - x2y1 /
The cross product is orthogonal to both vectors and its length is the area of the parallelogram given by \( x \) and \( y \).

**length()**
- Returns \(|v|\), the length of the vector.

**normalized()**
- Return the normalized version of the vector, that is a vector pointing in the same direction but with length 1.

**orthogonal**(other)
- Returns true if the two vectors are orthogonal.

**parallel**(other)
- Returns true if both vectors are parallel.

**unit()**
- Return the normalized version of the vector, that is a vector pointing in the same direction but with length 1.

**classmethod x_unit_vector()**
- Returns the unit vector (1 0 0)

**classmethod y_unit_vector()**
- Returns the unit vector (0 1 0)

**classmethod z_unit_vector()**
- Returns the unit vector (0 0 1)

**classmethod zero()**
- Returns the zero vector (0 0 0)

Geometry3D.utils.vector.x_unit_vector()
- Returns the unit vector (1 0 0)

Geometry3D.utils.vector.y_unit_vector()
- Returns the unit vector (0 1 0)

Geometry3D.utils.vector.z_unit_vector()
- Returns the unit vector (0 0 1)

### 5.4.7 Module contents

Geometry3D.utils.solve(matrix)

**class** Geometry3D.utils.Vector(*args)
- Bases: object

Vector Class

**angle**(other)
- Returns the angle (in radians) enclosed by both vectors.

**cross**(other)
- Calculates the cross product of two vectors, defined as

\[
\begin{vmatrix}
    x_1 & y_1 & z_1 \\
    x_2 & y_2 & z_2 \\
    x_3 & y_3 & z_3 \\
\end{vmatrix}
\]

The cross product is orthogonal to both vectors and its length is the area of the parallelogram given by \( x \) and \( y \).

**length()**
- Returns \(|v|\), the length of the vector.
normalized()
Return the normalized version of the vector, that is a vector pointing in the same direction but with length 1.

orthogonal (other)
Returns true if the two vectors are orthogonal

parallel (other)
Returns true if both vectors are parallel.

unit()
Return the normalized version of the vector, that is a vector pointing in the same direction but with length 1.

classmethod x_unit_vector()
Returns the unit vector (1 0 0)

classmethod y_unit_vector()
Returns the unit vector (0 1 0)

classmethod z_unit_vector()
Returns the unit vector (0 0 1)

classmethod zero()
Returns the zero vector (0 0 0)

Geometry3D.utils.x_unit_vector()
Returns the unit vector (1 0 0)

Geometry3D.utils.y_unit_vector()
Returns the unit vector (0 1 0)

Geometry3D.utils.z_unit_vector()
Returns the unit vector (0 0 1)

Geometry3D.utils.set_eps (eps=1e-10)
Input:
• eps: floating number with 1e-10 the default

Output:
No output but set EPS to eps
Significant numbers is also changed.

Geometry3D.utils.get_eps()
Input:
no input

Output:
• current eps: float

Geometry3D.utils.get_sig_figures()
Input:
no input

Output:
• current significant numbers: int

Geometry3D.utils.set_sig_figures (sig_figures=10)
Input:
• sig_figures: int with 10 the default

**Output:**

No output but set significant numbers to sig_figures
EPS is also changed.

`Geometry3D.utils.set_log_level(level='WARNING')`

**Input:**

  ‘WARNING’ is the default.

**Output:**

No output but setup the log level for the logger

`Geometry3D.utils.get_main_logger()`

**Input:**

No Input

**Output:**

main_logger: The logger instance
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