Introduction to Python

Functions

Topics

1) Functions
2) Function Inputs vs Outputs
3) Function Arguments
    a) Positional Arguments
    b) Keyword Arguments
    c) Default Values
4) Flow of Program
5) Template for programs

Example

Consider the following code which asks the user to enter a number and prints out the absolute value of the number. This problem was a lab assignment in the last lecture.

```
x = int(input('Enter an integer: '))
if x >= 0:
    print("The absolute value of", x, "is", x)
else:
    print("The absolute value of", x, "is", -x)
```

Sample Output:

Enter an integer: -4

The absolute value of -4 is 4

Example

Now what if the program asks the user for two numbers and then compute their absolute values? What do you think of the following code?

```
x = int(input('Enter an integer: '))
if x >= 0:
    print("The absolute value of", x, "is", x)
else:
    print("The absolute value of", x, "is", -x)

x = int(input('Enter an integer: '))
if x >= 0:
    print("The absolute value of", x, "is", x)
else:
    print("The absolute value of", x, "is", -x)
```

Note the redundancy! We like to reuse code without rewriting or copying/pasting code!

Functions

One way to organize Python code and to make it more readable and reusable is to factor out useful pieces into reusable *functions*.

A ***function*** is a named group of programming instructions that accomplish a specific task. If we want to perform the task, we simply "call" the function by its name. A function may be called as many times as we wish to redo the task.

The "30 seconds" button on the microwave is an example of a function. If we press it(call it by its name), it will run the microwave 30 seconds. Later, if we want to heat something else, we can press it again to run the microwave another 30 seconds.

In other programming languages, functions are also called **procedures** or **methods.**

Example

We like to take the redundant code below and convert it to a function.

```
x = int(input('Enter an integer: '))
if x >= 0:
    print("The absolute value of", x, "is", x)
else:
    print("The absolute value of", x, "is", -x)

x = int(input('Enter an integer: '))
if x >= 0:
    print("The absolute value of", x, "is", x)
else:
    print("The absolute value of", x, "is", -x)
```

Let's factor out this piece of code, convert it into a function by giving it a name!

Then we can call it repeatedly if we wish to run the code.

Functions

A **function** *or* **procedure** is a group of code that has a name and can be called using parentheses.

A function may have **parameters or input variables** to the function. Parameters are input variables that provide information to the function to accomplish its task.

In Python, a function is defined using the *def* statement.

```
def function_name(parameters):
    block of code
```

Absolute Value

We like to take the redundant code below and convert it to a function called absolute().

```
def absolute(x):
    if x >= 0:
        print(“The absolute value of”, x, "is", x)
    else:
        print(“The absolute value of”, x, "is", -x)


# several calls to abs()
absolute(-10)    # The absolute value of -10 is 10
absolute(5)      # The absolute value of 5 is 5
```

We placed the code into a function named absolute().
This block of code is called the function definition.

The function definition must precede any function calls.

Now we can reuse this code by calling on absolute() with different inputs!

Absolute Value

```
def absolute(x):
    if x >= 0:
        print(“The absolute value of”, x, "is", x)
    else:
        print(“The absolute value of”, x, "is", -x)

absolute(-10)
absolute(5)
```

The first time absolute() is called, input x variable has the value of -10

Once this function call is done executing. This value of x is released from memory.

Absolute Value

```
def absolute(x):
    if x >= 0:
        print(“The absolute value of”, x, "is", x)
    else:
        print(“The absolute value of”, x, "is", -x)

absolute(-10)
absolute(5)
```

The second time absolute() is called, a new variable x is created with the value 5.

Once this function call is done executing. This value of x is again released from memory.

Function Outputs

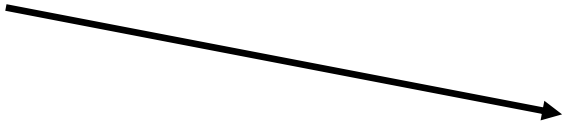
The previous example prints out a message as part of its output. But what if another programmer who wishes to use our function does not want that message printed? Or if another programmer simply wants the output to be used in another calculation?

We typically want functions to **output** or **return** some answer. The answer can then be printed in a message or used in a different calculation.

```
def absolute(x):
    if x >= 0:
        return x
    else:
        return -x

print("The absolute value of -10 is", absolute(-10))
```

the function returns or outputs 10
which is stored in the expression
absolute(-10)



Function Outputs

If a function returns a value, the function call expression represents the returned value!

For example, below, the expression absolute(-10) is equal to the returned value of 10.

```
def absolute(x):
    if x >= 0:
        return x
    else:
        return -x

print("The absolute value of -10 is", absolute(-10))
```

the function returns or outputs 10 which is stored in the expression absolute(-10)

This function notation is perfectly consistent with the math notation used in algebra.

If f(x) = 3x, then the expression f(5) is equal to 15 and the expression f(10) is equal to 30.

The expression absolute(-10) is equal to 10.

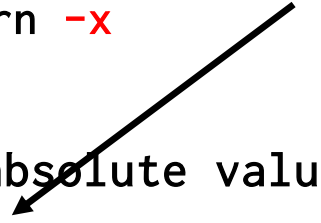
Function Outputs

The output or returned value can be used in another calculation.

```
def absolute(x):
    if x >= 0:
        return x
    else:
        return -x


print("The absolute value of -10 is", absolute(-10))
x = absolute(-5) + 3
print(x)   # 8
```

Here the returned value is used in another calculation.



Function Outputs

```
def absolute(x):
    if x >= 0:
        return x
    else:
        return -x
```

The important takeaway here is: Functions should NOT print the answer. It should RETURN the answer!

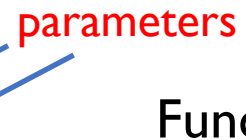
Printing should be done outside the function. Print the returned value.

```
print("The absolute value of -10 is", absolute(-10))
x = absolute(-5) + 3
print(x)   # 8
```

Note: Python already has a built-in absolute value function called abs().

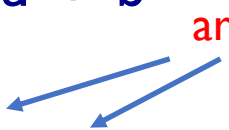
Functions

The **arguments** of a function are the inputs of the function. By default, arguments are positional.



Function definition.

```
def add(a, b):
    return a + b
```



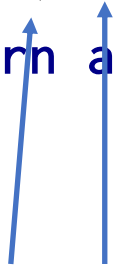
Function calling.

```
print(add(2, 4))
print(add(2))          # too few arguments
print(add(2, 4, 6)) # too many arguments
```

Functions Arguments (input)

```
def add(a, b):
    return a + b


a = add(2, 4)
print(a)        # 6
```



In function calling, the actual arguments 2 and 4 are sent to the formal parameters a and b respectively.

Functions Arguments (input)

```
def add(a, b):
    return a + b
```


```
a = add(2, 4)
print(a)        # 6
```

Note that the returned value 6 is sent back to the call expression add(2, 4).

This value add(2, 4) is stored in the variable a.

The variable a is then printed to the console.

Returned Value

A returned value from a function should be stored, printed or used in another calculation. Be careful to avoid the error explained below!

```
def add(a, b):
    return a + b

a = add(2, 4)        # returned value 6 is stored in a.
print(a)             # 6
b = add(2, 4) - 3    # returned value 6 used in a calculation.

add(4, 6)       # returned value 10 is neither stored nor printed
                # this value is lost! This is a common error!
                # This line of code effectively does nothing.
```

You Try it!

Write a computer program that, given the lengths of the two sides of a right triangle adjacent to the right angle, computes the length of the hypotenuse of the triangle. Use the template below.

```
# given a and b sides of a triangle, return hypotenuse
def hypotenuse(a, b):
    # implement your code here

# print out hypotenuse if sides are 3 and 4
# ask user for sides: side1 and side2
# store hypotenuse for side1 and side2 in variable h
# print h
```

Keyword Arguments

Input arguments can be specified by name (keyword arguments). In this case, the order does not matter.

```
def add(a, b):
     return a + b
```

```
The following are all equivalent:
x = add(1, 3)
y = add(a=1, b=3)
z = add(b=3, a=1)
```

Why Keyword Arguments

Using keyword arguments is encouraged since it makes calling functions more forgiving. It lifts the restriction on the order of the arguments.

```
def cost(qnty, item):
     print("There are", qnty, item, "left.")


cost(6, "apples")          # There are 6 apples left.
# if we don't remember the order of the arguments, we can
# use keyword arguments, for example:
cost(item="bananas", qnty=10) # There are 10 bananas left.
```

Later in the class, we will use Python libraries with complex functions that have many arguments. Being able to specify keyword arguments means we do not need to memorize the order of the arguments.

Keyword and Positional Arguments

If keyword arguments and positional arguments are used together, keyword arguments must follow positional arguments.

```
def add(a, b, c):
     return a + b + c
```

The following are all equivalent:

```
x = add(1, 3, 5)
y = add(1, b=3, c=5)
z = add(1, c=5, b=3)
```

The following gives an error:

```
w = add(a=1, 3, c=5)
```

Optional Keyword Arguments

Functions can take optional keyword arguments. These are given default values. Their default values are used if a user does not specify these inputs when calling the function. Default values must come after positional arguments in the function signature.

```
def subtract(a, b=0):
    return a - b

print(subtract(2))        # 2
```

a = 2, b defaults to 0

Functions

Functions can take optional keyword arguments. These are given default values. Their default values are used if a user does not specify these inputs when calling the function. Default values must come after positional arguments in the function signature.

```
def subtract(a, b=0):
    return a - b

print(subtract(2))      # 2
print(subtract(1, 3))   # -2
```

a = 1, b is overwritten; b = 3

Functions

Functions can take optional keyword arguments. These are given default values. Their default values are used if a user does not specify these inputs when calling the function. Default values must come after positional arguments in the function signature.

```
def subtract(a, b=0):
    return a - b

print(subtract(2))        # 2
print(subtract(1, 3))     # -2
print(subtract(2, b=5))   # -3
```

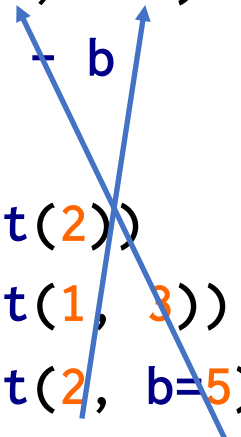
a = 2, b is overwritten; b = 5

Functions

Functions can take optional keyword arguments. These are given default values. Their default values are used if a user does not specify these inputs when calling the function. Default values must come after positional arguments in the function signature.

```
def subtract(a, b=0):
    return a - b

print(subtract(2))        # 2
print(subtract(1, 3))     # -2
print(subtract(2, b=5))   # -3
print(subtract(b=-1, a=6)) # 7
```



a = 6, b is overwritten; b = -1

Flow of a Program

A Python script is executed line by line top to bottom.

```
def fun():
    print("fun")

print("hello")
```

Function definitions are packaged into an executable unit to be executed later.

The code within a function definition executes only when invoked by a caller.

In this case, because the fun function is never called, the code inside the function never runs!

Output:

hello

Flow of a Program

A Python script is executed line by line top to bottom.

```
def fun():
    print("fun")
print("hello")
fun()
```

Note: "hello" is printed before "fun".

Output:

hello

fun

Variables and Parameters are Local

An assignment statement in a function creates a **local variable** for the variable on the left hand side of the assignment operator. It is called local because this variable only exists inside the function and you cannot use it outside.

```
def square(x):
    y = x * x     # y only exists inside function
    return y
z = square(8)
print(z)
print(y)          # NameError! name 'y' is not defined.
```

Functions calling other functions

Each function we write can be used and called from other functions.

```
def square(x):
    y = x * x
    return y
def sum_of_squares(x, y, z):
    a = square(x)
    b = square(y)
    c = square(z)
    return a + b + c
a = -5
b = 2
c = 10
result = sum_of_squares(a, b, c)
print(result)           # 129
```

The variables x and y are local variables in both functions and may even have different values.

Even though they are named the same, they are, in fact, very different.

Similarly, a, b and c in the sum_of_squares function are different than a, b and c outside of it.

Python Program Template

```
# declare and initialize global variables with file scope, these
# variables exist everywhere in the rest of the file including inside
# functions.
x = 3

# function definitions
def func1():
        …
def func2():
        …

# program logic flow starts here
# ask for user inputs, call functions above, etc..
a = func1()
print(a)
```

From now on, when we write a program, we will use this template.

Writing a Simple Program: Quadratic Roots

Let's write a full program that asks the user for three integers a, b and c which represent the coefficients of a quadratic function of the form

$f(x) = ax^2 + bx + c$ and outputs the number of real zeroes or roots of $f(x)$.

```
def num_of_roots(a, b, c):
        discriminant = b ** 2 - 4 * a * c
        if discriminant > 0:
                return 2
        elif discriminant < 0:
                return 0
        else:
                return 1
a = float(input('Enter a:'))
b = float(input('Enter b:'))
c = float(input('Enter c:'))
numroots = num_of_roots(a, b, c)
print("This quadratic has", numroots, "real root(s).")
```

Lab 1: Math Calculations

Create a new repl on replit. Write a program that implement the functions below. Test your functions by calling them and printing out their returned values.

area_rectangle: returns the area of the rectangle with length and width.

area_trapezoid: returns area of trapezoid with two bases and a height.

A = h(a + b)/2

area_triangle: returns area of a triangle given the sides: a, b and c.

$$A = \sqrt{s(s-a)(s-b)(s-c)}, \text{ where } s = \frac{a+b+c}{2}$$

fahrenheit_to_celsius: returns the temperature in celsius given the temperature in fahrenheit.

$$C = \frac{5}{9}(F - 32)$$

Lab 2: BMI

Create a new repl on replit. Write a program that asks the user to enter their height in inches and weight in pounds and display the body mass index(BMI). Implement the function bmi to calculate the bmi.

```
def bmi(height, weight):
    # implement this function to compute the bmi given the height
    # and weight.



# ask the user to enter height
# ask the user to enter weight
# call the bmi function and display the result.
```

Lab 3: Day Of the Week

Create a new repl on replit. Write a program that outputs the day of the week for a given date! You program must the program template discussed in this lecture.

Given the month, m, day, d and year y, the day of the week(Sunday = 0, Monday = 1, …, Saturday = 6) D is given by:

$$
\begin{aligned}
y_0 &= y - (14 - m)/12 \\
x_0 &= y_0 + y_0/4 - y_0/100 + y_0/400 \\
m_0 &= m + 12 \times ((14 - m)/12) - 2 \\
\mathcal{D} &= (d + x_0 + 31 \times m_0/12) \bmod 7
\end{aligned}
$$

Note: the / operator from the above equations is floor division // in Python. The mod operator is %.

Use the template on the next page.

Lab 3: Day Of the Week

Use the following template.

```
def compute_day(month, day, year):
      """ This function computes the values given from the previous slide
          and returns an integer in the set {0,1,..,5,6}.
      """
def day_of_week(d):
      """ Given d which computed from compute_day above. This function returns
          a string according to the value of d: "Sunday" for 0, "Monday for 1,
         etc..
      """


# ask users for month, day and year
# call compute_day and day_of_week above
# print out day of the week.
```

Lab 3: Day Of the Week

Your program should have output similar to the following:

Enter month: 10

Enter day: 27

Enter year: 2020

Day of the week: Tuesday

And try entering your birthday and test your parents!

References

1) Vanderplas, Jake, A Whirlwind Tour of Python, O'reilly Media.
2) Halterman, Richard, Fundamentals of Python Programming.