Computer Science Principles

CHAPTER 2 – COMPUTER PROGRAMMING FUNDAMENTALS

Announcements

Reading: Read Chapter 2 in the Conery textbook (Explorations in Computing)

Python programs from slides posted

Acknowledgement: These slides are revised versions of slides prepared by Prof. Arthur Lee, Tony Mione, and Pravin Pawar for earlier CSE 101 classes. Some slides are based on Prof. Kevin McDonald at SBU CSE 101 lecture notes and the textbook by John Conery.

Expressions

An **Expression** represents something like a number, string or value

"Hello, world!" is an expression

- It has a value
- In this case, it's a string (a sequence of characters)

Numbers are also expressions

- 5 is an integer expression
 - Recall that an integer is zero, or a positive or negative whole number with no fractional part
- 12.36 is a floating-point expression
 - Floating-point is a format that computers use to represent real numbers
 - Recall that a real number is zero, or a positive or negative number that might have a fractional part

Expressions

An expression may also look like 2 + 9

- This represents an addition
- Some of the simplest expressions in Python involve these arithmetic expressions

Each number is called an **operand** – these are the inputs to the function

The plus (+) is an **operator** – this is telling what to do with the input (in this case, add)

The expression may consist of many different operators and operands.

Arithmetic in Python

The symbols used for operators are commonly used in other languages and applications (e.g., spreadsheets)

- add: +
- subtract: -
- multiplication: *
- division: /
- integer division: //
- remainder: %

(divides and rounds down to the nearest whole number)

- (gives the remainder of an integer division, also called "modulo")
- exponentiation: **

Examples of arithmetic in Python

- 11 + 5 🏓 16
- 11−5 → 6
- 11 * 5 🗲 55
- 11/5 🇲 2.2

11 // 5 🇲 2

• This example shows integer division. Any remainder is discarded.

11 % 5 🏓 1

- The computer divides 11 by 5 and returns the remainder (which is 1), not the quotient (which is 2).
- The % is performing the "modulo operation"

Examples of arithmetic in Python

What happens when you have:

2 * (3 + 2) - 4 / 2

→ 8

Arithmetic in Python follows the **PEMDAS** rule:

- 1. First, evaluate all expressions in parentheses (P)
- 2. Then, perform exponentiations (E)
- 3. Next, perform multiplications (M) and divisions (D) in left-to-right order
- 4. Finally, perform additions (A) and subtractions (S) in left-to-right order

Arithmetic in Python

The ****** operator does exponentiation or raises a number to a power

For example: $2 * 5 \rightarrow 32$ because $2^5 = 32$

Recall raising a number to the power of ½ is the same as taking a square root
So 16 ** 0.5 would be the same as √16 which is 4

Expressions

Python also has **Boolean** expressions, which are expressions that can be **True** or **False**

So there are at least three kinds of data in Python programming:

- Strings
- Numbers
- true/false (Boolean) values

In computer programming, there are a wide variety of types of data because there are a wide variety of problems that computers can help solve

Variables

A variable in computer programming is similar to the concept of a variable in mathematics
A name for some value or quantity of interest in a given problem

billTotal = 10.50

The variable **named** billTotal is **assigned** the value 10.50

Now if we later refer to the billTotal, it will be 10.50

In a program, variables can store a person's age, GPA, name, or almost any other kind of information

- The value is temporarily stored in the main memory of the computer while the program is running
- A variable is a kind of **identifier** because it identifies (names) something in source code

Assignment statements

When we give a value to a variable, we are writing an **assignment statement**

An assignment statement consists of a variable name, the equals sign, and a value or expression

Examples:

- length = 3.5
- total = 2 + 5 (total becomes 7)
- o firstName = "Susan"

These examples show three different data types: a real number, an integer, and a string

Assignment statements

After assigning a value to a variable, you can change the value of the variable with another assignment statement:

total = 5 ... other code here ...

```
total = 17 + 6
```

... more code ...

Variables can also appear on the right-hand side (RHS) of an assignment statement: next_year = this_year + 1 total_earnings = income - taxes

Variables

It is important to choose variable names that are informative and helpful

Do you have any idea what these variables represent? **tb = st + tx + tp**

```
Do these names help?
total_bill = subtotal + tax + tip
```

Note how the underscore is used to separate words that define the identifier

• Spaces are not allowed in variable names

Variables

A Python variable name may contain lowercase letters, uppercase letters, digits and underscores

• First character must be a letter or underscore

Lowercase and uppercase letters are treated as completely different characters

- Because of this we say that Python is a **case-sensitive language**
- First_Name, first_name and FIRST_NAME would all be treated as different identifiers

There are a number of **keywords** built into the Python language that have pre-defined meanings

- Predefined keywords may not be used as variables
- Examples of predefined keywords are:

```
if
for
and
```

Want to compute the area of a square countertop with one corner cut off, as shown here



Assume that the triangular cut-out begins halfway along each edge

=

Note that this code has a few issues:

- It's just a formula with no explanation of what the numbers mean
- The code works only for countertops exactly 100 cm long. What if we had countertops of other sizes?

Addressing the first issue: giving an explanation of what the code does

```
# area = area of square - area of triangle
# area of triangle is 1/2 base*height
area = 100**2 - 50*50/2
```

The lines beginning with the # symbol are called **comments**

- Comments are notes that the programmer writes to explain what the program does
- Comments do not affect the input or output of the program or anything about how it runs

Now let's address the other issue: make it to generalizable and work with other countertop sizes

```
side = 100
square = side**2
triangle = (side / 2)**2 / 2
area = square - triangle
```

To compute the area for a countertop of a different size (e.g. 200), simply change the first line:

side = 200

This code is also more readable; comments aren't needed

• This is an example of **self-documenting code**

The spacing in between variables, numbers, and operator is optional, but is included here to make the formulas easier to read

Aside: input statements

To improve the code further, we can make it interactive so that the user can provide the value for the **side**

Do this by writing an **input** statement – An input statement reads a **string** from the keyboard

 As part of an input statement, the programmer must give a prompt message that tells the user what they should enter. For example:

name = input("What is your name? ")

The person's name will be assigned to the name variable

• You could also say that we are saving the person's name in the name variable

In the case of the area calculation, the user should enter a number, not a string

To collect a floating-point number, use: side = float(input("Enter side length: "))

If we wanted to only allow integer numbers as input, we would use: side = int(input("Enter side length: "))

The type chosen – **int** vs. **float** – depends on the application

• For our program, read in a float so the user could enter a fraction of a centimeter if desired

The last step is how to display the final result on the computer screen

Aside: print statements

print is a Python command

• It tells Python to display some text on the screen

The syntax to print a basic message is just this:

print("Hello, world!")

Any text printed with additional print commands will appear on a new line

For Python to print the next output on the same line, do this instead:

- print("Hello, world!", end="")
- This means print this message, but do not automatically go to the next line

Aside: print statements

To print a number, it must first be converted into a string, like so:

- print("The area is " + str(area))
- The assumption here is that **area** is a variable that contains the value we want to print

When used in this fashion, the + symbol performs **string concatenation**

• This simply means Python will join the two strings together into one

Example: countertop.py

This program prints the area of a# countertop formed by cutting the# corner off a square piece of material

```
side = float(input("Enter side length: "))
square = side**2
triangle = (side/2)**2 / 2
area = square - triangle
print("The area is " + str(area))
```



Example: coins.py

Here is an example that uses the modulo (remainder) operator with integer division:

Given a total number of cents, the computer should print how many dimes, nickels, and pennies are needed to make that change while minimizing the number of coins

• Note: 1 dime = 10 cents, 1 nickel = 5 cents, 1 penny = 1 cent.

Note:

The code will use several variables

It will also need the **str** command to print variables containing numbers to the screen

• Recall that **str** converts a number to a string so that it can be concatenated with other strings

```
Example: coins.py
```

cents = int(input("Enter the number of cents: "))

```
dimes = cents // 10
cents = cents % 10
nickels = cents // 5
cents = cents % 5
pennies = cents
```

```
print("That number of cents is equal to " +
    str(dimes) + " dimes, " + str(nickels) +
    " nickels and " + str(pennies) + " pennies.")
```



Escape sequences in programming languages like Python allow printing characters (symbols) on the screen that perform special functions

In Python, some of the escape sequences are:

- **\t** shifts the text to the right by one tab stop
- **\n** prints a newline
- \" prints a double quotation mark
- \' prints a single quotation mark

A lone backslash character \ is called the line-continuation character (it's not really an escape sequence, though)

• This symbol is a signal to Python that the current statement spans two or more lines of a file

Example: limerick.py

Source code:

print('There was an old man with a beard\n\
Who said, \"It\'s just how I feared!\"\n\
\tTwo owls and a hen\n\
\tFour larks and a wren\n\
Have all built their nests in my beard.')

Output:

There was an old man with a beard Who said, "It's just how I feared!" Two owls and a hen Four larks and a wren Have all built their nests in my beard.

Additional Arithmetic in Python

The constant $\boldsymbol{\pi}$ is built into Python

First the programmer must make it available by importing the **math** module:

• import math

Then **math.pi** can be used in expressions

• math.pi * 2

A Python module is a file consisting of Python source code that are all related somehow

Functions

Python's math module contains code related to mathematical functions

- $\circ\,$ The library has numbers (e, π , etc.)
- Also has a variety of useful mathematical functions (e.g. calculate the cosine of a variable)

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

```
name = input("What is your name? ")
```

print, int, float, and str are also functions

The next example introduces a new function, **format**, that lets the programmer format numerical output

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) / height²

A BMI in the range of 18.5-24.9 is considered "healthy"

We want to create a program that calculates and prints a person's BMI based on entered values.

However, we want to ensure the BMI is printed with 3 digit decimal precision (e.g. 19.421)
By default it will print 15 decimal digit, e.g. 19.421004314691235

Example: BMI calculator

To print a number to a designed number of digits, use the **format** function

Suppose there is a variable **total** to be printed with two decimal places. Here is how to do it:

```
print("Total: " + "{:.2f}".format(total))
```

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

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 first print statement gives the BMI with full accuracy. The second print statement rounds to 3 decimal places. The blank lines are present to make the code more readable. They do not affect program execution in any way. More about format function: <u>https://www.python-course.eu/python3_formatted_output.php</u>

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) 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
print(math.degrees(radians))
```

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
 - Jon'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

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



Program: flow of execution

- def message():
 - print(1)
 - message1()
 - print(2)

```
def message1():
```

```
print('a')
```

```
message2()
```

```
print('b')
```

```
def message2():
```

```
print('middle')
```

Note: this is a *program* with three functions and it starts with a call to *message*.

Output:

1 a middle b 2

Fruitful functions

square is an example of a *fruitful function*

• It returns a value when it is called

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

```
print(square(3))
```

What will get printed when this code runs?

Void 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

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

```
announce('hello!')
```

What would happen if you tried to print your announce call?

Void functions – Part 2

// void function
def announce(message):
 print(message)

```
print(announce('hello!'))
```

Since announce does not have a return statement, it returns None

So the statement print (announce ('hello!')) will print None.

```
Example: bmi_v2.py
```

```
# Function definition
                                                           Note how a program
def bmi(w, h):
                                                           is organized.
    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()

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 that calling this function will do a desired computation

Functions thus allow complex problems to be solved by dividing it into smaller, more manageable sub-problems

• This process is called problem decomposition (also functional decomposition)

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 (e.g. 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:

•
$$payment = (r * P)/(1 - (1 + r)^{-n})$$

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

Let's also improve formatting the output:

- To include a comma every three digits and have 2 decimal precision, write the format string as: '{:,.2f}'
- Also, a format string can be saved in a variable if it's needed to format several numbers in the same way:

fmt = '{:,.2f}'

Now we will create a function to compute the payment

Example: mortgage.py

```
def monthly payment(borrow amt, monthly rate, num months):
    return (borrow amt * monthly rate) / (1 - (1 + monthly rate) ** -num months)
def main():
    principal = float(input('Enter principal: '))
    annual rate = float(input('Enter annual interest rate as a percentage:'))
    vears = 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: '))
```

```
' 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</pre>

The 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 tax_rate(income):
    if income < 10000:
        return 0.0
    elif income < 20000:
        return 5.0
    else:
        return 7.0</pre>
```

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
2	>=	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 an employee is entitled to overtime pay
- 2. If so, how much are they paid?

For #1 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 the first 40 hours
- The pay for additional overtime hours (1.5 x hourly wage)

```
Example: paycheck.py
```

```
def compute_pay(hours, wage):
    if hours \leq 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

Next slide will show a function that takes these three values and returns the hiring decision as a string

The following Python capabilities will help with this task:

• The += operator can be used to increment a variable by some amount

```
amount += 5
amount = amount + 5 // Exact same as the line above
```

- -=, *= and /= also exist and perform similar operations
- A variable can be used to maintain a running total
- An if statement can contain elif clauses without a final else clause

```
Example: hiring.py
```

```
def decision(gpa, interview, test):
   points = 0
                                  # Variable to store the total points
   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:
 - 1 <= age <= 25
- A length in the range 15 (inclusive) up to, but not including, 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 (including Python) support many functions and other operations for strings.

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
```

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**

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 and add one

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.

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.endswith('It's")  # False
sentence.endswith('?')  # False
sentence.endswith('.')  # True
```

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?