COMS 3101-3 Programming Languages – Python: Lecture 1

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Agenda

- Course description
- Introduction to Python
  - Language aspects and usage cases
- Getting started
  - How to run Python
  - Basic data types, Control flows
- Advanced data types
  - List, tuples

COURSE DESCRIPTION

Instructor

- Kangkook Jee
  - 6th year ph.d student doing security research
- Python experience
  - 4 ~ 5 years
  - Other favorite languages
    - C, C++, bash
    - Little experience with Java
- Projects done with python
  - Prototyped compiler optimizations (12 ~ 15k lines)
  - Enjoy scripting with python for everyday chores

Syllabus

Lecture 1 (today)	Python intro, set-up environments, basic data types, control flow, intro to advanced data types (list, tuples)	- HW1 out
Lecture 2 (Sep 12)	More advanced data types(dictionary, string), file I/O	- HW1 due - HW2 out
Lecture 3 (Sep 19)	Module and Packages, Exceptions, Object oriented programming, functional programming with lambda	- HW2 due
Lecture 4 (Sep 26)	Intro to standard libraries (os, sys), serialization with pickle	Proposal due HW3 out
Lecture 5 (Oct 3)	Network programming with python, multi-processing and multi-threading, debugging with pdb, python unit testing	- HW3 due - HW4 out
Lecture 6 (Oct 10)	Selected topics: DB programming, Web development(Django with python) , Python native call, Performance optimizations	- HW 4 due

* Special topics for lecture 6 are tentative

Logistics

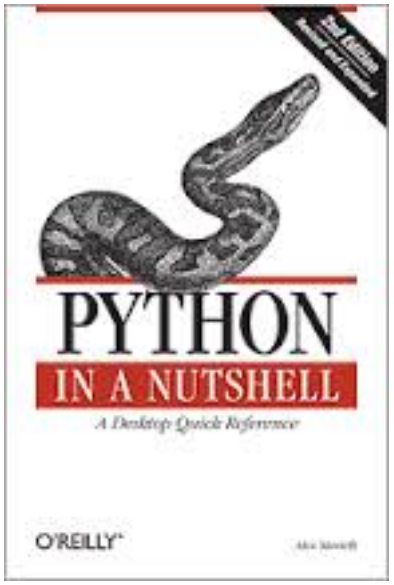
- Websites
  - Course home: http://www.cs.columbia.edu/~jikk/teaching/3101-3/
  - Piazza: / https://piazza.com/class/hl5f5yjwj1166r
- Teaching Assitant: TBA
- Office hours
  - Tuesday 11am ~ 2pm @ CSB 504
  - Friday 11am ~ 2pm $ CSB 504

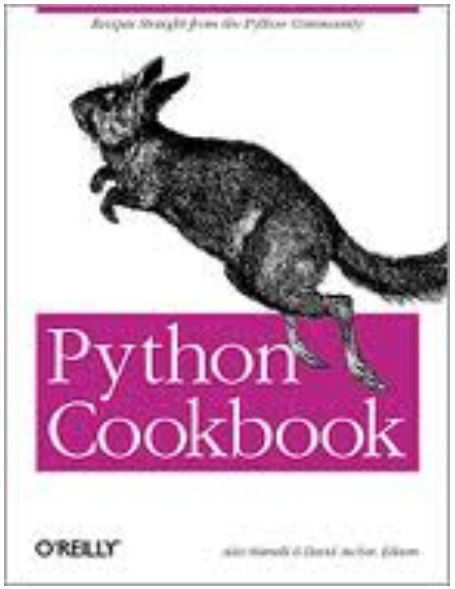
Grading / Deliverables

- Class participation: 10%
- Four homework: 40%
  - 4 homework assignments
  - Due following week before class
- Course Project
  - Project proposal: 10%
    - 1 ~ 2 pages summary/outline of course project
  - Course project deliverables: 40%
    - Leveraging python knowledge to create something interesting/ useful to you
- Late policy: two grace days, after which accepted at: -10% per day

Textbooks

- No required textbook for the course
- But, some reference readings





- CLIO also has some materials available online.

Online resources

- Official Python documentation.
  - http://docs.python.org
- Official beginners guide.
  - https://wiki.python.org/moin/BeginnersGuide/Programmers
- PEP documentation.
  - http://www.peps.io
- Online Python Cookbook.
  - http://code.activestate.com/recipes/langs/python
- Tutorials
  - Official Python tutorial: http://docs.python.org/tutorial/
  - Dive into Python: http://diveintopython3.ep.io/
- More from course website.

Python Language Aspects

- Easy to learn and use
  - Clear, readable syntax
  - Large collection of standard libraries
  - Automatic memory management with *garbage collection*
- Dynamic programming language
  - Interpreted language
  - Dynamic typing
  - Introspection
- Multiple programming paradigms
  - Mainly imperative but supports functional
  - Well supported OOP
- Extensive 3rd party modules
- Portable language
  - Different interpreters for many platforms

Scripting Language vs. Compiled Language

Scripting Language

- Executed from interpreter / VM
- Performance slowdown
- Type checking at runtime
- Limited functionalities
- Easy/Fast to write/debug
- Ex) shell (bash, csh), PHP, PERL

Compiled Language

- Executed as a native binary
- Efficient execution
- Type checking at compile time
- Advanced programming features
- Hard to debug
- Ex) C, C++, Fortan, Cobol

Python as a Scripting Language

- Shell tools
  - Launched from a console command
  - Usually, handles text inputs
- Control languages
  - Large applications exports Python API as a control front-end (IDA pro, Websphere, Sublime text)
- Development aids
  - Testing framework can be written with Python

More Use Cases

- Web development
  - With Python Djang framework
  - Yelp, YouTube, Reddit …
- Scientific / numeric computing
  - Machine learning, NLP, bioinformatics
- Complex applications with large code base
  - Dropbox, BitTorrent , Eve Online (MMORPG)

Python Deficits

- Limited support multi-threading
  - Multi-processing well supported
- Convenience comes with cost
  - Overall 10x/ 5x slowdown over programs written in C/Java
  - But, it saves your development time!
    - 3 ~ 5x less time than Java, 5 ~ 10x then C/C++
  - CPU time is cheaper than human time!

BOOTSTRAPPING PYTHON

Python Versions

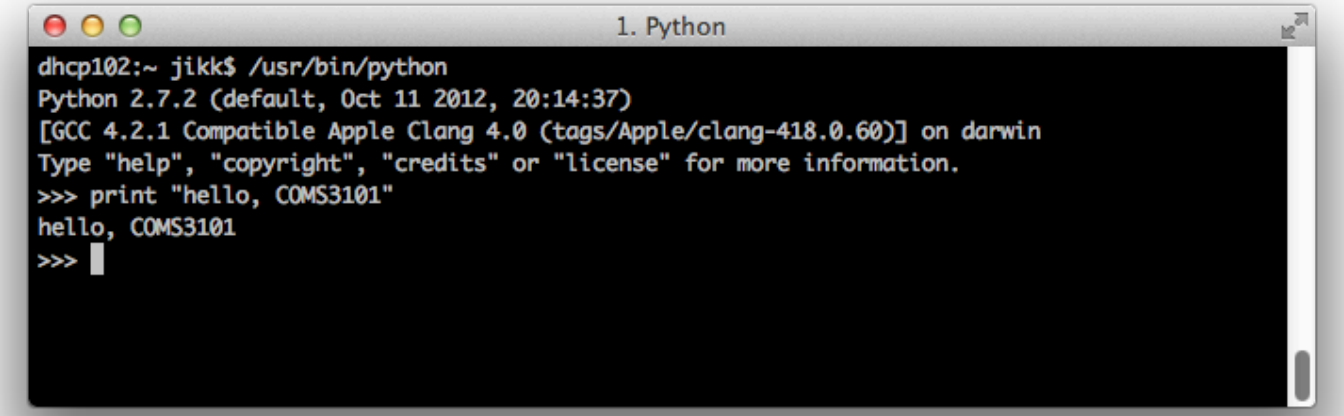
- Two branches
  - Python 2
    - Current and ultimate release: 2.7
  - Python 3
    - Current latest release: 3.3.2
    - Cannot execute 2.x code
- Many important packages not (yet) ported to Python 3
- 2to3 tool exists, but does not always work
- This course: subset of Python 2.7, largely compatible with Python 3

Running Python

- Python on Linux, Mac OS X
  - Located at /usr/bin/python
  - Default version 2.7.x
- Python on Windows
  - Download an install package(2.7.x) from http://www.python.org/download
  - Execute Python.exe (C:\Python2.7/python.exe) or IDLE
- To exit: Ctrl-D (Ctrl-Z on Windows)

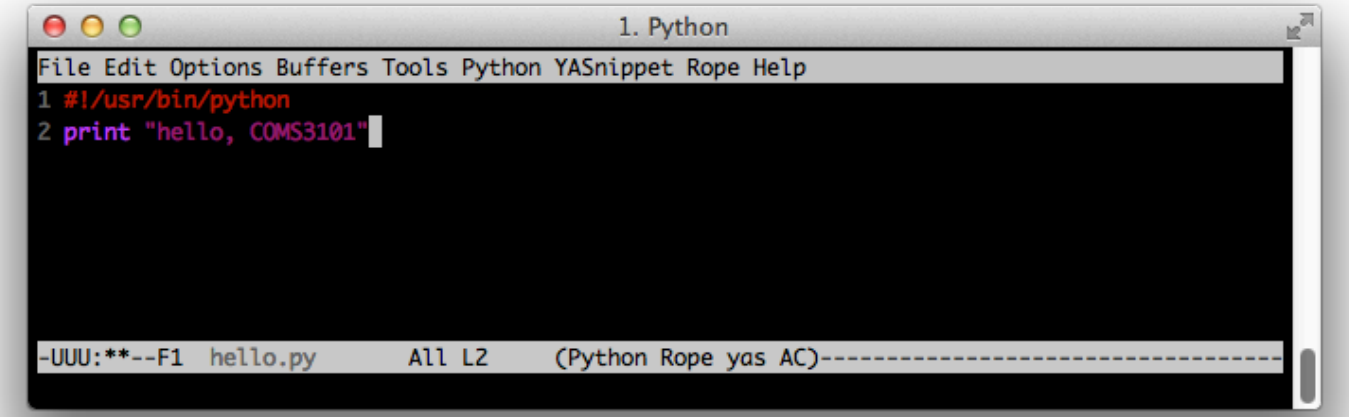
Two Execution Modes

Interpreter mode



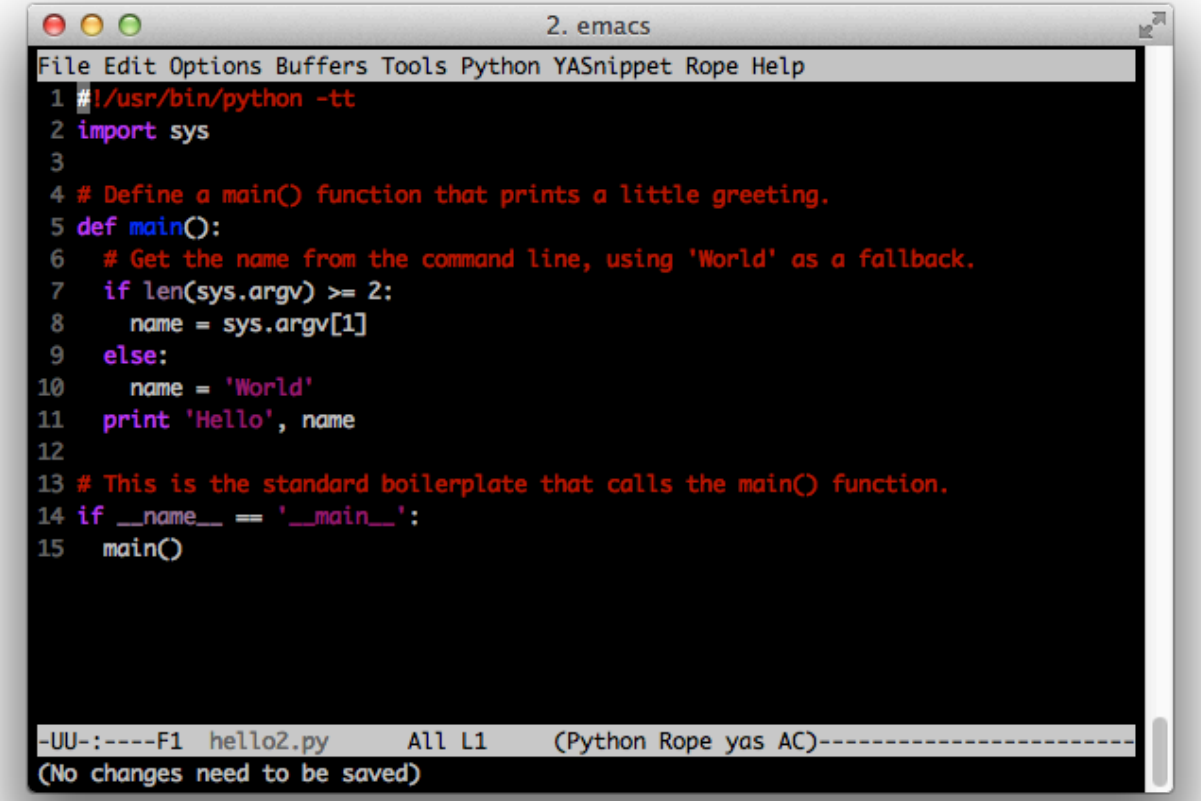
- Improved shells: IDLE, bpython, ipython

Batch mode



$chmod a+x hello.py ; ./hello.py

Extended Example: hello2.py



- Import 'sys' module (line 2) to process command line arguments
- 'main 'Function defined (line 5 ~ 11)
- Taking input from command line (line 7, 8)
- "__name__" variable to tell the interpreter that the script is executed from command line

Get it from http://www.cs.columbia.edu/~jikk/hello2.py

$chmod a+x hello2.py ; ./hello2.py COMS3103

Python Execution Model

- Python execution
  - Python code file names end in .py
  - Python interpreter executes the file from top to bottom
- Bytecode translation
  - Python first converts your sources (.py) to bytecode (.pyc)
    - Bytecode is a low-level platform independent from of your code
    - It is platform independent form and executes more quickly
  - Bytecode is executed from PVM (Python Virtual Machine)
  - If source has changed, the .py file is recompiled

Development Environments

- Text Based
  - Emacs, Vim, Sublime text
- GUI based
  - Eclipse with PyDev, Netbeans, IDLE

- Any of above are adequate for the class
  - Supports syntax highlighting, auto-completion
  - Some support: integrated debugging and code refactoring
  - Personal favorite: emacs + Ropemacs combo

LANGUAGE FUNDAMENTALS

Disclosure

- Slide Credit:
  - Daniel Bauer
  - Joshua B. Gordon

THANKS!

Elementary Python Syntax: Whitespaces Blocks

- Indentation level and line-breaks are syntactically relevant
  - Statements with same indentation belong to the same block
  - Single most hated Python feature
  - Actually useful: enforce readable code

Python

```
while x == 1:
....if y:
........f1()
....f2()
```

C / C++ / Java

```
while (x == 1) {
    if (y) {f1();}
    f2();
}
```

- Warning: Never mix tabstops and whitespaces!
  - Do not use tabs at all (outside of strings)
  - Set your editor/IDE to fill tabs with white spaces automatically
    - Recommendation: 4 space per indentation level

Elementary Python Syntax: Linebreaks

- Python program consist of a sequence of logical lines (statements)
  - The end of physical line marks the statement
  - Statement may contain one or more physical lines by
    - Joining phyical lines with "\" symbol
    - Open (, {, [have not yet been closed, the next line joined automatically
  - Indentation level only counts after finished lines

```
#a statement spanning multiple lines
cheeselist = ['cheddar', 'camembert', 'swiss',
              'mozzarella']

#use \ to join lines
cheeselist = ['cheddar', 'camembert', 'swiss', \
              'mozzarella']
```

Elementary Python Syntax: Comments

- Single-line comments

```
#Print some informative messages.
print('hello world!')  # Hi there!
```

- Multi-line comments
  - Tripple " or ' surrounding lines
  - Used as *Docstrings* at the beginning of function, method, class definitions and modules
    - For documentation with pydoc (later)

```
def pythagoras(leg_a, leg_b):
    """Compute the length of the hypotenuse oppiste
    of the right angle between leg_a and leg_b."""

    return math.sqrt(leg_a**2, leg_b**2)
```

Coding Style

- Refer to style guides
  - PEP8: Offical(?) style guide
  - Google's python style guide
  - Code Like a Pythonista: Idiomatic Python
- Tools that help you with styles
  - pyflakes, pylint
- General rules
  - Limit lines to 79 characters
  - Classnames should be written in CamelCase
  - Everything else (variables, function, modules ..) should be `lower_case_with_underscore`

DATA TYPES AND VARIABLES

Variables and Assignments

- Evaluate expression on the right hand side of = and assign to it the varable (name) on the left hand side
- No declaration for variable is needed

```
>>> answer
42
>>> answer += 5  # Shortcut += -= *= /=
>>> answer
47
```

- Multiple assignment in one line possible

```
>>> a, b = 2, 3
>>> a, b = b, a  # Swap variables
>>> print a, b
3 2
```

Python Data Types: Built-In Types

- Basic types
  - NoneType: None
  - Bool: True, False
    - Subtype of int
  - Numerics: int (12), long (23212L), float (34.2)
- Container types
  - str: 'Hello'
  - list: [1, 2, 3]
  - tuple: (1, 2, 3)
  - dict: {'A': 1, 'B':2}
  - set: {1, 2, 2, 3} → set([1, 2, 3])
- function, class, instance …
- In Python *everything* is an object and every object has a type
  - e.g., Type object as *Type* type

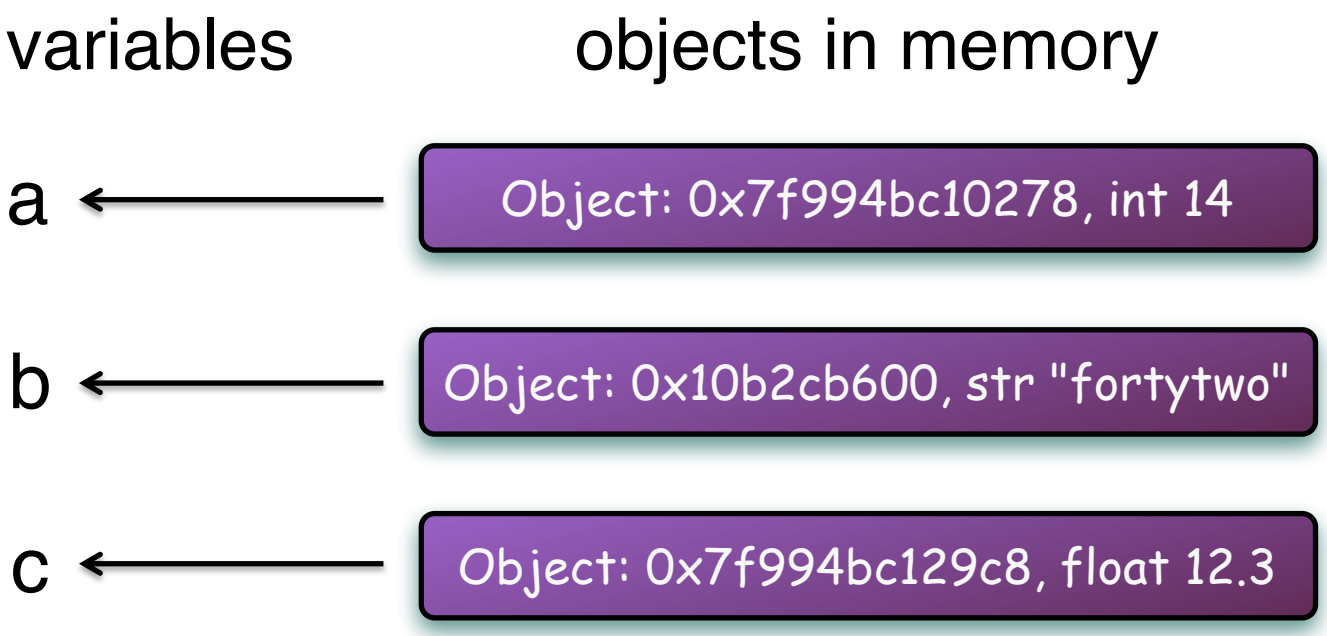
Dynamic Typing

- Type checking performed at runtime
  - To Make sure variables/objects have the correct type for an operation
- No declaration needed
- Can get type of a variable with ‘type(variable)’

```
>>> answer = 6 * 7
>>> answer += 3
>>> answer = 'fortytwo'
>>> answer += 3
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: cannot concatenate 'str' and 'int' objects
>>> type(answer)
<type 'str'>
```

Variable are Names

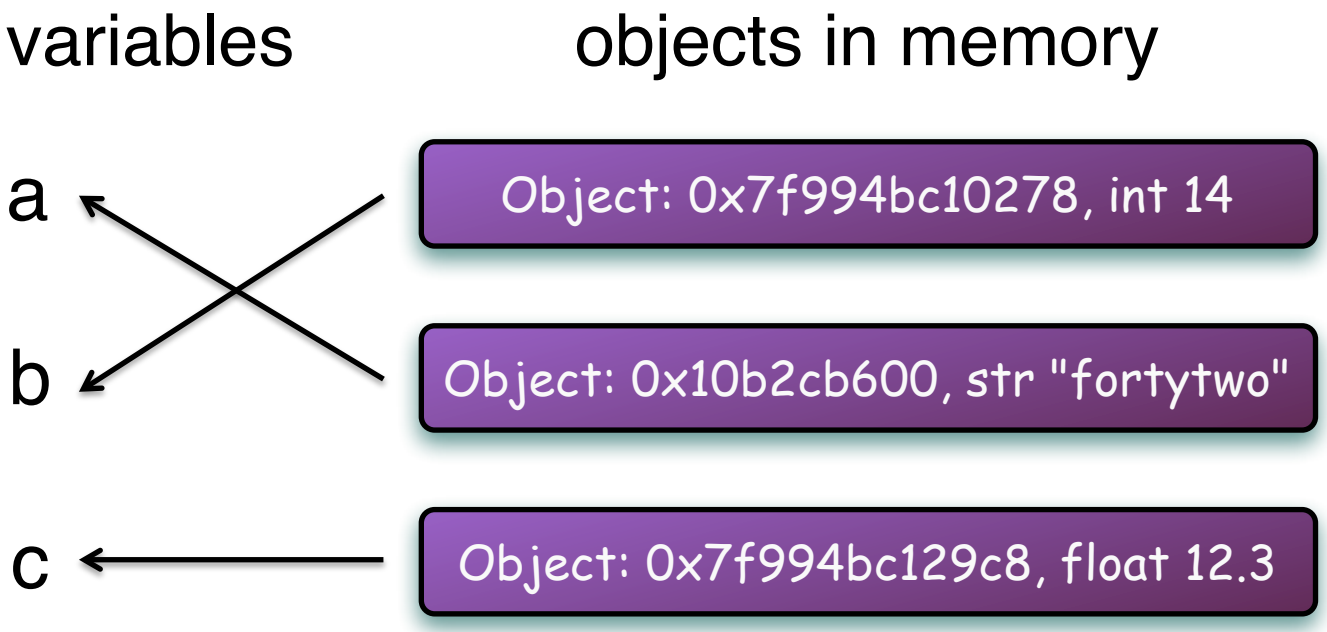
Objects never changes their types, but variables can be names for different objects during runtime




```
>>> a, b, c = 14, "fortytwo", 12.3
```

Variable are Names

Objects never changes their types, but variables can be names for different objects during runtime




```
>>> a, b, c = 14, "fortytwo", 12.3
>>> a, b = b, a
```

Variable are Names

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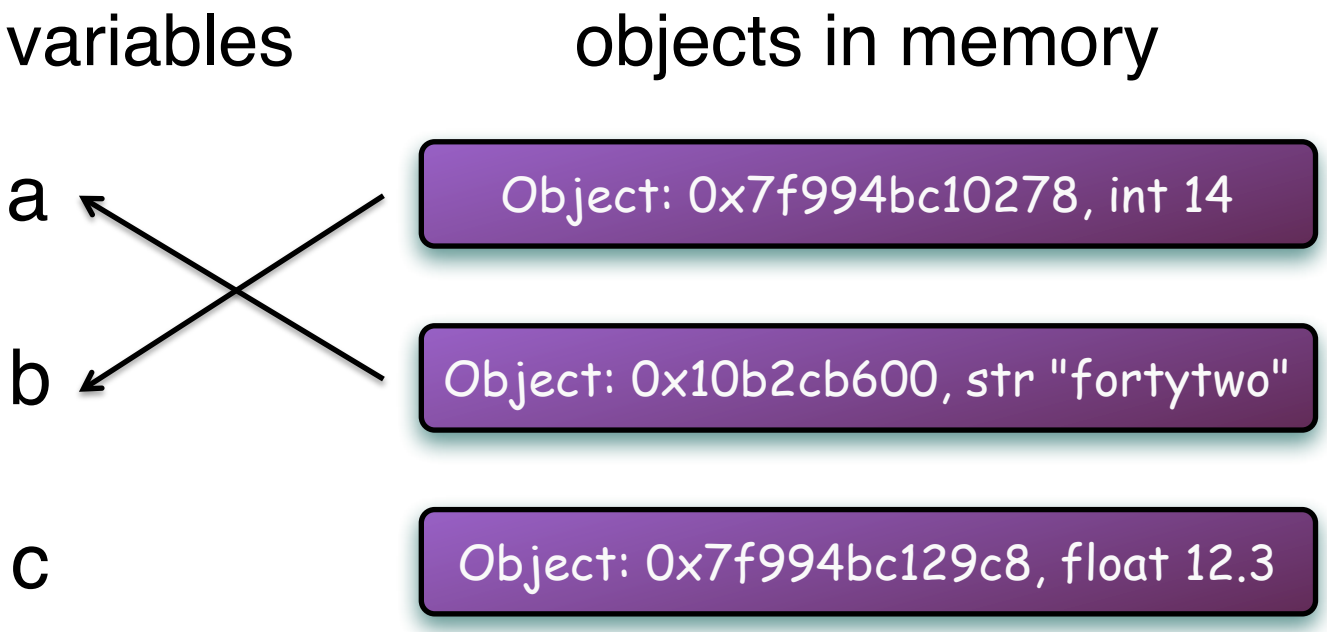
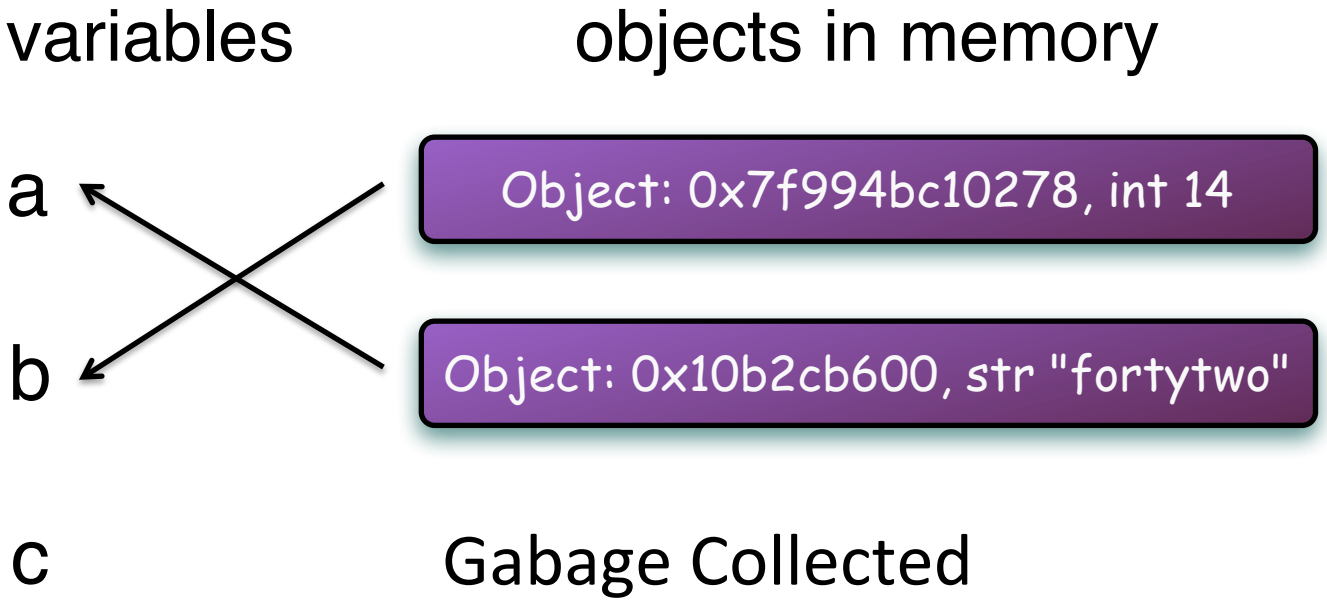



```
>>> a, b, c = 14, "fortytwo", 12.3
>>> a, b = b, a
>>> c = None
```

Variable are Names

Objects never changes their types, but variables can be names for different objects during runtime




```
>>> a, b, c = 14, "fortytwo", 12.3
>>> a, b = b, a
>>> c = None
```

Object Mutability

- Python has mutable and immutable objects
  - Mutable objects (lists, dictionaries, sets) can be modified

```
>>> cats = [‘felix’, ‘dinah’, ‘lucky’]  # list data type
>>> id(cats)  # get object ID
4482450136
>>> cats.append(‘garfield’)  # add an element to the list
>>> cats
['felix', 'dinah', 'lucky', 'garfield']
>>> id(cats)  # get object ID
4482450136
```

  - Immutable objects (boolean, numbers, string, tuple) cannot be changed once they are initialized

```
>>> >>> felix = 'Felix'
>>> id(felix)
4482446800
>>> felix += 'the cat'
>>> id(felix)
4482440080
```

Python uses Strong Typing

- Operations may expect operands of certain types
- Interpreter throws an exception if type is invalid

```
>>> answer = 6 * 7
>>> answer += 3
>>> answer = 'fortytwo'
>>> answer += 3
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: cannot concatenate 'str' and 'int' objects
>>> type(answer)
<type 'str'>
```

Evaluating Equality

- == for value equality
- Works for all objects (objects with different type will return `False`)

```
>>> a = [1, 2, 3]
>>> b = [1, 2, 3]
>>> a == b
True
```

```
>>> c = 1
>>> d = '1'
>>> c == d
False
```

- 'is' for object equality
  - if two variables are names for the same object

```
>>> a is b
False
>>> id(a) == id(b)
False
```

Comparison Operators

- All comparison operators work for all objects
  - Value equality: ==, !=, <, <=, >, >=
  - Object equality: is, is not
- Comparison operators retun an object of type bool (True, False)
- Result of comparison can be combined with boolean operators
  - not x
  - x and y
  - x or y

```
>>> a, b = 5, 7
>>> a >= 6
False
>>> False or (a == 5)
True
>>> a > 0 and not False
True
```

Numeric Operators

- Binary :`x + y, x - y, x * y, x / y, x ** y (power), x % y (modulo)`
- Unary: `+x, -y, not x`
- Built-in functions
  - Convert to int / long / float: `int(x), long(x), float(x)`
  - Absolute value: `abs(x)`

```
>>> 20 / 3
6
>> 20 % 3
2
>>> float(20) / 3  # type conversion
6.666666666666667
>>> float("1213")  # can convert(parse) string
1213.0
```

CONTROL FLOWS

Conditionals: `if` Statment

- If one `if` or `elif` matches the *indented* block statement is executed
  - Remaining conditions are ignored
- `elif` and `else` are optional
- If no `if` or `elif` is matches, the indented block statement for `else` is executed
- There no `switch` statement in Python

```
if conditionExp1:
    statement1
    ...
elif conditionExp2:
    statement2
    ...
elif conditionExp3:
    statement3
    ...
else:
    statement4
    ...
```

Expressions in `if` and `elif` Conditions

- Can use any expression as a condition
  - Will be casted to boolean type
  - 0 (number), None, empty containers(string, list, tuple, dict, set) →False
  - Any object → True
- Use boolean operators(and, or) to combine multiple objects

Loops: `while` Statements

- Execute the indented statements repeatedly while `conditionExp` evaluates `True`
- `else` branch is visited loop terminates as `conditionExp` being False

```
while conditionExp:
    statement1
    ...
else:
    statement2
    ...
```

```
count = 0
while x > 0:
    x=x/2
    count += 1
else:
    print('approximate log2:')
    print(count)
```

continue and break

'continue' interrupts the current iteration of the loop and continuews at the next iteration.

```
>>> x = 5
>>> while x:
...     x -= 1
...     if not x % 2:
...             continue
...     print (x)
...
3
1
```

'break' interrupts the complete loop and escape to statements below the loop

```
>>> x = 10
>>> while True:
...     print (x)
...     x -= 1
...     if x == 7:
...             break
...
10
9
8
```

Loops: for Statements

- Python's for statement iterates over the items of any `sequence` (a list or a string) , in order that appears from the sequence
- `else` branch is visited whe loop exhaust all entries from `sequence`

```
for in sequence:
    statement1
    ...
else:
    statement2
    ...
```

```
>>> sentence=""
>>> for word in ["hello! ", "COMS3101", "-3"]:
...     sentence += word
... else:
...     print (sentence)
...
hello! COMS3101-3
```

ADVANCED TYPES

Sequence Types

- Container objects that contain ordered sequences of elements:
  - String(a sequence of encoded characters)
    ```
    x = 'Read me! I'm string!'
    ```
  - list (mutable sequence of objects)
    ```
    x = [4, 8, 9, 10]
    ```
  - tuple(mutable sequence of objects)
    ```
    x = (10, 12, "hello")
    ```
- All sequence types supports some common operations
  - Get length, concatenation and repetition
  - Test for membership
  - Access for specific elements and 'slicing'
  - Iterate through elements

Length, Concatenation and Repetition

- `len(x)` returns the length of sequence x

```
>>> x = []  # empty list
>>> len(x)
0
>>> len("number of characters in string")
30
```

- `x + y` concatenates sequence of x and y

```
>>> 'hello' + 'COMS3101'
'helloCOMS3101'
```

- `x * n` or `n * x` repeats sequence x for n times

```
>>> 3 * ('rep',)  # single entry tuple
('rep', 'rep', 'rep')
```

Testing for Sequence Membership

- `x in y` returns `True` if collection y contains object x, `False` otherwise
  - Based on value equality (==)
  - x not in y is equivalent to not x in y

```
>>> 'coffee' in ['tea', 'coffee', 'juice']
True
```

- For string only:
  - `in` also tests if x is a substring of y

```
>>> 'tuna' in 'fortunate'
True
```

Finding Index and Counting Element

- `x.index(y)` returns the sequence index of the first occurrence of y

```
>>> (23, 5, 8, 5).index(5)
1
```

- `x.count(y)` returns the number of times y occurs in x

```
>>> 'banana'.count('a')
3
>>> 'banana'.count('an')  # works for substring
2
```

Sequence Indexing

- x[i] indexes the element of sequence x (starting from 0)

```
>>> x = ((1, 2, 3), 'foo', 1.0)
>>> x[1]
'foo'
>>> x[0][2] # nested indexing
3
```

- reverse indexing starts at -1

```
>>> x = ((1, 2, 3), 'foo', 1.0)
>>> x[-1]
1.0
```

Sequence Slicing

- Slicing returns a copy of subsequence
- `x[i:j]` returns the subsequence from position `i` (inclusive) to position j (exclusive)
- `x[i:]` returns the subsequence from position `i` from to the end
- `x[:j]` returns the subsequence from the beginning to position `j` (exclusive)

```
>>> x = [0,1,2,3,4]
>>> x[1:]
[1,2,3,4]
>>> x[:-2]  # using reverse indexing in slice indices
[0 ,1 ,2]
>>> x[2:3]
[2]
```

Iterating Elements Through Sequence

- Sequence data types implements the iterator protocol
- For-loop can *iterate* any sequence types

```
>>> sentence=""
>>> for word in ["hello! ", "COMS3101", "-3"]:
...     sentence += word
... else:
...     print (sentence)
...
hello! COMS3101-3
```