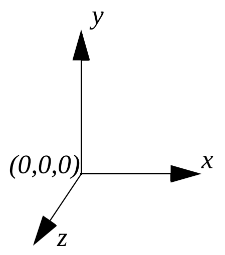
Simple 3D Programming Using VPython

I. VPython: the Python/ Visual / IDLE environment

The interactive development environment you will use is called “IDLE.”

The Visual window



When using the Visual graphics library with the Python programming language you are always working in 3D.

(0,0,0) is in the center of the display window. The +*x* axis runs to the right, the +*y* axis runs up, and the +*z* axis points out of the screen, toward you.

x, *y*, and *z* are measured in whatever units you choose; the display is automatically scaled appropriately. (You could, for example, create a sphere with a radius of 10^{-15} m to represent a nucleus, or a sphere with a radius of 10^{6} m to represent a planet—though it wouldn’t make sense to put both of these objects in the same display!)

The Output window

The output of any -print- statements you execute in your program goes to the Output window, which is a scrolling text window. You can use this window to print values of variables, print lists, print messages, etc.

The Code window

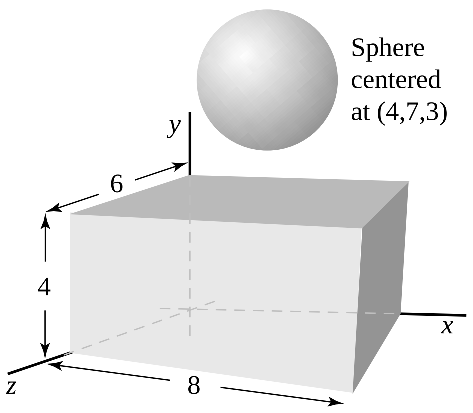
If you type the following simple program into the code window in IDLE and run it (see the Run menu), you will see a display like the one shown in the figure below. Note that you can use the left and right mouse buttons to navigate in the Visual window.

```
from visual import *

redbox=box(pos=vector(4,2,3), size=(8.,4.,6.),color=color.red)
greenball=sphere(pos=vector(4,7,3), radius=2, color=color.green)
```

II. Visual Entities

Objects, names, and attributes



The graphical objects you create, such as spheres, boxes, and curves, continue to exist for the duration of your program, and VPython will continue to display them, wherever they are. You must give each object a name (such as “redbox” or “greenball” in the example above) if you wish to refer to it again later in your program. All objects have *attributes*: properties like **`greenball.pos`** (the position of the sphere), **`greenball.color`**, and radius or other size parameter. If you change an attribute of an object, such as its position or color, VPython will automatically display the object in its new location, or with its new color.

You can set the values of attributes in the “constructor” (the code used to create the object), and you can also modify attributes later:

```
greenball.radius = 2.2
```

In addition to the built-in set of attributes, you may create new attributes. For example, you might create a sphere named “moon”; in addition to its radius and location, you might give it attributes such as mass (“**moon.mass**”) and momentum (“**moon.momentum**”).

Vectors

Not all objects in Visual are visible objects. For example, Visual allows you to create 3D vector quantities, and to perform vector operations on them. If you create a vector quantity called “**a**”, you may refer to its components as “**a.x**, **a.y**, and **a.z**”. To add two vectors, **a** and **b**, however, you do not need to add the components one by one; Visual will do the vector addition for you:

```
a = vector(1.,2.,3.)
b = vector(4.,5.,6.)
c=a+b
```

If you print **c**, you will find that it is a vector with components (5.,7.,9.).

Scalar multiplication

```
d = 3.*a       # d is a vector with components (3., 6., 9.)
```

Magnitude of a vector

```
d = mag(c)     # d is a scalar
z = mag(c)**2  # you can’t square a vector; just its magnitude
```

Vector products

```
f = cross(a,b) # cross product
g = dot(a,b)   # dot product
h = norm(a)    # normalized (unit) vector
```

The attributes of Visual objects can be vectors, such as position or momentum.

III. Simple Python Programming

Comments

A comment in a Python program starts with “#”

```
# this line is a comment
```

Importing the Visual Library

The first line of your program must be:

```
from visual import *
```

Variables

Variables can be created anywhere in a Python program, simply by assigning a variable name to a value. The *type* of the variable is determined by the assignment statement.

```
a = 3                            # an integer
b = -2.                          # a floating-point number
c = vector(0.4, 3e3, -1e1)       # a vector
Earth = sphere(pos=(0,0,0), radius=6.4e6) # a Visual object
bodies = [ship, Earth, Moon]     # a list of objects
```

Basic Visual objects such as sphere() and box() have a set of attributes such as color, and you can define additional attributes such as mass or momentum. Other objects, such as vector(), have built-in attributes but you cannot create additional attributes. Numbers, lists, and other built-in objects do not have attributes at all.

Warning about division:

Division of integers will not come out the way you may expect, since the result is rounded down to the nearest integer. Thus:

```
a = 2/3
print a  # a is 0
```

To avoid this, ***never use integers in mathematical expressions***. Place a decimal point after every number, like this:

```
b = 2./3.
print b  # b is 0.6666667, as expected
```

Exponentiation:

```
x**2     # Not x^2
```

Logical Tests

If, elif ("else if"), else:

```
if a == b:     # see table of logical expressions below
   c = 3.5     # indented code executed if test is true
elif a < b:
   c = 0.      # c will be set to zero only if a < b
else:
   c = -23.2
```

Logical expressions

`==`	`equal`
`!=`	`not equal (also <>)`
`<`	`less than`
`>`	`greater than`
`<=`	`less than or equal`
`>=`	`greater or equal`
`or`	`logical or`
`and`	`logical and`
`in`	`member of a sequence`
`not in`	`not sequence member`

Lists

A list is an ordered sequence of any kind of object. It is delimited by square brackets.

```
moons = [Io, Europa, Ganymede, Callisto]
```

The function "arange()" creates a sequence of numbers:

```
angles = arange (0., 2.*pi, pi/100.)
# numbers from 0. to 2.*pi-(pi/100.) in steps of (pi/100.)
```

```
numbers = arange(10)       # integer argument -> integers
print numbers              # [0,1,2,3,4,5,6,7,8,9]
```

Loops

The simplest loop in Python is a “while” loop. The loop continues as long as the specified logical expression is true:

```
while x < 23:
   x = x + vx*dt
```

To write an infinite loop, just use a logical expression that will always be true:

```
while 1==1:
   ball.pos = ball.pos + (ball.momentum/ball.mass)*dt
```

Since the value assigned to a true logical expression is 1, the following also produces an infinite loop:

```
while 1:
   a = b+c
```

Infinite loops are ok, because you can always interrupt the program by choosing “Stop Program” from the Run menu in IDLE.

It is also possible to loop over the members of a sequence:

```
moons = [Io, Europa, Ganymede, Callisto]

for a in moons:
   r = a.pos - Jupiter.pos

for x in arange(10):
   # see “lists” above
   ...

for theta in arange(0., 2.*pi, pi/100.):
   # see “lists” above
```

You can restart a loop, or terminate the loop prematurely:

```
if a == b: continue     # go back to the start of the loop
if a > b: break         # exit the loop
```

Printing

To print a number, a vector, a list, or anything else, use the “print” command:

```
print Europa.momentum
```

To print a text message, enclose it in quotes:

```
print “We have just crashed on the Moon with speed”, v, “m/s.”
```

More Information About Python

See *Description of Objects in Visual* for detailed descriptions of all aspects of Visual.

We have summarized a very small subset of the Python programming language. We recommend the following book to those who want to learn more about Python:

Learning Python, by Mark Lutz & David Ascher. 1999, O’Reilly.

There is significant Python documentation on the web, although it is not organized optimally for a novice. Visit the Python website at http://www.python.org/