Damir Horvat damir.horvat1@foi.hr

Marija Jakuš marija.jakus@foi.hr

Faculty of organization and informatics

University of Zagreb

Pavlinska 2, Varazdin, Croatia

MayaVi as a tool for presentation of geometric bodies

Abstract:

It is a common occurrence to talk about the necessity of implementing IC technology within math learning process. Today, learners' generations are dealing with technology from early childhood so, it is essential to adapt teaching methods to their needs and habits.

In this paper, we shall introduce MayaVi - software for animation, modelling and simulation. Through various examples, we will provide just one small segment of the MayaVi usage - the presentation of geometric bodies and intersection of geometric bodies with plane. This area of mathematics is a part of the national curriculum for the 2nd grade of secondary (technical) schools. As in teaching, the body sketches are mainly drawn by hand, we believe that an alternative, more dynamic and interactive approach could refresh and enrich the math teaching process.

Keywords: math, geometric bodies, MayaVi

Introduction

Stereometry is implemented within the math teaching program in the second grade of secondary technical schools. Learners enhance an existing gained knowledge of geometric bodies – the cube, cuboid, prism, pyramid, cylinder, cone and ball. For geometric bodies, volume and surface area are calculated. In addition, the relation between bodies and planes are determined through intersections.

Mathematical education should enable a development of the learner’s spatial ability and visualization and also the ability of recognition and usage of geometric properties in real objects.

Spatial ability is the intuitive sense for geometric abstracts and includes the ability of recognition, visual representation and transforming geometric shapes. Geometric thinking, according to van Hiele, is divided into 5 levels, of which visualization is level 0. Visualization in geometric bodies is usually shown through drawing sketches on a board. Interestingly, teachers rarely use technology for the presentation of sketches. In this paper, we present a tool which enables interactive sketches of body which usually captures the learner's interest in the teaching material.

Interactivity enables an overview of geometric bodies from different perspectives that contribute to better comprehension of the relation between two dimensional and three dimensional figures.

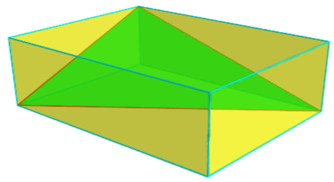
About MayaVi and Python

Python is a free programming language with a high level of abstraction and very readable code. It is very simple even for beginners and yet very powerful for serious projects. Python provides solutions using only a few lines of code, whereas other programming languages require several hundred lines. In solving these kinds of issues, different modules are used that substantially shorten the code's length. Additional modules are subsequently installed as they are usually not standard equipment of Python. One such module is MayaVi, a Python's module for visualization of 3D objects. MayaVi aims to keep a high level of abstraction bearing in mind that in different fields of human activity we often find problems that can be solved by similar methods. However, as Python is powerful programming language with a relatively simple syntax, MayaVi enables users to show complex 3D objects in a more simplified and faster way, without spending further time on writing complicate code. Due to this specification, MayaVi is not only a 3D visualization tool, but has many useful additions not directly related to visualization. Let us mention traits that simplify object programming allowing users to create small applications of their visualizations. So users can input graphic objects in their 3D visualizations, where they can interactively change certain parameters. While the program starts, rotation and zooming of the object are enabled automatically, an area of this complex operation already taken care of. Thus, MayaVi can be used within Python and additionally may be used as an independent application with its own graphic interface. In this way, beginners are able to upload data through menus and represent them without a great deal of programming knowledge.

Examples

We chose five examples from the workbook for 2nd grade of secondary technical schools. We will show how geometric bodies and their intersection with planes and other bodies can be presented using the MayaVi programming tool. For each example, we provide a text task, sketches made in MayaVi and code that describes body and intersection.

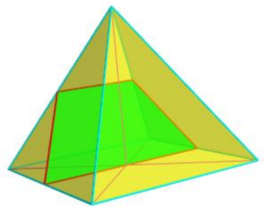
Example. 1. The plane that passes through the vertices A, C and D1 is suited to the base at 60º. What is the volume of the cuboid if the length of its fundamental edges are 6 cm and 8 cm?



```
#!/usr/bin/python
import numpy as np
from mayavi import mlab
c=5*np.tan(np.deg2rad(30))
X=np.array([0,6,6,0,0,6,6,0])
Y=np.array([0,0,8,8,0,0,8,8])
Z=np.array([0,0,0,0,c,c,c,c])
tocke = np.column_stack((X,Y,Z))
mlab.figure(figure=None, bgcolor=None, fgcolor=None, engine=None, size=(800, 600))
#mlab.points3d(X, Y, Z, color=(1,1,0), resolution=15, scale_factor=0.2)
mlab.triangular_mesh(X, Y, Z, [(0,1,2), (0,2,3), (0,4,5), (5,1,0), (1,2,5), (2,6,5), (5,6,4),
(6,7,4), (2,3,6), (3,7,6), (3,4,7), (3,0,4)], opacity=0.5,color=(1,1,0))
for i in xrange(tocke.shape[0]):
        for j in xrange(i+1,tocke.shape[0]):
                vektor = tocke[i]-tocke[j]
                if np.dot(vektor,vektor) in [c**2,36,64]:
                        mlab.plot3d( np.array([X[i], X[j]]), np.array([Y[i], Y[j]]),
                        np.array([Z[i], Z[j]]), tube_sides=8, color=(0,1,1) )
mlab.plot3d(np.array([X[1],X[3],X[4],X[1]]), np.array([Y[1],Y[3],Y[4],Y[1]]),
np.array([Z[1],Z[3],Z[4],Z[1]]), tube_sides=8,color=(1,0,0))
mlab.triangular_mesh(np.array([X[1],X[3],X[4]]), np.array([Y[1],Y[3],Y[4]]),
np.array([Z[1],Z[3],Z[4]]), [(0,1,2)], opacity=0.7,color=(0,1,0))
mlab.show()
```

Example 2. The plane passing foot of an altitude of standard height four-sided prisms is parallel to one's face. The area of intersection is 27 cm^2. If its faces are suited to the base at angle, what is the volume of the pyramid?

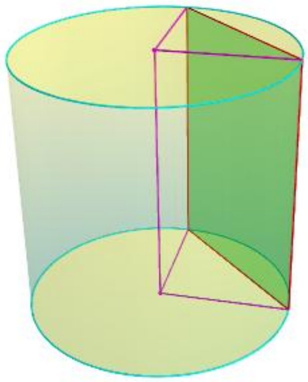
```
#!/usr/bin/python
import numpy as np
from mayavi import mlab
a=2
fi=60
v=a/2.0*np.tan(np.radians(fi))
X=np.array([0,a,a,0,a/2.0])
Y=np.array([0,0,a,a,a/2.0])
Z=np.array([0,0,0,0,v])
#tocke = np.column_stack((X,Y,Z))
mlab.figure(figure=None, bgcolor=None, fgcolor=None, engine=None, size=(800, 600))
mlab.points3d([a/2.0],[a/2.0],[0], color=(1,0,1), resolution=15, scale_factor=0.03)
mlab.triangular_mesh(X, Y, Z, [(0,1,2), (0,2,3), (0,1,4), (1,2,4), (2,3,4), (3,0,4)],
opacity=0.5,color=(1,1,0))
#bridovi piramide
for i in xrange(4):
	j=(i+1)%4
	mlab.plot3d( np.array([X[i], X[4]]), np.array([Y[i], Y[4]]), np.array([Z[i], Z[4]]),
	tube_sides=8, tube_radius=0.01, color=(0,1,1) )
	mlab.plot3d( np.array([X[i], X[j]]), np.array([Y[i], Y[j]]), np.array([Z[i], Z[j]]), t
	ube_sides=8, tube_radius=0.01, color=(0,1,1) )
#dijagonale baze i visina
mlab.plot3d( np.array([X[0], X[2]]), np.array([Y[0], Y[2]]), np.array([Z[0], Z[2]]),
tube_sides=8, tube_radius=0.005, color=(1,0,1) )
mlab.plot3d( np.array([X[1], X[3]]), np.array([Y[1], Y[3]]), np.array([Z[1], Z[3]]),
tube_sides=8, tube_radius=0.005, color=(1,0,1) )
mlab.plot3d([a/2.0,a/2.0],[a/2.0,a/2.0],[0,v], tube_sides=8, tube_radius=0.005, color=(1,0,1) )
#presjek
Xp=np.array([a,0,a/4.0,3/4.0*a])
Yp=np.array([a/2.0,a/2.0,a/4.0,a/4.0])
Zp=np.array([0,0,v/2.0,v/2.0])
for i in xrange(4):
	j=(i+1)%4
	mlab.plot3d( np.array([Xp[i], Xp[j]]), np.array([Yp[i], Yp[j]]), np.array([Zp[i],
	Zp[j]]), tube_sides=8, tube_radius=0.01, color=(1,0,0) )
mlab.triangular_mesh(Xp, Yp, Zp, [(0,1,2), (2,3,0)], opacity=0.7,color=(0,1,0))
mlab.show()
```



Example 3. The right cylinder with a bases radius of 10 cm and a height of 15 cm was cut parallel to the plane of the axis of the cylinder so that the end points to the tendon close to the centre of bases right angle. Calculate the surface area of the larger part of the cylinder which originated in this section.

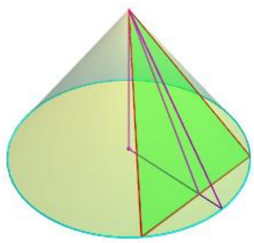
```
#!/usr/bin/python
import numpy as np
from mayavi import mlab
r=1.5
```

```
[u,v]=np.mgrid[0:2*np.pi:100j, 0:3:100j]
[u1,v1]=np.mgrid[0:2*np.pi:100j,0:r:100j]
u3=np.linspace(0.0, 2*np.pi, num=150)
mlab.figure(figure=None, bgcolor=(0.5,0.5,0.5), fgcolor=None, engine=None, size=(800, 600))
#plast valjka
x=r*np.cos(u)
y=r*np.sin(u)
z=v
mlab.mesh(x, y, z, colormap='summer',
opacity=0.2)
#baze valjka
x1=v1*np.cos(u1)
y1=v1*np.sin(u1)
z1=0*v1
z2=0*v1+3
mlab.mesh(x1, y1, z1, color=(1,1,0),
opacity=0.25)
mlab.mesh(x1, y1, z2, color=(1,1,0),
opacity=0.25)
#kruznice baza
x3=r*np.cos(u3)
y3=r*np.sin(u3)
z3=0*u3
mlab.plot3d(x3, y3, z3, tube_sides=8, tube_radius=0.01, color=(0,1,1))
mlab.plot3d(x3, y3, z3+3, tube_sides=8, tube_radius=0.01, color=(0,1,1))
#visina valjka
mlab.points3d([0,0], [0,0], [0,3], color=(1,0,1), resolution=15, scale_factor=0.05)
mlab.plot3d([0,0], [0,0], [0,3], tube_sides=10, tube_radius=0.01, color=(1,0,1))
#dodatni elementi
X=np.array([0,-r,-r,0,0,0])
Y=np.array([r,0,0,r,0,0])
Z=np.array([0,0,3,3,0,3])
mlab.plot3d(np.array([X[0],X[5],X[1]]), np.array([Y[0],Y[4],Y[1]]),
np.array([Z[0],Z[4],Z[1]]), tube_sides=8, tube_radius=0.01, color=(1,0,1))
mlab.plot3d(np.array([X[2],X[5],X[3]]), np.array([Y[2],Y[5],Y[3]]),
np.array([Z[2],Z[5],Z[3]]), tube_sides=8, tube_radius=0.01, color=(1,0,1))
#presjek
mlab.plot3d(np.array([X[0],X[1],X[2],X[3],X[0]]), np.array([Y[0],Y[1],Y[2],Y[3],Y[0]]),
np.array([Z[0],Z[1],Z[2],Z[3],Z[0]]), tube_sides=8, tube_radius=0.01, color=(1,0,0))
mlab.triangular_mesh(X,Y,Z, [(0,1,2),(0,2,3)], opacity=0.4,color=(0,1,0))
mlab.show()
```



Example 4. The height of the cone is 4 cm long, the length of generatrix is 10 cm. What is the area of conic section with plane passing the apex of the cone that is suited at 60º to the plane of the bases?

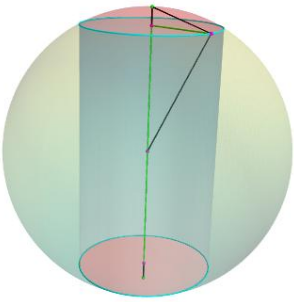
```
#!/usr/bin/python
import numpy as np
from mayavi import mlab
r=1.5
h=2
fi=60
d=h/np.tan(np.radians(fi))
[u,v]=np.mgrid[0:2*np.pi:150j, 0:1:100j]
[u1,v1]=np.mgrid[0:2*np.pi:100j,0:r:100j]
u2=np.linspace(0.0, 2*np.pi, num=150)
mlab.figure(figure=None, bgcolor=(0.5,0.5,0.5), fgcolor=None, engine=None, size=(800,
600))
#plast stosca
x=r*v*np.cos(u)
y=r*v*np.sin(u)
z=(1-v)*h
mlab.mesh(x, y, z, colormap='summer',
opacity=0.25)
#baza stosca
x1=v1*np.cos(u1)
y1=v1*np.sin(u1)
z1=0*v1
mlab.mesh(x1, y1, z1, color=(1,1,0),
opacity=0.25)
#bazna kruznica
x2=r*np.cos(u2)
y2=r*np.sin(u2)
z2=0*u2
mlab.plot3d(x2, y2, z2, tube_sides=8, tube_radius=0.01, color=(0,1,1))
#presjek
xd=np.sqrt(r**2-d**2)
mlab.plot3d([xd,-xd,0,xd], [d,d,0,d], [0,0,h,0], tube_sides=8, tube_radius=0.01, color=(1,0,0))
mlab.triangular_mesh([xd,-xd,0], [d,d,0], [0,0,h], [(0,1,2)], opacity=0.4,color=(0,1,0))
#visina presjeka, visina stosca, polumjer baze, izvodnica stosca
mlab.points3d([0], [0], [0], color=(1,0,1), resolution=15, scale_factor=0.05)
mlab.plot3d([0,0,0,0,0], [d,0,0,r,0], [0,h,0,0,h], tube_sides=10, tube_radius=0.01,
color=(1,0,1))
mlab.show()
```



Example 5. In the sphere with a radius of 30 cm, a cylindrical hole is drilled whose axis length is equal diameter of the sphere. What is the volume of sphere ring if the hole has a radius of 18 cm?

```
#!/usr/bin/python
import numpy as np
from mayavi import mlab
r=2
#velicina rupe
d1=1.2
```

d2=np.pi-d1
#polumjer cilindra
r1=r*np.sin(d1)
#polovica visine cilindra
h1=r*np.cos(d1)
[v,u]=np.mgrid[0:2*np.pi:150j,
d1:d2:150j]
[u1,v1]=np.mgrid[0:2*np.pi:150j, -
h1:h1:100j]
[v2,u2]=np.mgrid[0:2*np.pi:150j,
0:d1:150j]
[v3,u3]=np.mgrid[0:2*np.pi:150j,
d2:np.pi:150j]
u4=np.linspace(0.0, 2*np.pi, num=150)



mlab.figure(figure=None, bgcolor=(0.5,0.5,0.5), fgcolor=None, engine=None, size=(800,
600))
#sfera
x=r*np.sin(u)*np.cos(v)
y=r*np.sin(u)*np.sin(v)
z=r*np.cos(u)
mlab.mesh(x, y, z, colormap='summer',opacity=0.2)
#cilindar
x1=r1*np.cos(u1)
y1=r1*np.sin(u1)
z1=v1
mlab.mesh(x1, y1, z1, colormap='Blues', opacity=0.2)
#kapica1
x2=r*np.sin(u2)*np.cos(v2)
y2=r*np.sin(u2)*np.sin(v2)
z2=r*np.cos(u2)
mlab.mesh(x2, y2, z2, color=(1,0,0), opacity=0.2)
#kapica2
x3=r*np.sin(u3)*np.cos(v3)
y3=r*np.sin(u3)*np.sin(v3)
z3=r*np.cos(u3)
mlab.mesh(x3, y3, z3, color=(1,0,0), opacity=0.2)
#bazne kruznice cilindra
x4=r1*np.cos(u4)
y4=r1*np.sin(u4)
z4=0*u4
mlab.plot3d(x4, y4, z4+h1, tube_sides=8, tube_radius=0.01, color=(0,1,1))
mlab.plot3d(x4, y4, z4-h1, tube_sides=8, tube_radius=0.01, color=(0,1,1))
#pomocni elementi
mlab.points3d([0,0,0,0], [0,0,0,r1], [0,h1,-h1,h1], color=(1,0,1), resolution=20,
scale_factor=0.05)
mlab.points3d([0,0], [0,0], [r,-r], color=(0,1,0), resolution=20, scale_factor=0.05)
mlab.plot3d([0,0,0], [0,0,0], [-h1,0,h1], tube_sides=8, tube_radius=0.01, color=(0,1,0))
mlab.plot3d([0,0], [0,0], [h1,r], tube_sides=8, tube_radius=0.01, color=(1,1,0))
mlab.plot3d([0,0], [0,0], [-h1,-r], tube_sides=8, tube_radius=0.01, color=(1,1,0))

```
mlab.plot3d([0,0,0], [0,r1,0], [0,h1,r], tube_sides=8, tube_radius=0.01, color=(1,1,0))
mlab.plot3d([0,0], [0,r1], [h1,h1], tube_sides=8, tube_radius=0.01, color=(0,1,0))
mlab.show()
```

Conclusion:

Today, ICT is used in high school education mostly through PP presentations. New generations of teachers are using ICT in learning process more often and more wider.

With this paper, we try to present one of the free available tools that can help us to enrich geometry teaching and improve visualization of mathematic shapes and bodies. We present Maya Vi, Python modul for object visualization, through five examples chosen from the workbook for 2nd grade of secondary technical schools. For each example, we provide a text task, sketches made in MayaVi and code that describes body and intersection. We invite readers to try MayaVi through these examples. We also hope, we succeed to interest readers to explore other numerous opportunities that MayaVi provides.

Reference:

[1] Ramachandran P. and Varoquaux G. *MayaVi: 3D Visualization of Scientific Data,* IEEE Computing in Science & Engineering, **13** (2), pp. 40-51 (2011);

[2] Python, http://www.python.org/ (25.01.2013.)

[3] Horvat D. (2010.) Matematički alati na FOI. Znanstveno-stručni kolokvij Matematika i e-učenje. Zbornik radova. Juny 27. 2010, Dubrovnik. TIVA. 17.-21.

[4] Čižmešija A., Svedrec R., Radović N., Soucie T. , Geometrijsko mišljenje i prostorni zor u nastavi matematike u nižim razredima osnovne škole, Zbornik radova 4. Kongresa nastavnika matematike Republike Hrvatske (Zagreb, 2010.)

[5] Dobi Barišić K., Đeri I., Jukić Lj. (2011). What is the future of the integration of ICT in teaching mathematics, *The third international scientific colloquium Mathematics and Children*. Monography. March 18, 2011,Osijek Editor:Margita Pavleković. Element.128-140.

[6] Divjak B., Erjavec Z., Jakuš M., Žugec B. (2011). When technology influences learning?, *The third international scientific colloquium Mathematics and Children*. Monography. March 18, 2011, Osijek Editor: Margita Pavleković. Element. 92-99.

[7] Dakić B., Elezović N. (1999.). Udžbenik i zbirka zadataka za 2. razred tehničkih škola. Element. 226-254