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Python Tutorial

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Why Python?

- Python is a good, general purpose programming language, widely used, offering high programmer productivity
- Good candidate teaching language in CS0, maybe even CS1

Python Strengths

- High level of abstraction
- Expressive and powerful
- Simple syntax, easy to learn and use
- Small, portable, cross platform, free
- Support for many domains: database, text processing, scientific and numeric apps, graphics, GUIs, web apps, etc.

Python Weaknesses

- Less efficient than C++:
  - Python is a higher level language, with greater abstraction from the underlying hardware
  - Python is not fully compiled
  - However: high performance modules can be written in other languages (like C) as needed
- Dynamic typing:
  - Interpreter cannot automatically detect all type errors
  - However: dynamic typing makes it much easier to write general purpose routines

Python Philosophy

- "Small and simple is beautiful" philosophy
- Free, open source, cross platform
- Highly extensible and modular
- Multiparadigm PL, with support for procedural, object-oriented, and functional programming
- Encourages good programming practices
- Fun to learn and use (named after a well-known British comedy troop)

Python History

- Python 1.0 (Guido van Rossum, ~1990)
- Python 2.0 (2000) – still in wide use
- Python 3.0 (2009) – more consistent syntax
- Ongoing language development
- TIOBE language of the year in 2007, 2010, 2011 (greatest growth in popularity)
- One of top ten PL's by any metric

Applications

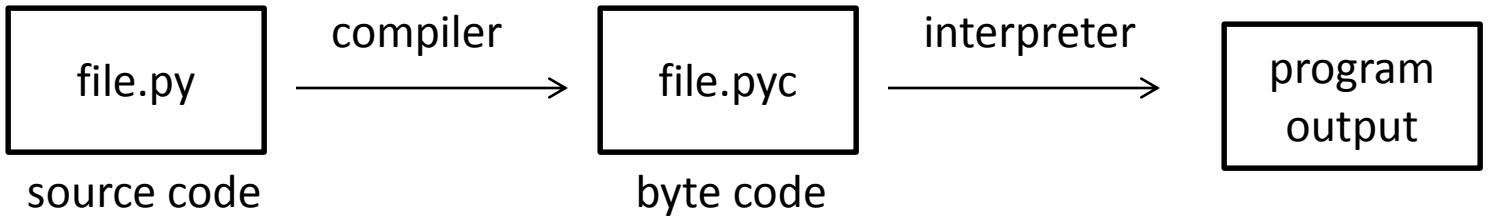
- Scripting language: install scripts, web applications, text processing, prototyping
- Embedded language (GIMP, Maya, ArcGIS, etc.)
- Library bindings (SQL, Qt, ROS, OpenCV, etc.)
- Used by Google, Yahoo, CERN, NASA, ILM, YouTube, BitTorrent, many more

Python Resources

- Website: www.python.org
- Extensive libraries
- Online documentation and tutorials
- Batteries included:
  - IDLE (IDE)
  - Tkinter (GUI)
  - Regular expressions
  - Unit testing
  - Threading and multiprocessing
  - Web programming
- Many third party packages (PyPi repository)

Usage

- Python interpreter: read-eval-print loop (REPL)
- Scripts and modules are partially compiled and partially interpreted:



- Scripts: **`python file.py`**
- Modules: **`import module`**

Python Implementations

- CPython –produces standard Python bytecode
- Jython – produces Java bytecode
- IronPython – targets the .NET platform, produces DLR bytecode (note also *Python Tools for Visual Studio*)

Python Program Execution

- Python is a (partially) interpreted language.
- Statements are translated and executed in sequence.
- No main() function, but easy to fake it. This pattern allows a program to be interpreted as either a script or a module:

```
if __name__ == '__main__':
    # "main" program stmts go here
```

Code Formatting

- *Indentation is required, not optional.* Statement blocks (function bodies, if-else, loops) *must* be indented to the same level.
- One statement per line recommended.
- Use backslash (\) to continue statement over multiple lines.
- Use semicolon (;) to separate multiple statements on one line.

Comments

- Inline comments use #

```
x = 10          # inline comment
```

- Multiline comments use triple quoted strings
- These also serve as docstrings for online help

```
'''This is a multiline
   (or docstring) comment'''
```

Data Types

- Simple types: int, float, complex, boolean
- Aggregate types: string, list, tuple, dict, set, range, file
- No arrays! (well, there is an array module…)
- Dynamic typing: data type is associated with value, not variable name
- Dynamic memory (de)allocation

Data Types

- Integers (**int**) are infinite precision
- **Floats** are IEEE double precision
- **Boolean** are True, False
- Strings (**str**) are immutable (create a new string instead), support both ASCII and Unicode
- Many string methods, also overloaded ops + (concatenation) and * (repetition)

Data Types: Lists

- **Lists** are a very general data type: `[ e1, e2, … ]`
- Subscript like arrays: `mylist[i]`
- Slices: `mylist[i:j]`
- May store heterogeneous values
- Superset of stacks, queues, deques
- Implement nonlinear structures (trees, graphs, multidimensional arrays) via nested sublists
- Many list methods, also overloaded op + (append)

Data Types

- **Tuples** are immutable lists: **(e1, e2, …)**
- **Sets** provide membership (*in* op), union, intersection, difference: **{ e1, e2, … }**
- Dictionaries (**dicts**), aka associative arrays or maps, are hash tables that store (key, value) pairs: **{ k1:v1, k2:v2, … }**

Data Types

- **Range** type provides a range of integer values
  - range(start, end, increment)
  - Often used for iteration
- **File** type
  - May open file for read/write/append access
  - Text vs. binary files, sequential vs. random access
  - *Pickle* module allows you to write (“dump”) data structure to a file, and read it back in (“load”)

Expressions

- Operators are similar to C++
- Similar precedence and associativity
- Float division: x / y
- Integer division: x // y
- Exponentiation: x ** y
- No increment (++) or decrement (--) ops

Modules

- Modules are libraries
- Usage: import modulename
  modulename.resourcename

```
import math
x = float(input("Enter a value: "))
y = math.pi * math.sqrt( x )
```

Online Help

- dir(object) – list of object attributes
- help(topic) – online help

```
help()              # go into online help utility

help(list)          # help on list type

import math
dir(math)     # list all math module attributes
help(math)    # help on all math functions
help(math.sqrt)   # only math sqrt function
```

Ten Statement Python

1. **Assignment**: var = expr
2. **Input**: var = input("prompt")
3. **Output**: print(expr1, expr2, …)
4. **File i/o**: open(), close(), read(), write()
5. **Function definition**: def sqr(x): return x*x

Ten Statement Python (cont.)

6. **Selection**: if stmt
7. **Repetition**: while loop
8. **Repetition**: for(each) loop
9. **Exception handling**: try, except
10. **Class definition**: class C(parent): methods

Of course there's more…

Assignment

- Variable name is a reference to an object
- Not declared or typed (although you may declare variables to be global)
- Cannot reference a variable until it has been bound to a value via assignment: var = expr
- When value changes, data type may change
- Tradeoff: flexibility vs. reliability (type checking) and efficiency

Assignment

- Simple:

```
var = expr
```

- Compound:

```
var += expr, var -= expr, etc.
```

- Extended:

```
var1, var2 = expr1, expr2
```

Console Input

- `var = input( "prompt" )`
- Prompt string is optional
- Returns input as string; use typecast to convert to desired data type:

```
x = int(input("Enter an integer: "))
```

Console Output

- **`print( expr1, expr2, … )`**
- Expressions must be strings, but most types are automatically converted to printable representations
- Options:
  - sep=‘separator string’ (defaults to space)
  - end=‘end string’ (defaults to newline)
  - file=ofp (defaults to stdout)
- Two methods for producing formatted output

Formatted Output

- **format operator (%)**
  - `"format string" % (expr1, expr2, …)`
  - Format string contains format specifiers similar to C printf: %d, %f, etc.
- **string type format method**
  - `"format string".format(expr1, expr2, …)`
  - Format string uses different format specifiers, but functionality is equivalent

Formatted Output

- Format operator (%)

```
for i in range( 10, 50, 10 ):
  print('%3d %7.2f' % (i, sqrt(i)))
```

- String format method

```
for i in range( 10, 50, 10 ):
  print('{0:3d} {1:7.2f}'.format(i, sqrt(i)))
```

- Output (both methods)

```
 10    3.16
 20    4.47
 30    5.48
 40    6.32
```

Selection: if statement

- Similar to C++ else-if stmt:

```
if test:
    stmt block
[ elif test:
    stmt block ]*
[ else:
    stmt block ]
```

- Note: [] means optional, []* means 0 or more
- No switch/case statement

Selection: if statement

```
if x < 0:
    print( x, "is negative" )
elif x > 0:
    print( x, "is positive" )
else:
    print( x, "is zero" )
```

Iteration: while loop

- Similar to C++ while loop

```
while test:
    stmt block
[ else:
    stmt block ]
```

- *else* block executes on normal termination (not when *break* out of loop)

Iteration: while loop

```
x = 0
while x <= 0:
    x = int( input( "Enter a "
                    "positive integer:")
else:
    print( "You entered", x )
```

Iteration: for (each) loop

- Iterates through almost any type of collection

```
for loopvar in iterable:
    stmt block
[ else:
    stmt block ]
```

- *else* block executes on normal termination (not when *break* out of loop)

Iteration: for (each) loop

- Typical C++ code:

```
for ( int i = 0; i < n; i++ )
    sum += numlst[i];
```

- Python equivalent:

```
for i in numlst:
    sum += i
```

Iteration: for (each) loop

```
for i in range(0,100,10):
    print( i, end = ' ' )
else:
    print( "\nThat's all, folks!" )
```

Output

```
0 10 20 30 40 50 60 70 80 90
That's all, folks!
```

Iteration: for (each) loop

```
for i in "HELLO":
    print( i )
```

Output

```
H
E
L
L
O
```

Iteration: for (each) loop

```
for i in [ 100, 3.14159, "hi" ]:
    print( i )
```

Output

```
100
3.14159
hi
```

File I/O: Input

- Open file for reading:

```
ifp = open( "input file" )
```

- Read data from file:

  `ifp.read()` - entire file contents

  `ifp.readline()` - one line of file

- Or iterate line-by-line with for loop:

```
for line in ifp: print( line )
```

- Close file:

```
ifp.close()
```

File I/O: Output

- Open file for writing:

```
ofp = open( "output file", "w" )
```

- Write expression to file:

```
ofp.write( expr )
print( expr, file = ofp )
```

- Close file:

```
ofp.close()
```

- **help(open)** – lists various file r/w modes

File I/O

- Copy a text file

```
fin = open( "input.txt" )
fout = open( "output.txt", "w" )
fin.read( buffer )
fout.write( buffer )
fin.close()
fout.close()
```

- Line by line copy

```
for line in fin: fout.write( line )
```

Function Definitions

- Function parameters and return values are dynamically typed, which makes it trivial to write generic functions

```
def funcname( param1, param2, ... ):
    '''docstring''' # produces online help
    stmt1
    stmt2
    . . .
    return value
```

Function Definitions

```
def sumlist( numlst ):
  '''sum a list of any numeric type'''
  sum = 0
  for i in numlst:
    sum += i
  return sum
```

Function Definitions

```
def fib( n ):
    """nth Fibonacci number (iterative)"""
    a, b = 0, 1      # initial values
    for i in range( n ):
        a, b = b, a + b
    return a
```

Function Definitions

```
def fib( n ):
    """nth Fibonacci number (recursive)"""
    if n < 2:
        return n;
    else:
        return fib( n - 1 ) + fib( n - 2 )
```

Functions

- parameter passing is by value (more accurately, by assignment)
- optional arguments (with default values)
- variable number of arguments
- keyword arguments
- multiple return values (put in list)

Functions

- Functions are first-class objects in Python:
  - pass as function parameters
  - return as function value
  - assign to symbols
- Scope: define function prior to call
- Prototyping: use stub

```
def fname( params ): pass
def fname( params ): ...
```

Handling Exceptions

- Exceptions are runtime errors, such as divide by zero
- Python exception handling is similar to C++
- “try” block encloses code in which exception might occur
- Exception handlers are placed in “except” blocks
- Optional “else” and “finally” blocks

Handling Exceptions

```
def divide( x, y ):
    try:
        result = x / y
    except ZeroDivisionError:
        print("division by zero")
    except:      # catches all exceptions
        print("some other error")
    else:        # executed if no exception
        print("result is", result)
    finally:     # always executed
        print("that's all folks!")
```

Python Classes

- Python supports multiple inheritance, with an object class at the root of the hierarchy
- Class definitions are similar to C++ and Java, but only methods are declared (dynamic typing!)
- First argument (current object) is explicitly listed, usually called “self”
- Constructor is called __init__
- Overloaded operators are called __eq__, __add__, etc.

Classes

```
class Cmplx( object ):
  def __init__( self, r = 0, i = 0 ):
    self.r = r; self.i = i
  def __str__( self ):
    return "%g+%gi" % ( self.r, self.i )
  def __eq__( self, z ):
    return self.r == z.r and self.i == z.i
  def conj( self ):
    return Cmplx( self.r, -self.i )

z1 = Cmplx( 3, 4 ); z2 = Cmplx( -2.1, 6.3 )
if ( z1 == z2 ): print( "z1  =", z1 )
else:            print( "z1* =", z1.conj() )
```

Advanced Stuff

- List comprehensions
  - compact form of iteration over lists and other sequences
- Regular expression module
  - powerful string matching capabilities
  - match set of symbols, repeated occurrences, etc.

List Comprehensions

- Interesting, concise form of iteration
- [expr for var in sequence]

```
a = [ x * x for x in range(1,9) ]
```

vs.

```
b = []
for x in range(1,9):
    b += x * x
```

- Both forms produce `[1,4,9,16,25,36,49,64]`

List Comprehensions

- [expr for var in sequence if test]

```
a=[ x * x for x in range(1,9) if x % 2 == 0 ]
```

vs.

```
b = []
for x in range(1,9):
    if x % 2 == 0:
        b += x * x
```

- Both forms produce `[4,16,36,64]`

Example: Word Concordance

- Parse text file into words, compute word frequencies, print words sorted first by frequency and then alphabetically
- Good application of hash tables
- 450 lines of C++ code (total)
- 30 lines of Python code (total), only 6 (six!) needed to construct concordance
- Performance penalty: Python runs 1.25-2.00X more slowly than C++ but…
- Processing the complete works of Shakespeare (5M text file) only takes 1 second in Python

Python Word Concordance

```
# 1) read the file into one long string
words = open( filename ).read()
# 2) convert to lowercase, split into words
wrdlst = re.findall('[a-z]+', words.lower())
# 3) count occurrence of each word
d = dict()
for w in wrdlst: d[w] = d.get(w,0) + 1
# 4) invert the dictionary
wc = [ ( d[k],k ) for k in d ]
# 5) sort by word frequency
wc.sort()
```

Questions?

- Slides can be downloaded as PythonTutorial.pdf *
- Comments and corrections are welcome: john.weiss@sdsmt.edu

**** http://www.mcs.sdsmt.edu/csc461/Resources/Python/PythonTutorial.pdf***