CS101 - Local/Global Variables and Graphical Objects

Lecture 5

School of Computing
KAIST
Roadmap

Last week we learned

- Functions, parameters, return values
Roadmap

Last week we learned
  - 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 $ax^2 + bx + c$:

```python
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.
Local variables

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    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.
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)
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:

\[
\begin{align*}
    a & \rightarrow 2 \\
    b & \rightarrow 4 \\
    c & \rightarrow 5 \\
    x & \rightarrow 3 \\
    quad\_term & \rightarrow 18 \\
    lin\_term & \rightarrow 12
\end{align*}
\]
Why local variables?

Humans are not good at remembering too many things at the same time. We can see the big picture and understand a large-scale software system only if we could use each part without remembering how it works internally.
Why local variables?

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

```python
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.
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    # 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. → **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:

```python
hubo = Robot()          # global variable hubo

def turn_right():
    for i in range(3):
        hubo.turn_left()  # using global variable
```

```python
global variable hubo
```
Global variables

Variables defined outside of a function are called *global variables*. Global variables can be used inside a function:

```python
hubo = Robot()
```

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

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

```python
def f1():
    return 3 * a + 5
```
Local and global

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

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

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

```python
def f2(x):
    a = 3 * x + 17
    return a * 3 + 5 * a
```
Local and global

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

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

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

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

What does this `test` function print?

```python
a = 17
def test():
    print(a)
a = 13
    print(a)
test()
```
Local and global

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

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

What does this **test** function print?

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

**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.

```python
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()
g() 
print("A = ", a)
```
Parameters are names

What does this code print?

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

x, y = 123, 456
swap(x, y)
print(x, y)
```
Parameters are names

What does this code print?

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

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

x ➔ 123
y ➔ 456

x, y = 123, 456
swap(x, y)
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Parameters are names

What does this code print?

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

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

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

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

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

```python
sun = create_sun(30, "yellow")
```
Function arguments

We have learnt about parameters and function arguments:

```python
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")
```

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

We can provide default parameters:

```python
def create_sun(radius = 30, color = "yellow"):  
sun = Circle(radius)
sun.setFillColor(color)
sun.setBorderColor(color)
sun.moveTo(100, 100)
return sun
```
Default parameters

We can provide default parameters:

```python
def create_sun(radius = 30, color = "yellow"):
    sun = Circle(radius)
    sun.setFillColor(color)
    sun.setBorderColor(color)
    sun.moveTo(100, 100)
    return sun
```

Now we can call it like this:

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

We can provide default parameters:

```python
def create_sun(radius = 30, color = "yellow"):  
    sun = Circle(radius)  
    sun.setFillColor(color)  
    sun.setBorderColor(color)  
    sun.moveTo(100, 100)  
    return sun
```

Now we can call it like this:

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

But not like this:

```python
moon = create_sun("silver")
```
Normal and default parameters

Default parameters have to follow normal parameters:

```python
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

Default parameters have to follow normal parameters:

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

```python
>>> 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

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:

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

```python
>>> 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 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
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- `math` for mathematical functions
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- `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:

```python
>>> help("cs1media")
>>> help("cs1media.picture_tool")
```
Importing modules

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

```python
import math
print(math.sin(math.pi / 4))
```
Importing modules

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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:

```python
from math import *
print(sin(pi / 4)) # OK
```
Importing modules

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

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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:

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

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

```python
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:

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

Or only import the functions you need:

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

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

```python
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:

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

Or only import the functions you need:

```python
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:

```python
from cslrobots import *
create_world()
hubo = Robot()
hubo.move()
hubo.move()
hubo.turn_left()
```
Import examples

We used this:

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

Instead we could use this:

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

We used this:

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

Instead we could use this:

```python
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:

```python
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:

```python
from cslgraphics 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)
Drawable objects

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

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

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

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

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

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

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

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

Only for Circle, Square, Rectangle and Polygon
Reference point

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

\begin{verbatim}
sq = Square(100)
canvas.add(sq)
sq.setFillColor("blue")
sq.setBorderColor("red")
sq.setBorderWidth(5)
sq.moveTo(200, 200)
\end{verbatim}
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)`.  

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

Animation:

```python
for i in range(100):
    sq.move(1, 0)
```
Every object has a reference point. The location of the reference point on the canvas is set using \texttt{move(dx, dy)} and \texttt{moveTo(x, y)}.

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canvas.add(sq)
sq.setFillColor("blue")
sq.setBorderColor("red")
sq.setBorderWidth(5)
sq.moveTo(200, 200)
\end{verbatim}

Animation:

\begin{verbatim}
for i in range(100):
    sq.move(1, 0)
\end{verbatim}
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)
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()
def animate_sunset(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

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

\[
r = \text{Rectangle}(150, 75) \\
canvas.add(r) \\
r.setFillColor("yellow") \\
r.moveTo(280, 150)
\]

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:

```javascript
sq.rotate(45)
```
Rotating, scaling, flipping

We can rotate an object around its reference point:

\[ \text{sq.rotate}(45) \]

Scaling makes an object smaller or larger:

\[ \text{sq.scale}(1.5) \]
\[ \text{r.scale}(0.5) \]
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)
```
Rotating, scaling, flipping

We can rotate an object around its reference point:

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

Scaling makes an object smaller or larger:

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

Fade-out:

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

Flipping mirrors around an axis.

```python
r.flip(45)
```
A layer groups together several graphic objects so that they can be moved and transformed as a whole:

```python
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)
```
Layers

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

```python
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 a car:

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

The whole layer can be transformed as a single object:

```python
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**.
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.
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.
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.
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.
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!

```python
sun = Circle(30)
sun.setFillColor("dark orange")
moon = sun
moon.setFillColor("wheat")
print(un.getFillColor())
```
Functions are objects

A function is an object:

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

>>> print(f)
<function f at 0xb7539a3c>

>>> print(type(f))
<class 'function'>
```
Functions are objects

A function is an object:

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

>>> print(f)
<function f at 0xb7539a3c>

>>> print(type(f))
<class 'function'>
```

We can use a function as an argument:

```python
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)
```