Last time... Introduction to Algorithms

- An algorithm is a recipe for solving a problem.

**Search Problem**
- **Input:**
  - a list of objects
  - a specific object
- **Output:**
  - True if the object is in list
  - False if the object is *not* in list

**Sorting Problem**
- **Input:**
  - a collection of orderable objects
- **Output:**
  - a collection where each item is in order

**Problem Specification**
Input: Some stuff!
OUTPUT: Information about the stuff!
Lecture Overview

• Programming languages (PLs)

• Introduction to Python and Programming

Disclaimer: Much of the material and slides for this lecture were borrowed from
— E. Grimson, J. Guttag and C. Terman MIT 6.0001 class
— Ruth Anderson, Michael Ernst and Bill Howe’s CSE 140 class
— Swami Iyer’s Umass Boston CS110 class
Lecture Overview

• Programming languages (PLs)

• Introduction to Python and Programming
Programming Languages

• Syntax and semantics
• Dimensions of a PL
• Programming paradigms
Programming Languages

• An artificial language designed to express computations that can be performed by a machine, particularly a computer.

• Can be used to create programs that control the behavior of a machine, to express algorithms precisely, or as a mode of human communication.

• e.g., C, C++, Java, Python, Prolog, Haskell, Scala, etc..
Creating Computer Programs

• Each programming language provides a set of primitive operations.

• Each programming language provides mechanisms for combining primitives to form more complex, but legal, expressions.

• Each programming language provides mechanisms for deducing meanings or values associated with computations or expressions.
Aspects of Languages

• Primitive constructs
  – Programming language – numbers, strings, simple operators
  – English – words

• Syntax – which strings of characters and symbols are well-formed
  – Programming language – we’ll get to specifics shortly, but for example 3.2 + 3.2 is a valid C expression
  – English – “cat dog boy” is not syntactically valid, as not in form of acceptable sentence
Aspects of Languages

• Static semantics – which syntactically valid strings have a meaning

  – English – “I are big” has form `<noun> <intransitive verb> <noun>`, so syntactically valid, but is not valid English because “I” is singular, “are” is plural

  – Programming language – for example, `<literal> <operator> <literal>` is a valid syntactic form, but `2.3/’abc’` is a static semantic error
Aspects of Languages

• Semantics – what is the meaning associated with a syntactically correct string of symbols with no static semantic errors

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– English – can be ambiguous
  • “They saw the man with the telescope.”

– Programming languages – always has exactly one meaning
  • But meaning (or value) may not be what programmer intended
Where Can Things Go Wrong?

• **Syntactic errors**
  – Common but easily caught by computer

• **Static semantic errors**
  – Some languages check carefully before running, others check while interpreting the program
  – If not caught, behavior of program is unpredictable

• **Programs don’t have semantic errors, but meaning may not be what was intended**
  – Crashes (stops running)
  – Runs forever
  – Produces an answer, but not programmer’s intent
Our Goal

• Learn the syntax and semantics of a programming language

• Learn how to use those elements to translate “recipes” for solving a problem into a form that the computer can use to do the work for us

• Computational modes of thought enable us to use a suite of methods to solve problems
Dimensions of a Programming Language

Low-level vs. High-level

• Distinction according to the level of abstraction

• In low-level programming languages (e.g. Assembly), the set of instructions used in computations are very simple (nearly at machine level)

• A high-level programming language (e.g. Python, C, Java) has a much richer and more complex set of primitives.
Dimensions of a Programming Language

General vs. Targeted

• Distinction according to the range of applications

• In a general programming language, the set of primitives support a broad range of applications.

• A targeted programming language aims at a very specific set of applications.
  - e.g., MATLAB (matrix laboratory) is a programming language specifically designed for numerical computing (matrix and vector operations)
Dimensions of a Programming Language
Interpreted vs. Compiled

• Distinction according to how the source code is executed

• In interpreted languages (e.g. LISP), the source code is executed directly at runtime (by the interpreter).
  – Interpreter control the flow of the program by going through each one of the instructions.

• In compiled languages (e.g. C), the source code first needs to be translated into an object code (by the compiler) before the execution.
Programming Language Paradigms

• **Functional**
  • Treats computation as the evaluation of mathematical functions (e.g. Lisp, Scheme, Haskell, etc.)

• **Imperative**
  • Describes computation in terms of statements that change a program state (e.g. FORTRAN, BASIC, Pascal, C, etc.)

• **Logical (declarative)**
  • Expresses the logic of a computation without describing its control flow (e.g. Prolog)

• **Object oriented**
  • Uses "objects" – data structures consisting of data fields and methods together with their interactions – to design applications and computer programs (e.g. C++, Java, C#, Python, etc.)
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Lecture Overview

- Programming languages (PLs)

- Introduction to Python and Programming
Programming in Python

• Our programming environment
  – Python programming language
  – PyCharm, an integrated development environment (IDE)
  – Terminal
Programming in Python

• To program in Python
  – Compose a program by typing it into a file named, say, `helloworld.py`
  – Run (or execute) the program by typing `python helloworld.py` in the terminal window
Input and Output

• Bird’s-eye view of a Python program

- **Input types:** command-line arguments, standard input, file input
- **Output types:** standard output, file output, graphical output, audio output
Input and Output

• Command-line arguments are the inputs we list after a program name when we run the program

  $ python my_program.py arg_1 arg_2 ... arg_n

• The command-line arguments can be accessed within a program, such as my_program.py above, via the array (aka list) sys.argv\(^1\) as sys.argv[1], sys.argv[2], . . . , sys.argv[n]

• The name of the program (my_program.py) is stored in sys.argv[0]

\(^1\)The sys module provides access to variables and functions that interact with the Python interpreter
Input and Output

```python
import sys

print('Hi, ', end='')
print(sys.argv[1], end='')
print('. How are you?')
```

$ python useargument.py Alice
Hi, Alice. How are you?
$ python useargument.py Bob
Hi, Bob. How are you?
$ python useargument.py Carol
Hi, Carol. How are you?
1. Python is like a calculator

2. A variable is a container

3. Different types cannot be compared

4. A program is a recipe

**Colvin Run Mill Corn Bread**

1 cup cornmeal  
1 cup flour  
⅛ teaspoon salt  
4 teaspoons baking powder  
3 tablespoons sugar  
1 egg  
1 cup milk  
½ cup shortening (soft) or vegetable oil

Mix together the dry ingredients. Beat together the egg, milk and shortening/oil. Add the liquids to the dry ingredients. Mix quickly by hand. Pour into greased 8x8 or 9x9 baking pan. Bake at 425 degrees for 20-25 minutes.
1. Python is Like a Calculator
You Type Expressions. Python Computes Their Values.

- 5
- 3+4
- 44/2
- 2**3
- 3*4+5*6
- (72 – 32) / 9 * 5

Python has a natural and well-defined set of precedence rules that fully specify the order in which the operators are applied in an expression

- For arithmetic operations, multiplication and division are performed before addition and subtraction
- When arithmetic operations have the same precedence, they are left associative, with the exception of the exponentiation operator **, which is right associative
- We can use parentheses to override precedence rules
An Expression is Evaluated From the Inside Out

• How many expressions are in this Python code?

\[(72 - 32) / 9.0 \times 5\]

\[(72 - 32) / 9.0 \times 5\]
\[(40) / 9.0 \times 5\]
\[4.44 \times 5\]
\[22.2\]
Another Evaluation Example

\[
\frac{(72 - 32)}{(9.0 \times 5)}
\]

\[
\frac{40}{(9.0 \times 5)}
\]

\[
\frac{40}{45.0}
\]

\[
.888
\]
2. A Variable is a Container

A variable is a name associated with a data-type value
Variables Hold Values

• Recall variables from algebra:
  – Let \( x = 2 \) ...
  – Let \( y = x \) ...

• To assign a variable, use “\texttt{varname = expression}”
  \( \texttt{pi = 3.14} \)
  \( \texttt{pi} \)
  \( \texttt{var = 6*10**23} \)
  \( 22 = x \)     # Error!

• Not all variable names are permitted!

  • Variable names must only be one word (as in no spaces)
  • Variable names must be made up of only letters, numbers, and underscore (_)
  • Variable names cannot begin with a number
Changing Existing Variables (“re-binding” or “re-assigning”)

\[
\begin{align*}
  x &= 2 \\
  x &= 2 \\
  y &= 2 \\
  y &= y \\
  x &= 5 \\
  x &= 5 \\
  y &= y
\end{align*}
\]

- “=” in an assignment is not a promise of eternal equality
  - This is different than the mathematical meaning of “=”

- Evaluating an expression gives a new (copy of a) number, rather than changing an existing one
How an Assignment is Executed

1. Evaluate the right-hand side to a value
2. Store that value in the variable

```python
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
```

State of the computer:

<table>
<thead>
<tr>
<th>x: 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>y: 2</td>
</tr>
<tr>
<td>z: 3</td>
</tr>
</tbody>
</table>

Printed output:

<table>
<thead>
<tr>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

To visualize a program’s execution:

http://pythontutor.com
More Expressions: Conditionals (value is True or False)

22 > 4    # condition, or conditional
22 < 4    # condition, or conditional
22 == 4   ...

x = 100   # Assignment, not conditional!
22 = 4    # Error!
x >= 5
x >= 100
x >= 200

not True
not (x >= 200)
3<4 and 5<6
4<3 or 5<6
temp = 72

water_is_liquid = (temp > 32 and temp < 212)
More Expressions: strings

• A string represents **text**
  – 'Python'
  – `myString = "BBM 101-Introduction to Programming"
  – ""

• Empty string is not the same as an unbound variable
  – "" and ‘‘ are the same

• We can specify tab, newline, backslash, and single quote characters using escape sequences ‘\t’, ‘\n’, ‘\’, and ‘\’’, respectively

**Operations:**

• **Length:**
  – `len(myString)`

• **Concatenation:**
  – "Hacettepe" + " " + ' University'

• **Containment/searching:**
  – 'a' in `myString`
  – "a" in `myString`
Strings

ruler1 = '1'
ruler2 = ruler1 + ' 2 ' + ruler1
ruler3 = ruler2 + ' 3 ' + ruler2
ruler4 = ruler3 + ' 4 ' + ruler3
print(ruler1)
print(ruler2)
print(ruler3)
print(ruler4)

1
1 2 1
1 2 1 3 1 2 1
1 2 1 3 1 2 1 4 1 2 1 3 1 2 1
3. Different Types should not be Compared

```python
anInt = 2
aString = "Hacettepe"
anInt == aString  # Error
```
Types of Values

• Integers (**int**): −22, 0, 44
  – Arithmetic is **exact**
  – Some funny representations: 12345678901L

• Real numbers (**float**, for “floating point”): 2.718, 3.1415
  – Arithmetic is **approximate**, e.g., 6.022*10**23

• Strings (**str**): "I love Python", " "

• Truth values (**bool**, for “Boolean”): True, False

George Boole
Operations Behave differently on Different Types

3.0 + 4.0
3 + 4
3 + 4.0
"3" + "4"  # Concatenation
3 + "4"  # Error
3 + True  # Error

Moral: Python only sometimes tells you when you do something that does not make sense.
## Operations on Different Types

<table>
<thead>
<tr>
<th></th>
<th>Python 3.5</th>
<th>Python 2.x</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.0 / 4.0</td>
<td>3.75</td>
<td>3.75</td>
</tr>
<tr>
<td>15 / 4</td>
<td>3.75</td>
<td>3.0</td>
</tr>
<tr>
<td>15.0 / 4</td>
<td>3.75</td>
<td>3.75</td>
</tr>
<tr>
<td>15 / 4.0</td>
<td>3.75</td>
<td>3.75</td>
</tr>
<tr>
<td>15.0 // 4.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>15 // 4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>15.0 // 4</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>15 // 4.0</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

Before Python version 3.5, operand used to determine the type of division.

**//:** Integer Division

**/:** Division
Type Conversion

<table>
<thead>
<tr>
<th>Expression</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>float(15)</code></td>
<td>15.0</td>
</tr>
<tr>
<td><code>int(15.0)</code></td>
<td>15</td>
</tr>
<tr>
<td><code>int(15.5)</code></td>
<td>15</td>
</tr>
<tr>
<td><code>int(&quot;15&quot;)</code></td>
<td>15</td>
</tr>
<tr>
<td><code>str(15.5)</code></td>
<td>15.5</td>
</tr>
<tr>
<td><code>float(15) / 4</code></td>
<td>3.75</td>
</tr>
</tbody>
</table>
A Program is a Recipe
Design the Algorithm Before Coding

• We should think (design the algorithm) before coding

• Algorithmic thinking is the logic. Also, called problem solving

• Coding is the syntax

• Make this a habit

• Some students do not follow this practice and they get challenged in all their courses and careers!
What is a Program?

• A program is a sequence of instructions

• The computer executes one after the other, as if they had been typed to the interpreter

• Saving your work as a program is better than re-typing from scratch

```python
x = 1
y = 2
x + y
print(x + y)
print("The sum of", x, "and", y, "is", x+y)
```
The `print()` Statement

- The `print` statement always prints one line
  - The next print statement prints below that one

- Write 0 or more expressions after `print`, separated by commas
  - In the output, the values are separated by spaces

- Examples:
  ```python
  x = 1
  y = 2
  print(3.1415)
  print(2.718, 1.618)
  print()
  print(20 + 2, 7 * 3, 4 * 5)
  print("The sum of", x, end="")
  print(" and", y, "is", x+y)
  ```

  3.1415
  2.718 1.618
  22 21 20
  The sum of 1 and 2 is 3

  To avoid newline
Exercise: Convert Temperatures

- Make a temperature conversion chart as the following
- Fahrenheit to Centigrade, for Fahrenheit values of: -40, 0, 32, 68, 98.6, 212
- \[ C = (F - 32) \times \frac{5}{9} \]
- Output:

<table>
<thead>
<tr>
<th>Fahrenheit</th>
<th>Centigrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40</td>
<td>-40.0</td>
</tr>
<tr>
<td>0</td>
<td>-17.7778</td>
</tr>
<tr>
<td>32</td>
<td>0.0</td>
</tr>
<tr>
<td>68</td>
<td>20.0</td>
</tr>
<tr>
<td>98.6</td>
<td>37.0</td>
</tr>
<tr>
<td>212</td>
<td>100.0</td>
</tr>
</tbody>
</table>

- You have created a Python program!

- (It doesn’t have to be this tedious, and it won’t be.)
Expressions, Statements, and Programs

• An expression evaluates to a value
  
  3 + 4
  
  pi * r**2

• A statement causes an effect
  
  pi = 3.14159
  
  print(pi)

• Expressions appear within other expressions and within statements
  
  (fahr - 32) * (5.0 / 9)
  
  print(pi * r**2)

• A statement may not appear within an expression
  
  3 + print(pi)    # Error!

• A program is made up of statements
  
  – A program should do something or communicate information
1. Python is like a calculator

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**Colvin Run Mill Corn Bread**
1 cup cornmeal
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Programming Languages

• A programming language is a “language” to write programs in, such as Python, C, C++, Java

• The concept of programming languages are quite similar

• Python:  
  ```
  print("Hello, World!")
  ```

• Java:  
  ```
  public static void main(String[] args) {
      System.out.println("Hello, World!");
  }
  ```

• Python is simpler! That’s why we are learning it first 😊
Evolution of Programming Languages
The 2019 Top Programming Languages

<table>
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<th>Rank</th>
<th>Language</th>
<th>Type</th>
<th>Score</th>
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