CS101, Spring 2015

Local/Global Variables and Graphical Objects

Lecture #5

Roadmap

Last week we covered

- Functions with parameters and return values

This week we will learn

- Local and global variables
- Modules
- Graphics
  - Drawable objects
  - Reference points
  - Color interpolation
  - Depth
  - Transformation
- Mutability

Local variables

A function to evaluate the quadratic function $ax^2 + bx + c$:

```
def quadratic(a, b, c, x):
  quad_term = a * x ** 2
  lin_term = b * x
  return quad_term + lin_term + c
```

The names `quad_term` and `lin_term` exist only during the execution of the function `quadratic`. They are called local variables.

A function's parameters are also local variables. When the function is called, the arguments in the function call are assigned to them.

Variable are names

```
def quadratic(a, b, c, x):
  quad_term = a * x ** 2
  lin_term = b * x
  return quad_term + lin_term + c

result = quadratic(2, 4, 5, 3)
```

Local variables are names that only exist during the execution of the function:

a → 2

b → 4

c → 5

x → 3

quad_term → 18

lin_term → 12

Why local variables?

Humans are not good at remembering too many things at the same time. We can only understand software if we can use each part without needing to remember how it works internally.

To use the function `quadratic`, we only want to remember this:

```
def quadratic(a, b, c, x):
  # implemented somehow
```

Modularization means that software consists of parts that are developed and tested separately. To use a part, you do not need to understand how it is implemented.

cs1robots is a module that implements the object type `Robot`. You can use `Robot` easily without understanding how it is implemented. $\longrightarrow$ object-oriented programming

Global variables

Variables defined outside of a function are called global variables.

Global variables can be used inside a function:

```
hubo = Robot()

def turn_right():
  for i in range(3):
    hubo.turn_left()
```

global variable hubo

using global variable

In large programs, using global variables is dangerous, as they can be accessed (by mistake) by all functions of the program.

Local and global

If a name is only used inside a function, it is global:

```
def f1():
  return 3 * a + 5
```

If a name is assigned to in a function, it is local:

```
def f2(x):
  a = 3 * x + 17
  return a * 3 + 5 * a
```

What does this test function print?

```
a = 17
def test():
  print a
  a = 13
  print a
```

Error!

a is a local variable in test because of the assignment, but has no value inside the first print statement.

Assigning to global variables

Sometimes we want to change the value of a global variable inside a function.

```
hubo = Robot
hubo_direction = 0

def turn_left():
  hubo.turn_left()
  global hubo_direction
  hubo_direction += 90

def turn_right():
  for i in range(3):
    hubo.turn_left()
  global hubo_direction
  hubo_direction -= 90
```

Local and global variables

```
a = "Letter a"

def f(a):
  print "A = ", a

def g():
  a = 7
  f(a + 1)
  print "A = ", a

print "A = ", a
f(3.14)
print "A = ", a
g()
print "A = ", a
```

```
A =  Letter a
A =  3.14
A =  Letter a
A =  8
A =  7
A =  Letter a
```

Parameters are names

What does this code print?

```
def swap(a, b):
  a, b = b, a

x, y = 123, 456
swap(x, y)
print x, y
```

$x \longrightarrow 123$

$y \longrightarrow 456$

a is a new name for the object 123, not for the name x!

A Python module is a collection of functions that are grouped together in a file. Python comes with a large number of useful modules. We can also create our own modules.

- `math` for mathematical functions
- `random` for random numbers and shuffling
- `sys` and `os` for accessing the operating system
- `urllib` to download files from the web
- `cs1robots` for playing with Hubo
- `cs1graphics` for graphics
- `cs1media` for processing photos

You can get information about a module using the `help` function:

```
>>> help("cs1media")
>>> help("cs1media.picture_tool")
```

Importing modules

Before you can use a module you have to import it:

```
import math
print math.sin(math.pi / 4)
```

Sometimes it is useful to be able to use the functions from a module without the module name:

```
from math import *
print sin(pi / 4)          # OK
print math.pi              # NameError: name 'math'
```

Or only import the functions you need:

```
from math import sin, pi
print sin(pi / 4)          # OK

print cos(pi / 4)          # NameError: name 'cos'
print math.cos(pi/4)       # NameError: name 'math'
```

Import examples

We used this:

```
from cs1robots import *
create_world()
hubo = Robot()
hubo.move()
hubo.turn_left()
```

Instead we could use this:

```
import cs1robots
cs1robots.create_world()
hubo = cs1robots.Robot()
hubo.move()
hubo.turn_left()
```

In general, it is considered better not to use `import *`.

We first need to create a canvas to draw on:

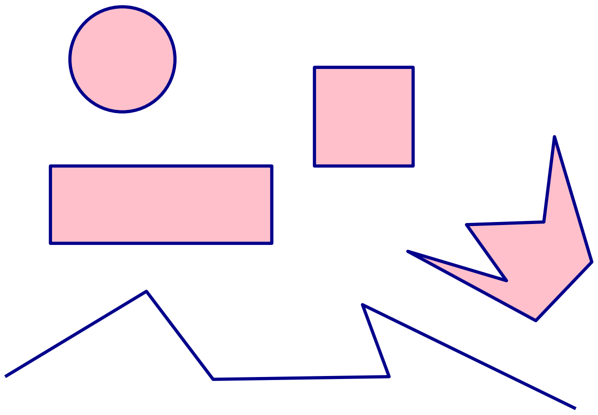
```
from cs1graphics import *

canvas = Canvas(400, 300)
canvas.setBackgroundColor("light blue")
canvas.setTitle("CS101 Drawing exercise")
```

The coordinate system: x goes from 0 to 399 left-to-right, y from 0 to 299 top-to-bottom.

Drawable objects

To create a drawing, we add drawable objects to the canvas:

1. `Circle(radius)`
2. `Square(side)`
3. `Rectangle(width, height)`
4. `Polygon`
5. `Path`
6. `Text(message, font_size)`
7. `Image(image_filename)`



fillable objects

Border color (color is a string or an (r, g, b)-tuple):

```
obj.setBorderColor(color)
obj.getBorderColor()
```

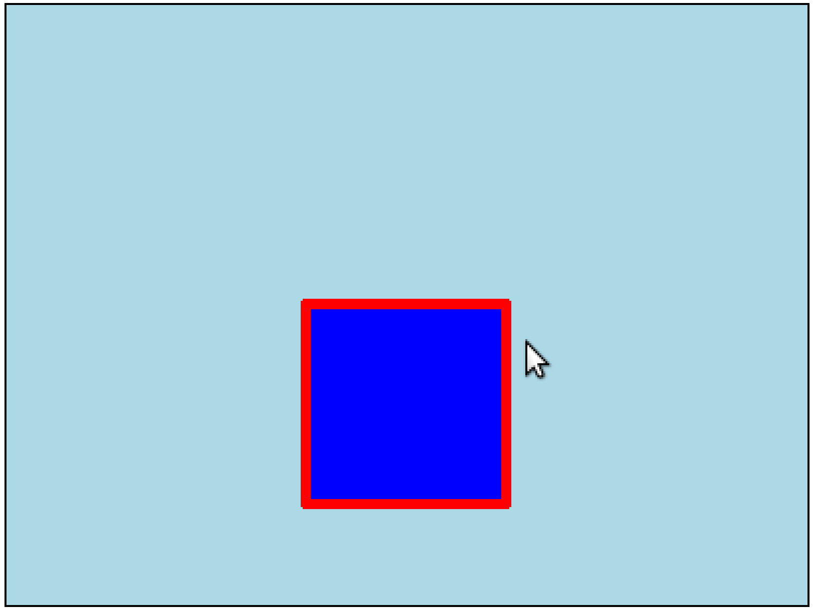
Fill color (color is a string or an (r, g, b)-tuple):

```
obj.setFillColor(color)
obj.getFillColor()
```

Reference point

Every object has a reference point. The location of the reference point on the canvas is set using `move(dx, dy)` and `moveTo(x, y)`.

```
sq = Square(100)
canvas.add(sq)
sq.setFillColor("blue")
sq.setBorderColor("red")
sq.setBorderWidth(5)
sq.moveTo(200, 200)
```



absolute coordinates

Animation:

```
for i in range(100):
  sq.move(1, 0)
```

relative coordinates

```
def animate_sunrise(sun):
  w = canvas.getWidth()
  h = canvas.getHeight()
  r = sun.getRadius()
  x0 = w / 2.0
  y0 = h + r
  xradius = w / 2.0 - r
  yradius = h
  for angle in range(181):
    rad = (angle/180.0) * math.pi
    x = x0 - xradius * math.cos(rad)
    y = y0 - yradius * math.sin(rad)
    sun.moveTo(x, y)
```

Color interpolation

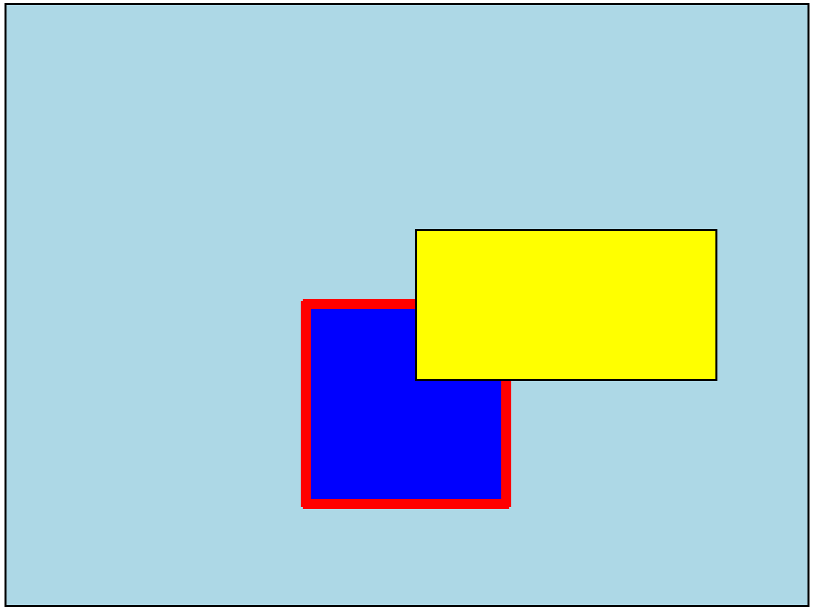
```
def interpolate_colors(t, color1, color2):
  """Interpolate between color1 (for t == 0.0)
  and color2 (for t == 1.0)."""
  r1, g1, b1 = color1
  r2, g2, b2 = color2
  return (int((1-t) * r1 + t * r2),
          int((1-t) * g1 + t * g2),
          int((1-t) * b1 + t * b2))

def color_value(color):
  """Convert a color name to an (r,g,b) tuple."""
  return Color(color).getColorValue()
```

Colorful sunrise and sunset

```
def animate_sunrise(sun, morning_sun, noon_sun,
                    morning_sky, noon_sky):
  morning_color = color_value(morning_sun)
  noon_color = color_value(noon_sun)
  dark_sky = color_value(morning_sky)
  bright_sky = color_value(noon_sky)
  w = canvas.getWidth()
  # as before ...
  for angle in range(181):
    rad = (angle/180.0) * math.pi
    t = math.sin(rad)
    col = interpolate_colors(t, morning_color, noon_color)
    sun.setFillColor(col)
    col = interpolate_colors(t, dark_sky, bright_sky)
    canvas.setBackgroundColor(col)
    x = x0 - xradius * math.cos(rad)
    y = y0 - yradius * math.sin(rad)
    sun.moveTo(x, y)
```

Depth

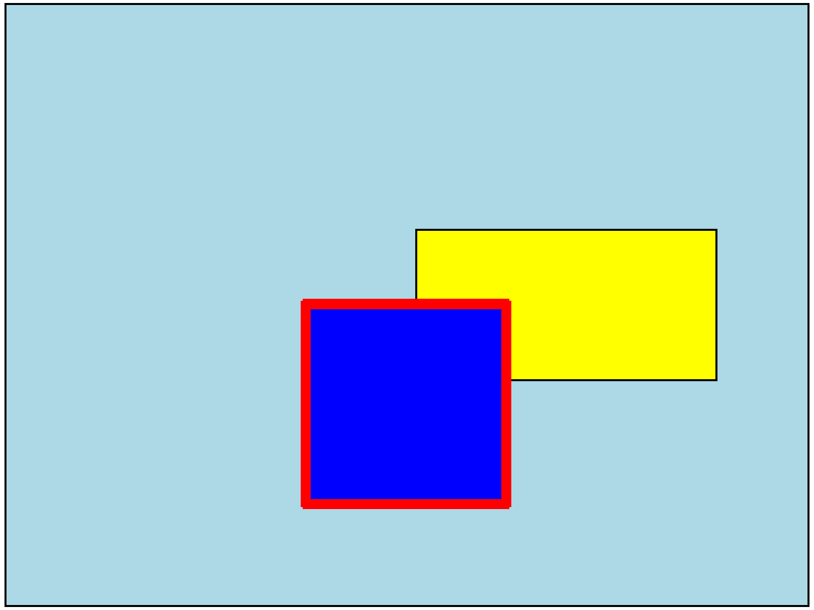
```
r = Rectangle(150, 75)
canvas.add(r)
r.setFillColor("yellow")
r.moveTo(280, 150)
```



Changing the depth:

```
sq.setDepth(10)
r.setDepth(20)
```

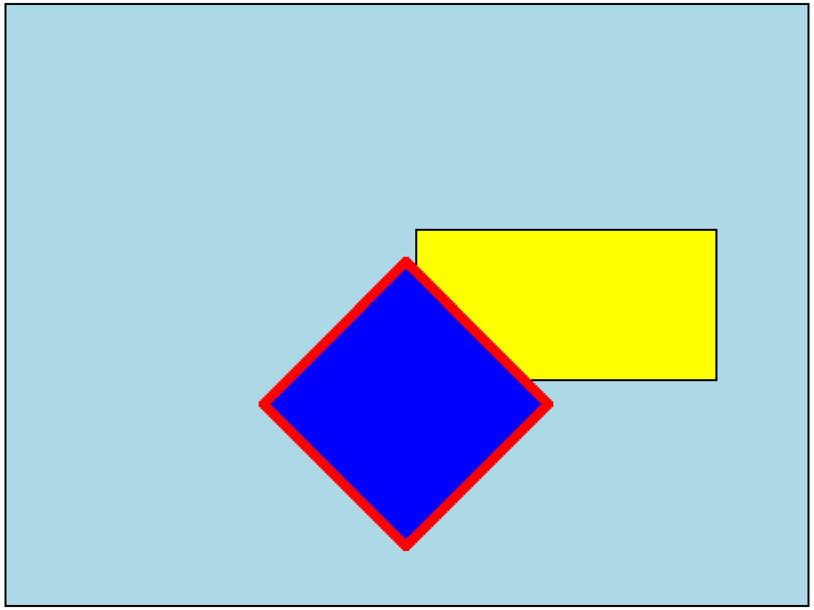
Objects with smaller depth appear in foreground.



Rotating, scaling, flipping

We can rotate an object around its reference point:

```
sq.rotate(45)
```

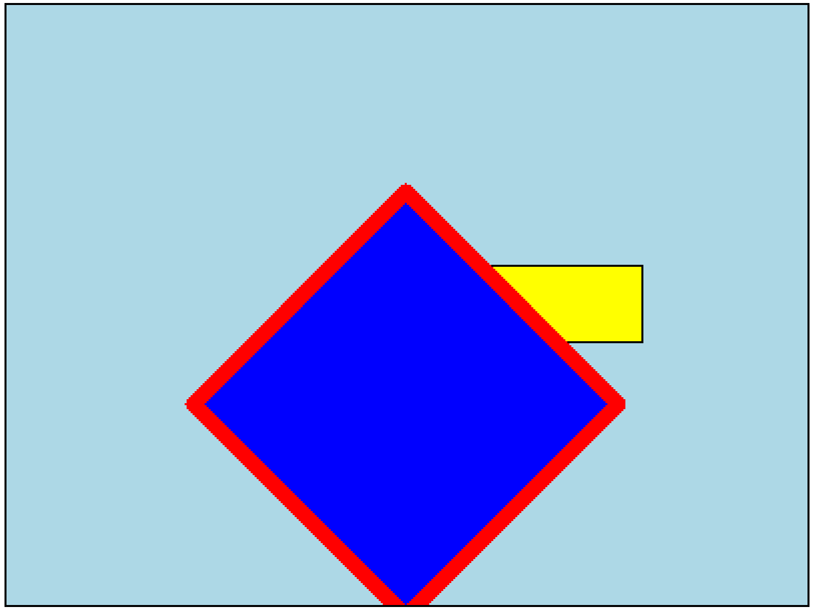


Scaling makes an object smaller or larger:

```
sq.scale(1.5)
r.scale(0.5)
```

Fade-out:

```
for i in range(80):
  sq.scale(0.95)
canvas.remove(sq)
```



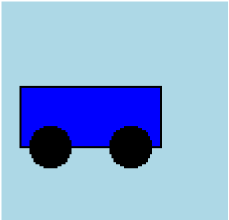
Flipping mirrors around an axis.

```
r.flip(45)
```

Layers

A layer groups together several graphic objects so that they can be moved and transformed as a whole:

```
car = Layer()
tire1 = Circle(10, Point(-20,-10))
tire1.setFillColor('black')
car.add(tire1)
tire2 = Circle(10, Point(20,-10))
tire2.setFillColor('black')
car.add(tire2)
body = Rectangle(70, 30, Point(0, -25))
body.setFillColor('blue')
body.setDepth(60)
car.add(body)
```



Animate car:

```
for i in range(250):
  car.move(2, 0)
```

The whole layer can be transformed as a single object:

```
for i in range(50):
  car.move(2, 0)
for i in range(22):
  car.rotate(-1)
for i in range(50):
  car.move(2,-1)
for i in range(22):
  car.rotate(1)
for i in range(50):
  car.move(2,0)
for i in range(10):
  car.scale(1.05)
car.flip(90)
```

Objects: state and actions

We have met some interesting types of objects: tuples, strings, robots, photos, and graphic objects like circles and squares.

An object has state and can perform actions.

`Robot`: The robot's state includes its position, orientation, and number of beepers carried.
It supports actions to move, turn, drop and pick beepers, and to test various conditions.

`Circle`: Its state consists of its radius, position, depth, border and fill color.
It supports various actions to change its color, size, and position, and to perform transformations.
Picture: Its state consists of the photo's width and height, and a color value for every pixel.
It supports actions to look at or modify the color of each pixel.

Mutable and immutable objects

Objects whose state can never change are called immutable. In Python, string and tuple objects are immutable.

Objects whose state can change are called mutable. Robots, photos, and graphic objects are mutable.

Remember that we can have more than one name for the same object. Be careful if this is a mutable object!

```
sun = Circle(30)
sun.setFillColor("dark orange")
moon = sun
moon.setFillColor("wheat")
print sun.getFillColor()
```

Functions are objects

A function is an object:

```
def f(x):
  return math.sin(x / 3.0 + math.pi/4.0)

print f          →  <function f at 0xb7539a3c>
print type(f)    →  <type 'function'>
```

We can use a function as an argument:

```
def print_table(func, x0, x1, step):
  x = x0
  while x <= x1:
    print x, func(x)
    x += step

print_table(f, -math.pi, 3 * math.pi, math.pi/8)
```