Introduction to:
Computers & Programming:
Variables, Functions, Modules, Scripts
and some graphics

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Outline

• More function IO:
  – Assignment of multiple values to variables
  – Keyword parameters
  – Returning multiple values from a function
• Filename – just one more type of Identifier
• Two types of .py files
  – Programs (scripts)
  – Library Files (modules)
• Loading programs
  – To run
    – Into Idle for editing
• Loading and using modules
• Writing a python script
• Writing a python module
Multiple Variable Assignment

• It is possible to use one assignment with multiple variables
  – chicken, egg, one, two = 'chicken', 'egg', 1 2

• The variables are assigned in order
  – chicken is assigned the value 'chicken'
  – egg is assigned the value 'egg'
  – etc.

• This is equivalent to writing several assignment statements
  – chicken = 'chicken'
  – egg = 'egg'
  – one = 1
  – two = 2
Parameters of Functions

• Input parameters to functions are local variables
  – `def print_pattern(char1, char2, len1=1, len2=2, repeat=3):
    for rep in range(repeat):
      print(char1*len1, char2*len2, sep='')
      if len2>1:
        if len1>len2:
          len1 = len1-1
          len2 = len2+1
        else:
          len1 = len1+5
      else:
        len1 = len1+1
        len2 = len2+1
    – `print_pattern('*','+',len1=5,len2=4,repeat=10)

• Normal Parameters are required
• Keyword Parameters include defaults
• Parameters, like other variables can change by means of assignment statements
Return Multiple Values

• A function can return multiple values
• def div_w_remainder(dividend, divisor):
  whole = dividend // divisor
  remainder = dividend % divisor
  return (whole, remainder)
• cookies_each, xtra_cookies = div_w_remainder(50, 20)
A Few modules

- Math module
  - import math
    - math.pi, math.e
    - math.floor, math.ceil, math.log, ...

- Random module
  - import random
    - random.random, random.randint, random.seed()
    - Note: in CS random always really means pseudorandom

- OS module
  - Import os
    - os.sep, os.linesep
    - os.chdir, os.getcwd()
Filenames are identifiers

- Files used in python include: program, input and output files
- This lecture only concerns program files (modules and scripts)
  - These should have filetype .py
- When creating program files, it is advisable to follow the same principles as with variables and function names:
  - Use letters, numbers and underscore
  - Begin with a letter
  - Pick filenames that tell you something about the file contents
  - These rules can prevent bugs when loading files with “import”
Finding Files on Your Computer

• Lets find scripts in the **turtledemo** directory on my computers
  – Apple: /Library/Frameworks/Python framework/Versions/3.4/lib/python3.4/turtledemo
  – Windows: C:\Python34\Lib\turtledemo
  – May be different on your computer – it depends on installation, whether you moved the files, etc.

• Searching for turtledemo (or any python file)
  – For Apple to find it, you must set “kind” in the search window to include “systems” files
    • Use command F to set this – indicate that “system files are included”
  – For Windows, you must search from C:
    • This worked on my Windows computer, if you have difficulty, you may need to change settings to search for more types of files (and search C:, not a subdirectory)

• Next 2 slides: A quick introduction to file systems on your computer
Computer Files Form a Directed Graph

/  
|  |
|---|---|
| Applications | Library | Home |
| | | | System |
| | | | var |
| | | | |
| | | | |
| | | | |

 frameworks

Application Support

Quicktime

Python Framework

.

.

turtledemo

bytedesign.py
colormixer.py

............
yinyang.py
The Structure of File Systems

- Special Symbol for root of graph and separator
  - Unix-compatible (linux, Apple, …) = /
  - Windows (DOS) only = \
- The root corresponds to a either a disk drive or all disk drives
- For Windows, C: is usually the “main” disk drive
- The terminal nodes (nodes with no children) of the graph are regular files
- The internal nodes (nodes with children) of the graph are “directories” or “folders”, i.e., they refer to sets of files
- It is possible to have files or directories “shared” by multiple parents
  - These are handled via “file linking” or “short cuts”
- In many operating systems, certain classes of files are “hidden” from the users, e.g., system files, files that contain settings for programs, possibly all programming files (e.g., python files)
  - This reflects a philosophy that users should be protected from understanding the details of what is going on
  - Computer science professors don't share this philosophy
  - We recommend making all files visible, so you can understand how your computer works and so you can find program files
What is a Script?

• A script is a file that contains a single program
  – Functions defined in other files (modules) are loaded with the keyword `import`
• Scripts can be run in several ways:
  – Double-clicking if the `python3 launcher` is the default program for files of type `.py`
  – By using `open with` and choosing the `python3 launcher`
    • Recommended – python2 probably computer's default for .py files
  – Typing `python3 filename.py` on a command line (in a shell)
• These can also be loaded, edited and run in IDLE
• Example: `colormixer.py` is a script in the `turtledemo` directory
  – We can run it
  – We can open it with Idle, examine the code and run it
The Example colormixer

• When we run it
  – There are 3 sliders corresponding to red, green and blue
    • primary colors for light (magenta, yellow and cyan are primary colors for pigment)
  – Moving the sliders show the result of mixing these colors differently

• When we look at the code
  – This program imports parts of the turtle module
  – It creates some of its own object types (details omitted)
  – The real action is in the main function
The code in colormixer

- By convention, many programmers name their principle function that calls all others \textit{main}.
- The program first defines some variables and creates objects of two types:
  - \textit{screen} and \textit{colorturtle} (the programmer's modified version of a type called \textit{turtle})
  - And writes the message “Drag” to label the window
- The method \textit{shift}, part of the definition of \textit{colorturtle}, maps the y position of a turtle to a numerical value
- The function \textit{setbgcolor} sets the red, green and blue components for the background color of the screen at the end of each call to the function \textit{shift}.
  - These component values are based on the y positions of the red, green and blue turtles
What is the turtle module?

• A file called turtle.py
  
  – `import turtle` loads this in python
  
  – `help(turtle)` lists the various functions, variables and objects that are part of the turtle module

• History of Turtle Graphics
  
  – Originally implemented as part of the *LOGO* language
  
  – Implementations used for teaching young children about programming (e.g., Microworlds)
  
  – Turtle module = python implementation
The Basic Idea behind Turtle Graphics

- Do graphics by creating 'turtles'
- A **turtle** is an object on a Cartesian Plane
  - The **turtle** can look like a turtle, but need not
  - A *Cartesian Plane* is a grid as in High School Geometry
    - Vertical positions are represented as: $X = -1, X = 0, X = 1$, etc.
    - Horizontal positions are represented as: $Y = -1, Y = 0, Y = 1$, etc.
    - Points are $(X,Y)$ pairs where $X$ indicates how far to the left or right and $Y$ indicates how far up or down, e.g., $(1,1)$ is located diagonally up from the middle $(0,0)$
- Turtles have pens which write when the pen is *down*, but don't when the pen is *up*
- The ink color of the pen can be changed by setting their R,G,B values
Basic Components of Turtle Graphics in Python (and elsewhere)

- Object types: **Turtle** and **Screen**
  - In effect, this adds to our list of data types
    - integer, string, float, Turtle, Screen, …
  - These are initialized using functions with no arguments
    - `turtle.Turtle()` and `turtle.Screen()`
    - Use 'turtle.' prefix for commands from the turtle module
      - Or 'math.' for commands from the math module, etc.

- Simple commands that are connected to the Turtle object using dot notation
  - `fd(NUM)` – moves forward NUM units (i.e., moves forward from the turtles' point of view)
  - `left(DEG)` and `right(DEG)` – pivot left/right DEG degrees
  - `pd()` and `pu()` – put pen down (to draw) and up (to stop)
A Simple Turtle Graphics Example

• Loading module, creating a screen and a turtle

```python
import turtle
my_screen = turtle.Screen()
my_turtle = turtle.Turtle()
```

• Putting the pen down and drawing a square

```python
my_turtle.pd()
my_turtle.fd(100)
my_turtle.left(90)
my_turtle.fd(100)
my_turtle.left(90)
my_turtle.fd(100)
my_turtle.left(90)
my_turtle.fd(100)
```
Drawing a 2\textsuperscript{nd} Square Under the 1\textsuperscript{st} One

my_turtle.pu()
my_turtle.fd(100)
my_turtle.pd()
my_turtle.fd(100)
my_turtle.left(90)
my_turtle.fd(100)
my_turtle.left(90)
my_turtle.fd(100)
my_turtle.left(90)
my_turtle.fd(100)
Modules, aka, Library Files?

- Modules are files of functions and variables
  - Designed to be incorporated in other programs
  - Typically on a single theme (math, graphics, astronomy, ...)
  - Some modules are built in, i.e., installed with Python
  - You can download or write others yourself

- To load a module
  - 'import module_name'
    - You can use functions, global variables and objects
      - Use dot notation, e.g., module_name.function()
  - 'from module import functionX' (or objectX)
    - Use functionX without dot notation
    - Overwrite function and global variable definitions if they have the same name
  - 'from module import *' – same as above, except import everything
Modules

• Example (the math module)
  
  import math
  help(math)
  math.ceil(5.1)
  help(math.ceil)

• The 'help' function
  – Lists variables, functions, methods, etc. for a module
  – Also gives function definitions

• Use 'dot' notation for module variables/functions

• Alternatively: from module_name import *
  – Let's you drop the dot notation
  – Can cause problems (name conflicts)
four-squares.py Script

• Uses 2 modules: *turtle* and *time*

• Encapsulates square drawing as a single function which we call 4 times

• The square drawing function puts down the pen; moves forward and turns left three times each; and then puts down the pen

• The main function draws four squares, (redundantly) puts down the pen in between squares and sleeps for 15 seconds at the end
  – Note that the redundancy insures that the function works properly in all environments
four-squares.py Script 2

- The comments suggest ways to modify the program
- Turtles come in several different shapes
  - (turtle.getshapes() will list them)
  - 'turtle' is in fact one of the possible shapes
  - This is being called with a keyword argument shape='turtle'
    - Args identified by name, rather than order
- colormode(255) allows colors to be set in combinations of Green, Yellow and Blue on a scale from 0 (no color) to 255 (saturated)
- The package is very detailed. It has its own manual: http://docs.python.org/py3k/library/turtle.html
Is there a way to improve the code?

• Do you notice any redundancy in the `draw_turtle_square` function?
  – Is there any way that a loop could be used to simplify the code?

• Is there any way we could generalize this function so that we could use one function for drawing, not just squares, but other shapes as well?
One Way to Describe a Checkerboard

- A Checkerboard is an 8 X 8 square with alternating colors, e.g., red and black.
- A Checkerboard can be broken down into 4 bars, each a 2 X 8 bar of alternating colors.
- A 2 X 8 bar of alternating colors can be broken down into 4 composite squares, each consisting of 2 X 2 small squares.
A Pictoral Description

$x_4 =$

$x_4 =$

$x_4 =$
One Way A Turtle Can Draw a Checkerboard?

• The turtle can draw one square and it could fill in with a color of our choice
• The turtle can make four such squares next to each other, forming a composite square.
• It can make four composite squares next to each other, to form a bar.
• It can make four such bars, one under the other to form a checkerboard.
for_loop_checkerboard.py 1

- Basic setup
  - import turtle
  - my_screen = turtle.Screen()
  - my_screen.setup(0.5, 0.75, 0, 0)
    - width, height, startx, starty
  - my_turtle = turtle.Turtle(shape='turtle')

- draw_colored_turtle_square
- draw_4_black_and_red
- draw_4_black_and_red_4_times
- make_checkerboard
for_loop_checkerboard.py 2

• Setup and then do something 4 times
  – Building block
  – Move in between blocks

• draw_colored_turtle_square
  – Setup: set colors and begin to fill
  – Repeated Steps:
    • put the pen down, move forward, turn left
  – Pick pen up and fill in color

• draw_4_black_and_red
  – Setup: initialize fill color and pen color
  – Repeated Steps: change fill color, draw_colored_turtle_square, turn right, move forward
for_loop_checkerboard.py  3

• draw_4_black_and_red_4_times
  – repeated steps:
    • draw_4_black_and_red
    • move forward

• make_checkerboard
  – Setup: set turtle speed
  – Repeated Steps:
    • draw_4_black_and_red_4_times
    • Turn 180 degrees, move forward, turn 270 degrees,
      move forward, turn 270 degrees
Summary

• Identifiers in Python include:
  – variables
    • local variable names apply inside of functions
    • global variable names apply whenever they are not clobbered by a local variable name
  – functions – encapsulate sets of commands
  – program files
    • Scripts – special purpose
    • Modules (aka library files) – reusable code

• Intro to Graphics:
  – typically use X,Y coordinates for points on a plane
  – use some sort of RGB encoding for color
Homework

- [http://cs.nyu.edu/courses/fall17/CSCI-UA.0002-007/hw5.html](http://cs.nyu.edu/courses/fall17/CSCI-UA.0002-007/hw5.html)