CS101 - Local/Global Variables and Graphical Objects

Lecture 5

School of Computing
KAIST

Roadmap

Last week we learned

- Functions, parameters, return values

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- Functions, parameters, 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
```

Local variables

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

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```

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)
```

Variable are names

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  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:

$$a \rightarrow 2$$

$$b \rightarrow 4$$

$$c \rightarrow 5$$

$$x \rightarrow 3$$

$$quad\_term \rightarrow 18$$

$$lin\_term \rightarrow 12$$

Why local variables?

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

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def quadratic(a, b, c, x):
  # implemented somehow
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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. → **object-oriented programming**

Global variables

Variables defined outside of a function are called **global variables**.

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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

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def turn_right():
  for i in range(3):
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```

global variable `hubo` (arrow pointing to `hubo = Robot()`)

using global variable (arrow pointing to `hubo.turn_left()`)

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

Local and global

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

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

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

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What does this `test` function print?

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

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Error!
`a` is a **local** variable in `test` function 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

```python
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)
```

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)
```

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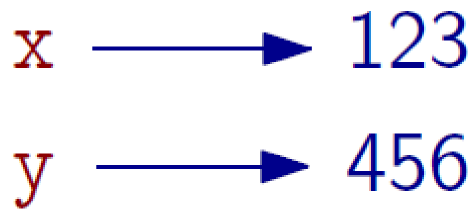

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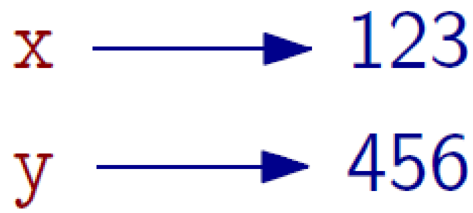

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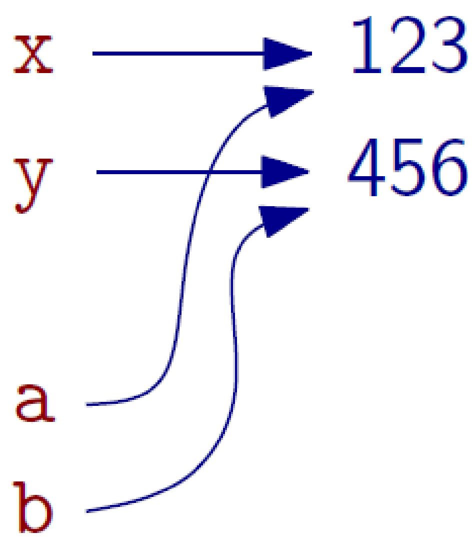

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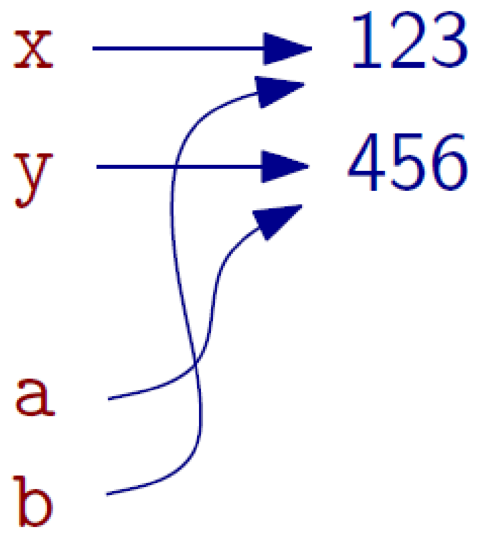

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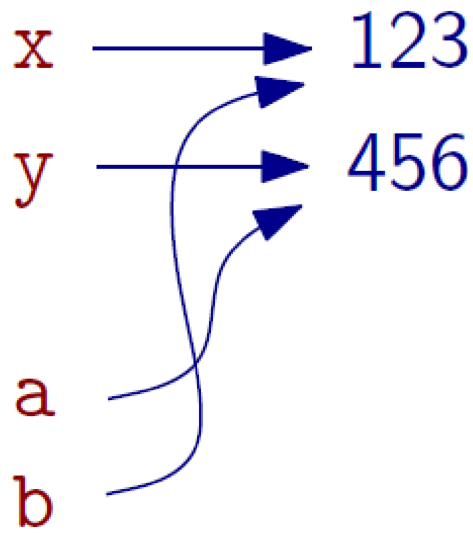

`a` is a new name for the object `123`, not for the name `x`!

Function arguments

We have learnt about **parameters** and function **arguments**:

```
def create_sun(radius, color):
  sun = Circle(radius)
  sun.setFillColor(color)
  sun.setBorderColor(color)
  sun.moveTo(100, 100)
  return sun

sun = create_sun(30, "yellow")
```

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sun = create_sun(30, "yellow")
```

Arguments are mapped to parameters one-by-one, left-to-right.

Default parameters

We can provide default parameters:

```
def create_sun(radius = 30, color = "yellow"):
  sun = Circle(radius)
  sun.setFillColor(color)
  sun.setBorderColor(color)
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```

Now we can call it like this:

```
sun = create_sun()
star = create_sun(2)
moon = create_sun(28, "silver")
```

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Now we can call it like this:

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sun = create_sun()
star = create_sun(2)
moon = create_sun(28, "silver")
```

But not like this:

```
moon = create_sun("silver")
```

Normal and default parameters

Default parameters have to follow normal parameters:

```
def avg(data, start = 0, end = None):
  if not end:
    end = len(data)
  return sum(data[start:end]) / float(end-start)
```

Normal and default parameters

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```
def avg(data, start = 0, end = None):
  if not end:
    end = len(data)
  return sum(data[start:end]) / float(end-start)
```

```
>>> d = [ 1, 2, 3, 4, 5 ]
>>> avg(d)
3.0
>>> avg(d, 2)
4.0
>>> avg(d, 1, 4)
3.0
```

Named parameters

We can include the name of the parameter in the function call to make the code clearer. Then the order of arguments does not matter:

```
moon = create_sun(color = "silver")
moon = create_sun(color = "silver", radius = 28)
```

Named parameters

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```
moon = create_sun(color = "silver")
moon = create_sun(color = "silver", radius = 28)
```

```
>>> avg(d, end=3)
2.0
>>> avg(data=d, end=3)
2.0
>>> avg(end=3, data=d)
2.0
>>> avg(end=3, d)
SyntaxError: non-keyword arg after keyword arg
```

Modules

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 shuffing
- `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

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

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print(math.pi) # NameError: name 'math'
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print(math.pi) # NameError: name 'math'
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Or only import the functions you need:

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

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()
```

Import examples

We used this:

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

Instead we could use this:

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

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 *`.

Graphics

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")
```

Graphics

We first need to create a canvas to draw on:

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from cs1graphics import *

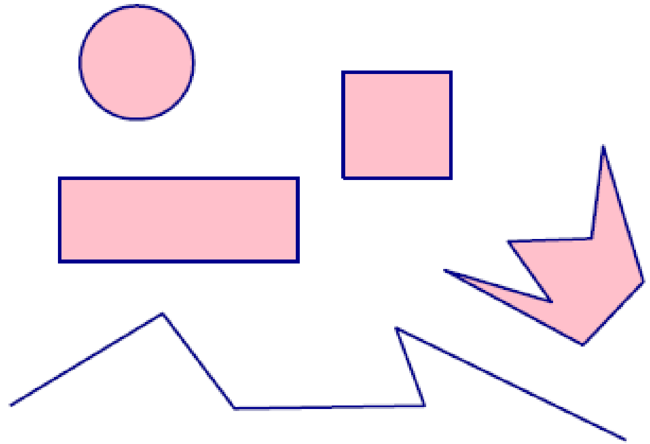
canvas = Canvas(400, 300)
canvas.setBackgroundColor("light blue")
canvas.setTitle("CS101 Drawing exercise")
```

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:

- Circle(radius)
- Square(side)
- Rectangle(width, height)
- Polygon
- Path
- Text(message, font_size)
- Image(image_filename)



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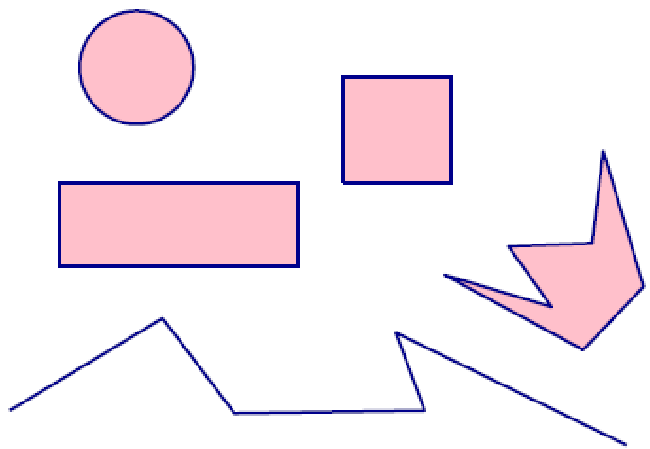

Border color (color is a string or an (r, g, b)-tuple):

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

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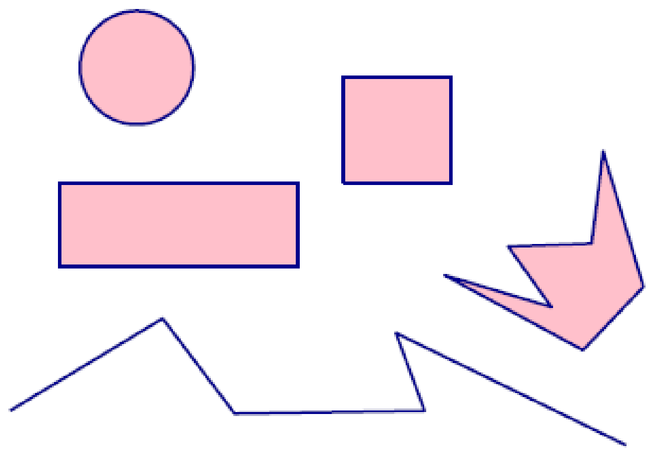


Border color (color is a string or an (r, g, b)-tuple):

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

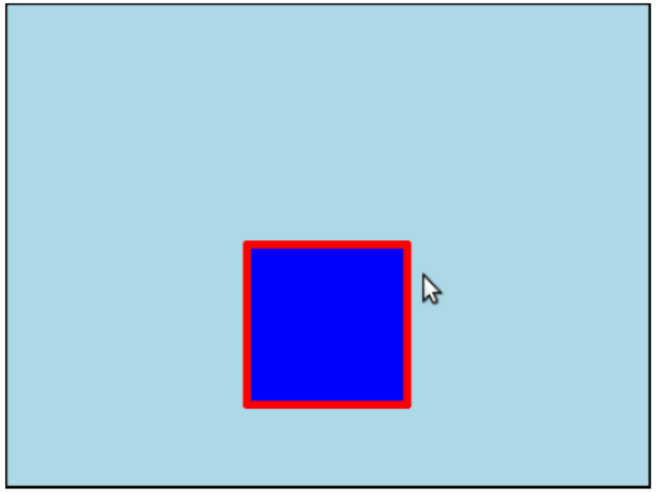
Fill color (color is a string or an (r, g, b)-tuple):
Only for Circle, Square, Rectangle and Polygon

```
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)
```



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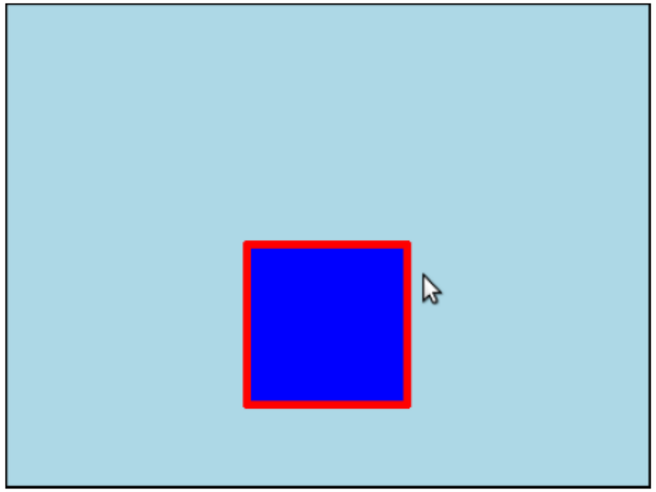

Animation:

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

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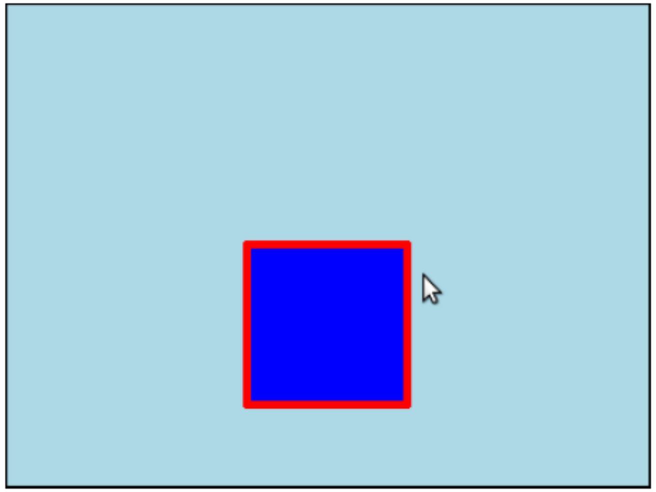

Animation:

```
for i in range(100):
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```

absolute coordinates

relative coordinates

Sunrise and sunset

```
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))

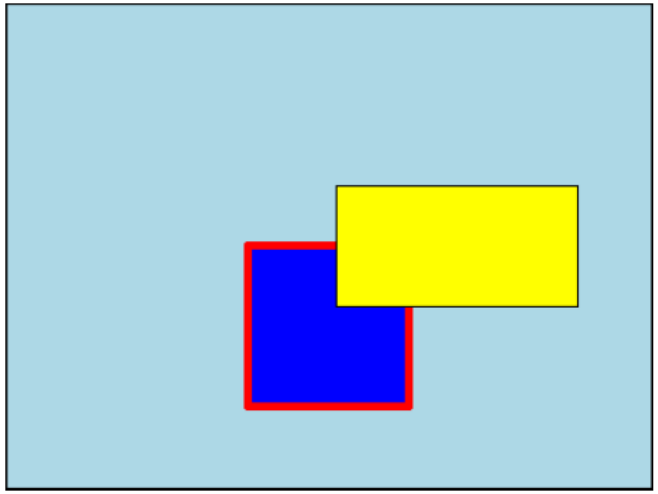
def color_value(color):
  """Convert a color name to an (r,g,b) tuple."""
  return Color(color).getColorValue()
```

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)
```



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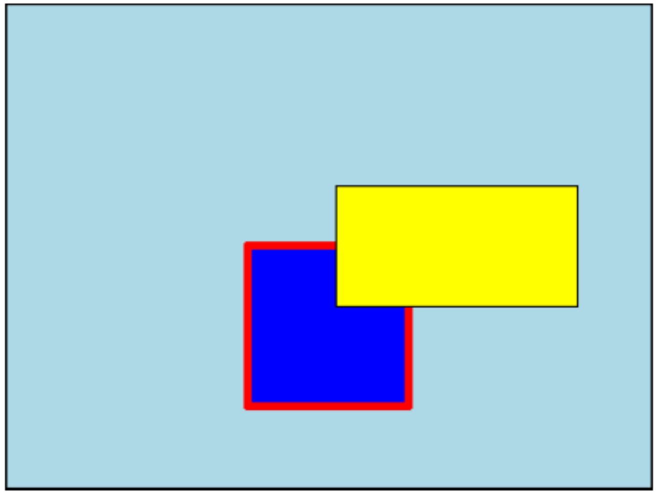
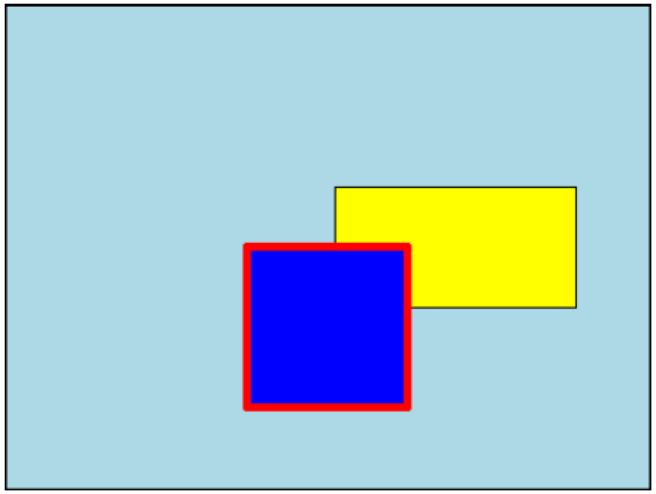


Changing the depth:

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

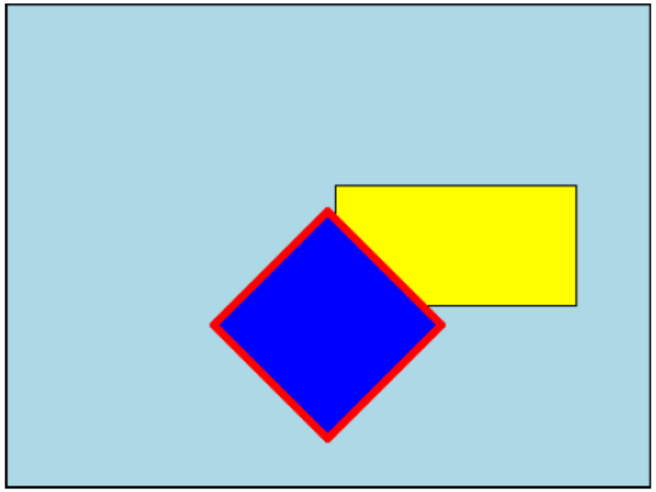
Objects with smaller depth appear in foreground.



Rotating, scaling, flipping

We can rotate an object around its reference point:

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



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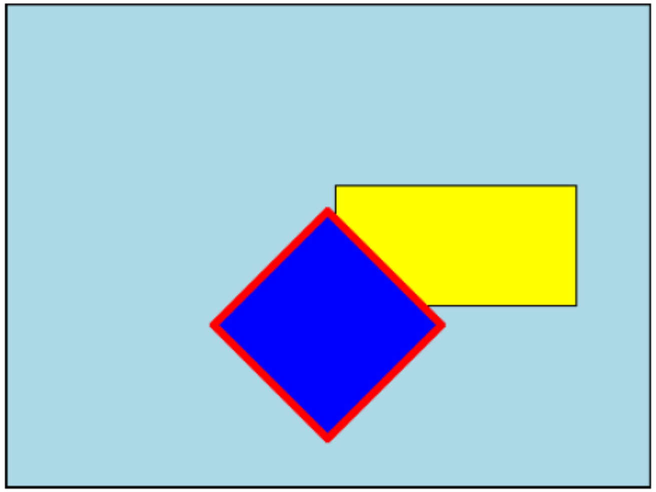
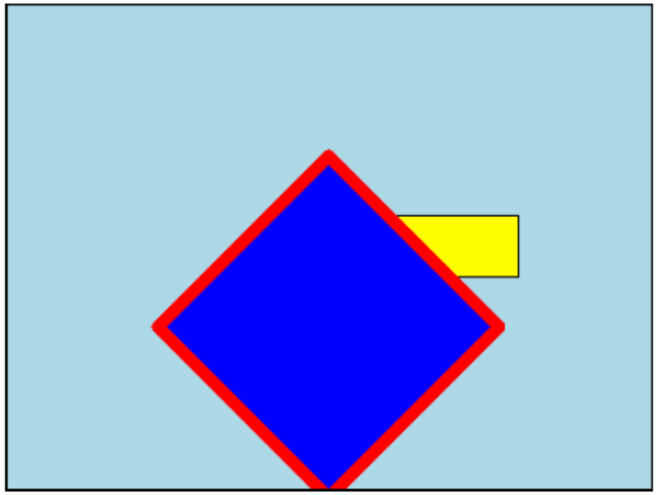


Scaling makes an object smaller or larger:

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



Rotating, scaling, flipping

We can rotate an object around its reference point:

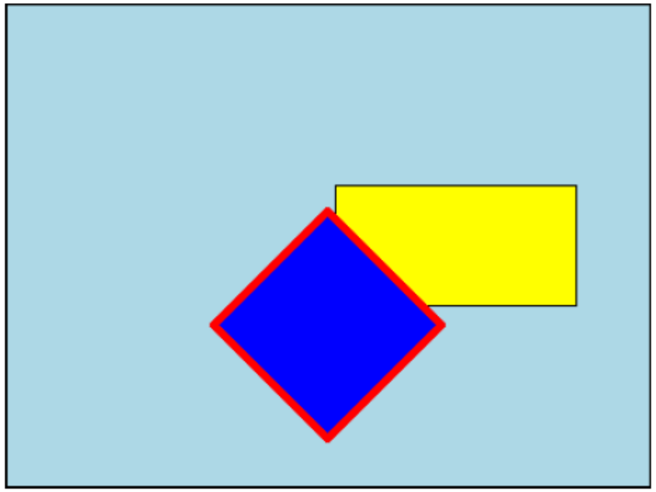
```
sq.rotate(45)
```

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)
```



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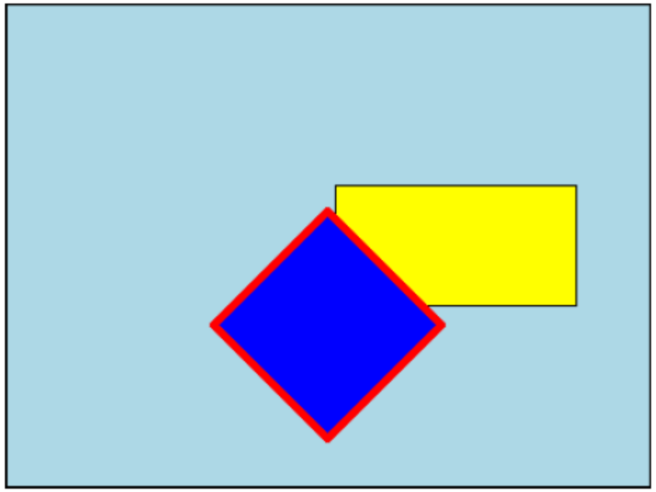

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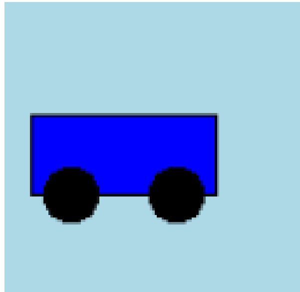
Flipping mirrors around an axis.

```
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)
```



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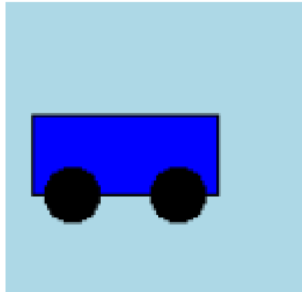

Animate a car:

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

Transformations

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.

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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.

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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(un.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>
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```

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)
```