Introduction to Computational and Algorithmic Thinking

LECTURE 2B – COMPUTER PROGRAMMING FUNDAMENTALS II

Announcements

This lecture: Computer Programming Fundamentals

Reading: Read Chapter 2 of Conery

Acknowledgement: Some of the lecture slides are based on CSE 101 lecture notes by Prof. Kevin McDonald at SBU and the textbook by John Conery.

Functions

- Recall that Python has a math module
  - The library has numbers (*e*, π , etc.)
  - It also has a variety of useful mathematical functions
- In *programming*, a **function** is a name given to a set of statements that perform a well-defined task
- For example, the **input** function performs a task (getting user input) and also returns the value entered by the user
- **print**, **int**, **float,** and **str** are also functions
- The next example introduces a new function, **format**, that lets the programmer format numerical output in a desired way

Example: BMI calculator

- Once numbers are stored in variables, they can be used in calculations
- The Body Mass Index (BMI) is a metric used to gauge a person's general health
- Given a person's weight in pounds and total height in inches, a person's BMI is calculated as:

  BMI = (weight * 703) / height^2

- A BMI in the range of 18.5-24.9 is considered "healthy"
- The next program being examined calculates and prints a person's BMI based on entered values
- The result is printed to 15 digits of accuracy, which is more digits than necessary

Example: BMI calculator

- To print a number to a designed number of digits, use the **format** function
- Suppose there is a variable **total_due** to be printed with two decimal places. Here is how to do it:

```
print("Total due: $" +
      "{:.2f}".format(total_due))
```

- If we wanted four digits, we would write **{:.4f}** instead
- Note that when using the **format** method, do not also use **str** to print a number
- In the code for this program, there are two print statements
  - one gives the BMI to the full accuracy
  - one rounds the result to three decimal places

Example: bmi_v1.py

```
weight = float(input('Enter weight in pounds: '))
feet = float(input('Enter feet portion of height: '))
inches = float(input('Enter inches portion of height: '))

total_inches = feet * 12 + inches

bmi = (weight * 703) / total_inches ** 2

print('Your BMI is ' + str(bmi))
print('Your BMI is ' + '{:.3f}'.format(bmi))
```

- The blank lines are present to make the code more readable. They do not affect program execution in any way.
- More about format function: https://www.python-course.eu/python3_formatted_output.php

Other functions in Python

- Some examples:

```
type(45)
int(34.56)
float(45)
str(3421)
len('apple')
round(2.32)
abs(-45)
pow(2, 3) # cf. 2**3
help(pow)
. . .
```

```
import math
math
math.log(10)
math.log10(10)
math.log10(1e6)
radians = 0.7
math.sin(radians)
math.sqrt(3)
...
```

```
import random
random.random()
random.randint(0,100)
```

Try these on a Python Console or as part of a program

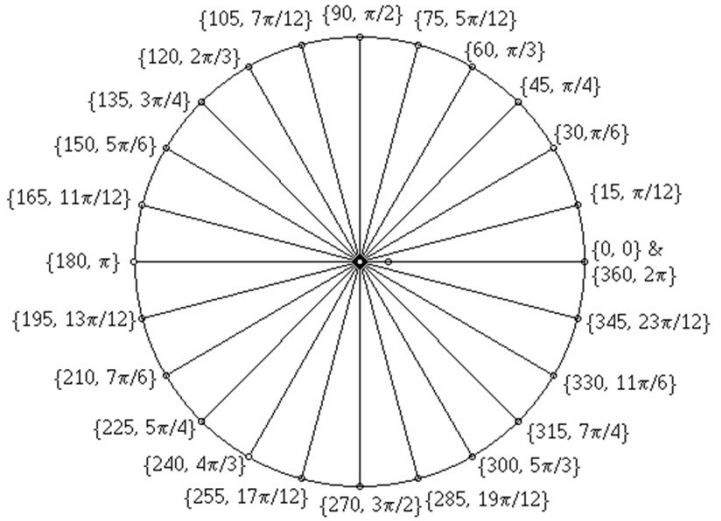
Function composition

- Can compose functions as is done in mathematics, e.g., f(g(x,y))

```
import math
radians = 0.7
math.radians(math.degrees(radians))

radians = 0.3
math.acos(math.cos(radians))

pow(abs(-3), round(5.6))
```



Defining new functions

- Functions in program have many benefits, including:
  - They make code easier to read and understand
    - ➔ don't need to know the details of how or why a function works
  - They allow code to be used more than once (code re-use)
- To define a new function in Python we use a **def** statement
  - Consider writing a function that computes a person's Body Mass Index
  - Can then call this function as many times as desired
  - The alternative would be to copy and paste the code multiple times
  - First rule of programming: don't repeat yourself!

Creating new functions

- From mathematics: a 2 step process
  1. Define a function, once

     f(x, y) = x*y + 1
  2. Apply/Use/Invoke/Call the function, as many times as desired

     f(2,3) = 2*3 + 1 = 7

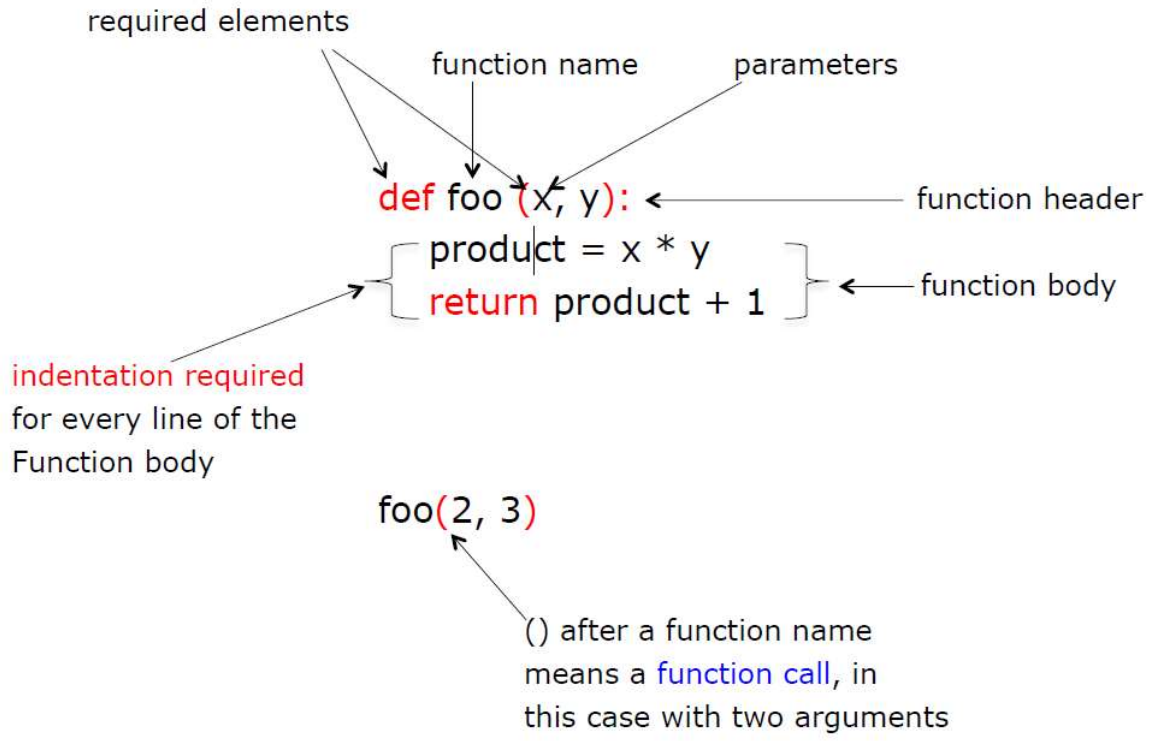
- Do the same in programming: again a 2 step process
  1. Define a function, once

```
def f(x, y):
    return x * y + 1
```

  2. Apply/Use/Invoke/Call the function, as many times as desired

```
f(2, 3)
```

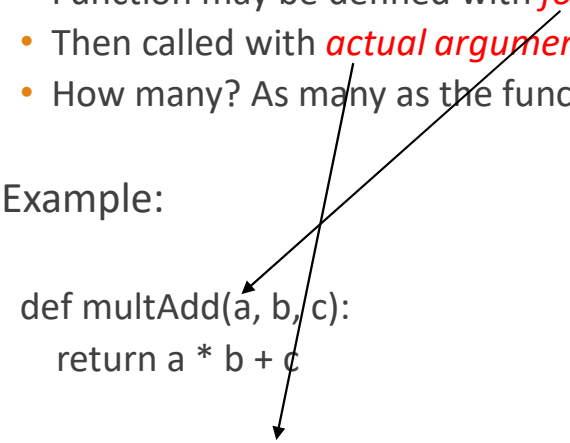
Mechanics of defining/calling a function



Parameters and arguments

- Function can have zero or more parameters
  - Function may be defined with *formal parameters*
  - Then called with *actual arguments*
  - How many? As many as the function needs!

- Example:



```
def multAdd(a, b, c):
    return a * b + c

print(multAdd(1, 2, 3))
print(multAdd(2.1, 3.4, 4.3))
print(multAdd(abs(pow(2,3)), 3.2 + 2.3, 45.34))
```

Program: flow of execution

```
def message():
    print(1)
    message1()
    print(2)
def message1():
    print('a')
    message2()
    print('b')
def message2():
    print('middle')
    message()
```

Note: three functions and a call to message on the left is a *program*!

Output:

1
a
middle
b
2

Void functions vs. fruitful functions

- **announce** below is an example of a *void function*
  - It does not return any useful value when it is called; it only prints a value
- **square** is an example of a *fruitful function*
  - It returns a value when it is called

```
// void function
def announce(msg):
    print(msg)

announce('hello!')
```

```
// fruitful function
def square(n):
    return n * n

print(square(3))
```

See what gets printed by the print statement in each case!

- Don't expect a void function to return any useful value.
  - The call announce('hello') returns **None** to indicate that.
- So the statement **print(announce('hello!'))** will print **None**.

Example: bmi_v2.py

```
# Function definition
def bmi(w, h):
    return (w * 703) / (h ** 2)

# main is to use the function defined above.
def main():
    weight = float(input('Enter weight in pounds: '))
    feet = float(input('Enter feet portion of height: '))
    inches = float(input('Enter inches portion of height: '))

    total_inches = feet * 12 + inches
    my_bmi = bmi(weight, total_inches)
    print('Your BMI is ' + '{:.3f}'.format(my_bmi))

# This sets up a call to the function main.
main()
```

Note how a program is organized.

Why functions? Abstraction

- One of the most important concepts in computer science is **abstraction**
  - Give a name to a group of statements and use it, e.g., **bmi**(…)
- From the outside, the details are hidden
  - only care calling this function will do a desired computation
- Functions thereby allow complex problems to be solved by subdividing it into smaller, more manageable sub-problems
  - This process is called **problem decomposition** (also **functional decomposition**)
- Often programmers use functions to engage **in top-down software design**
  - They design the software as a series of steps
  - Each step corresponds to one or more functions

Example: bmi_v3.py

- Here's an alternative way of implementing the **bmi** function
  - It illustrates proper indentation and relies on two **local variables**, **numerator** and **denominator**

- A *local variable* is a variable accessible only inside the function where it is created

Example: bmi_v3.py

```
def bmi(w, h):
    numerator = w * 703
    denominator = h ** 2
    return numerator / denominator

def main():
    weight = float(input('Enter weight in pounds: '))
    feet = float(input('Enter feet portion of height: '))
    inches = float(input('Enter inches portion of height: '))

    total_inches = feet * 12 + inches
    my_bmi = bmi(weight, total_inches)
    print('Your BMI is ' + '{:.3f}'.format(my_bmi))

main()
```

Example: Distance calculator

- Example: A distance traveled is provided in miles, yards, and feet (i.e. 3 miles, 68 yards, 16 feet)
  - Need this to be converted to total inches traveled and print the result
  - This requires some unit conversions
- Recall the following equivalences:
  - 1 foot = 12 inches
  - 1 yard = 3 feet
  - 1 mile = 5,280 feet
- Finally, to print a comma every three digits we can use the formatting string '**{:,}**' when printing an integer

Example: distance.py

```
def distance(m, y, f):
    return (m * 5280 * 12) + (y * 3 * 12) + (f * 12)

def main():
    miles = int(input('Enter the number of miles: '))
    yards = int(input('Enter the number of yards: '))
    feet = int(input('Enter the number of feet: '))

    inches = distance(miles, yards, feet)

    print('Distance in inches: ' + '{:,}'.format(inches))

main()
```

Example: Mortgage calculator

- The monthly payment on a fixed-rate mortgage can be calculated using this formula:

  $pmt = (r * P) / (1 – (1 + r)^{-n})$

- Where
  - P is the principal (the amount we borrowed)
  - r is the monthly interest rate as a decimal (i.e., the annual interest rate as a decimal divided by 12)
  - n is the number of months the loan will last
- To include a comma every three digits, write the format string as `{:,.2f}' for floats
- Also, a format string can be saved in a variable if it's needed to format several numbers in the same way:
  - fmt = `{:,.2f}'
- Following is a function to compute pmt

Example: mortgage.py

```
def monthly_payment(borrow_amt, monthly_rate, num_months):
    return (borrow_amt * monthly_rate) /
                (1 - 1 / (1 + monthly_rate) ** num_months)

def main():
    principal = float(input('Enter principal: '))
    annual_rate = float(input('Enter annual interest rate as a percentage: '))
    years = int(input('Enter term of mortgage in years: '))

    payment = monthly_payment(principal, annual_rate / 12 / 100, years * 12)
    totalPaid = payment * years * 12
    totalInterest = totalPaid - principal

    fmt = '{:,.2f}' # formatter string
    print('Principal: $' + fmt.format(principal))
    print('Annual interest rate: ' + fmt.format(annual_rate) + '%')
    print('Term of loan in years: ' + str(years))
    print('Monthly payment: $' + fmt.format(payment))
    print('Total money paid back: $' + fmt.format(totalPaid))
    print('Total interest paid: $' + fmt.format(totalInterest))

main()
```

Conditional execution

- Often an algorithm needs to make a decision
- The steps which are executed next depend on the outcome of the decision
- Example: a person's income range determines the income taxation rate
  - If the income is above a certain minimum, use one tax rate; otherwise, use a lower rate
- In Python, an **if-statement** allows testing conditions and executing different steps depending on the outcome

Example: Tuition calculator

- Suppose part-time students (< 12 credits) at a fictional college pay $600 per credit and full-time students pay $5,000 per semester.
- Use an if-statement to write a short program that implements this logic

Example: tuition.py

```
numCredits = int(input('Enter number of credits: '))

if numCredits < 12:
   cost = numCredits*600
   print('A student taking ' + str(numCredits) +
         ' credits is part-time and will pay $' +
         str(cost) + ' in tuition.')
else:
   print('A student taking ' + str(numCredits) +
         ' credits is full-time and will pay
         $5,000 in tuition.')
```

Conditional execution

- if-statements can also appear in functions:

```
def tax_rate(income):
    if income < 10000:
        return 0.0
    else:
        return 5.0
```

- Here, value returned by the function depends on value passed as an argument to the parameter
- Things to note about the **if** statement:
  - The words **if** and **else** are keywords
  - There is a **colon (:)** at the end of the if and else **clauses**
  - The statements to be executed are **indented**

Multi-way if-statements

- When an algorithm needs to choose among more than two alternatives, it can use **elif** clauses
- **elif** is short for "else if"
- This function distinguishes between three tax brackets:

```
def marginal_tax_rate(income):
    if income < 10000:
        return 0.0
    elif income < 20000:
        return 5.0
    else:
        return 7.0
```

- Can use as many **elif** parts as needed

Boolean expressions

- The expressions inside **if** and **elif** statements are special kinds of expressions
- The result of these expressions is either **True** or **False**
- An expression that evaluates to **True** or **False** is called a **Boolean expression**
- Boolean expressions often involve **relational operators**:
  - equal to / not equal to
  - greater than / greater than or equal to
  - less than / less than or equal to

Boolean expressions

The notation >= means “greater than or equal to” and is one of six **relational operators** supported by Python:

Mathematical Operator	Python Equivalent	Meaning
=	==	is equal to
≠	!=	is not equal to
>	>	is greater than
≥	>=	is greater than or equal to
<	<	is less than
≤	<=	is less than or equal to

Example: Overtime calculator

- Someone who works more than 40 hours a week is entitled to “time-and-a-half” overtime pay
- How can the following be determined?
  1. Whether or not an employee is entitled to overtime pay
  2. If so, how much?
- #1 is pretty simple: use an if-statement
- For #2, a different calculation is required depending on whether employee will earn overtime pay or not
- Regular pay formula: hourly wage × hours worked
- The overtime formula has two parts:
  - The pay for first 40 hours
  - The pay for additional overtime hours

Example: paycheck.py

```
def compute_pay(hours, wage):
    if hours <= 40:
        paycheck = hours * wage
    else:
        paycheck = 40 * wage + (hours - 40) * 1.5 * wage
    return paycheck

def main():
    hours_worked = float(input('Enter # of hours worked: '))
    hourly_wage = float(input('Enter hourly wage: '))

    pay = compute_pay(hours_worked, hourly_wage)
    print('Your pay is $' + '{:.2f}'.format(pay))

main()
```

Example: Hiring decisions

- A hiring manager is trying to decide which candidates to hire
- Each potential hire is evaluated based on GPA, interview performance, and an aptitude exam
- A GPA of at least 3.3 is worth 1 point
- An interview score of 7 or 8 (out of 10) is worth 1 point; a score of 9 or 10 is worth 2 points
- An aptitude test score above 85 is worth 1 point
- Hiring decisions are then based on point totals:
  - 0, 1 or 2 total points: Not hired
  - 3 total points: hired as a Junior Salesperson
  - 4 points: hired as a Manager-in-Training

Example: Hiring decisions

- Following is a function that takes these three values and returns the hiring decision as a string
- The following Python capabilities/features will help with this task:
  - The **+=** operator can be used to increment a variable by some amount
  - **-=**, ***=** and **/=** also exist and perform analogous operations
  - A variable can be used to maintain a tally or running total
  - An if-statement can contain **elif** clauses without a final **else** clause

Example: hiring.py

```
def decision(gpa, interview, test):
    points = 0                # Point total accumulator

    if gpa >= 3.3:
        points += 1

    if interview >= 9:
        points += 2
    elif interview >= 7:
        points += 1           # note: no else clause

    if test > 85:
        points = points + 1

    if points <= 2:
        return 'Not hired'
    elif points == 3:
        return 'Junior Salesperson'
    else:
        return 'Manager-in-Training'
```

Ranges and relational operators

- The relational operators can be used to express ranges of values
- Examples:
  - An age in the range 1 through 25, inclusive:

    0 <= age <= 25
  - A length in the range 15 (inclusive) through 27:

    15 <= length < 27
  - A year in the range 1900 through 1972, exclusive of both:

    1900 < year < 1972

More on strings

- Python strings can begin and end with single quotes or double quotes
  - **'Stony Brook'** and **"Stony Brook"** are both valid ways of defining the same string
- Recall that the plus symbol joins two strings into a single longer string (concatenation)
- The asterisk repeats a string a specified number of times
  - Example: **'Hello' * 3** will evaluate to **'HelloHelloHello'**

String functions

- Strings are very fundamental to programming
  - most languages support many functions and other operations for strings
  - Python is no exception.
- The Python function named **len** (short for "length") counts the number of characters in a string
  - **len** counts every character in a string, including digits, spaces, and punctuation marks
  - Example:

```
school = 'Stony Brook University'
n = len(school) # n will equal 22
```

String methods

- Many other functions on strings are called using a different syntax
- Instead of writing **func(s)**, they are written **s.func()**
  - The name of the string is written first, followed by a period, and then the function name
- Functions called using this syntax are referred to as **Methods**

String methods

- As an example of a string method, consider how to figure out how many words are in a sentence
- If there is exactly one space between each word, just count the number of space characters
- The method named **count** does exactly that:

```
sentence = 'It was a dark and stormy night.'
sentence.count(' ') + 1 # equals 7
```

- Note the argument passed to **count** is a string containing exactly one character: a single space character.

String methods

- Two other useful methods are **startswith** and **endswith**
  - These are both Boolean functions and return **True** or **False** depending on whether a string begins or ends with a specified value
- Examples:

```
sentence = 'It was a dark and stormy night.'
sentence.startswith('It’)      # True
sentence.startswith('it’)      # False
sentence.startswith("It's")    # False
sentence.endswith('?’)         # False
sentence.endswith('.’)         # True
```

String methods

- Another example:

```
filename = input('Enter a filename: ')
if filename.endswith('.py'):
    print('The file contains a Python program.')
else:
    print('The file does not contain a Python program.')
```

Questions?