Introduction to Computer Programming

COMS 127

Hebi Li

Outline

Team

- COMS 127: Introduction to Computer Programming
- Instructor: Prof. Forrest Bao

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- Hebi Li (me): random person, 1st week lecture

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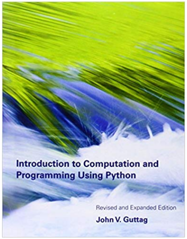
- Hebi Li (me): random person, 1st week lecture
- TAs: TBD

Syllabus

- Meating times: Monday, Wednesday, Friday 2:10-3:00 PM
- Location: Food Science 2432
- Textbook: Guttag, John V. *Introduction to computation and programming using Python*. Mit Press, 2013.



Plan for this week

Monday: Introduction to programming

- Intro to Programming
- Programming history & trends
- Introduction to python

Wednesday: Setup python enviroment

Bring your laptop!

- Editors
- IDEs
- Online interpreters: Jupyter notebooks

Friday: expressions and variables

TOC

Have you ever writing any programs?

If so, which is your favorite, and why?

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"Main stream"

- ☐ C/C++
- ☐ Java
- ☐ Javascript
- ☐ python

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"Main stream"

- ☐ C/C++
- ☐ Java
- ☐ Javascript
- ☐ python

Other options

- ☐ scripting languages: perl, ruby, shell script
- ☐ Lisp dialect: common lisp, clojure, scheme
- ☐ Domain specific: R
- ☐ shining & new languages: rust, go, julia

What operating system do you use

- ☐ Linux
- ☐ Windows
- ☐ Mac OS

What editor do you use?

- ☐ notepad
- ☐ Sublime text
- ☐ Atom
- ☐ Eclipse
- ☐ VS Code
- ☐ Emacs
- ☐ Vim
- ☐ Online editors (e.g. jupyter notebook)

TOC

What is a program?

wikipedia definition

A computer program is a collection of instructions that performs a specific task when executed by a computer.

...

A computer program is usually written by a computer programmer in a programming language.

...

From the program in its human-readable form of source code, a compiler or assembler can derive machine code. ... Alternatively, a computer program may be executed with the aid of an interpreter.

Hello World!

Hello world:

```
print ("Hello World")
```

Hello World!

Hello world:

```python
print ("Hello World")
```

`print` is a library call. You can print anything out in python:

```python
print(1)
print(1+2)
1+2
```

Major components of computer programs

Basic ingredients

- variables
- expressions
- statements

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Control flow

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- loop: for-loop

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- list
- hash tables (dictionaries)

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- stardard libraries
- 3rd-party libraries

Basic ingredients

- variables
- expressions
- statements

```
pi = 3.14              # variable: pi
r = 10
pi * r * r             # expression, evaluates to 314
print(pi * r * r)
area = pi * r * r      # assignment statement
print(area)            # print statement
```

Control flow

- conditional: if .. else ..
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conditional

```
a = -3
if a > 0:
  print('a is positive')
elif a < 0:
  print('a is negative')
else:
  print('a = 0')
```

Control flow

- conditional: if .. else ..
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conditional

```
a = -3
if a > 0:
  print('a is positive')
elif a < 0:
  print('a is negative')
else:
  print('a = 0')
```

loop

```
for i in range(2, 10):
  print(i)

for i in range(2, 10):
  if is_prime(i):
    print(i)
```

data structures

- list
- hash tables (dictionaries)

data structures

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list
```
l = [10, 8, 9, 1, 5, 6]
print(l[0])   # => 10
print(l[1])   # => 8
print(l[2:4]) # => [9,1]
print(len(l)) # => 6
print(sorted(l))
# => [1, 5, 6, 8, 9, 10]
```

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print(sorted(l))
# => [1, 5, 6, 8, 9, 10]
```

dict
```
d = dict()
d["hello"] = "world"
d[2] = "two"
d["five"] = 5
print(d["hello"])
# => "world"
```

Functions

statements

```
pi = 3.14
r = 10
area = pi * r * r
print(area)

r2 = 11
area2 = pi * r2 * r2
r3 = 12
area3 = pi * r3 * r3
```

Functions

statements

```
pi = 3.14
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- For code reuse and abstraction.

Functions

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area3 = pi * r3 * r3
```

- For code reuse and abstraction.

function
```
def circle_area(r):
    pi = 3.14
    return pi * r * r

for r in range(10):
  print(circle_area(r))
```

Classes: object-oriented programming

Class consists of

- fields: class local variables
- methods: functions to operate on the fields

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```
class Shape():
    def area(self):
        return 0
```

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Class consists of

- fields: class local variables
- methods: functions to operate on the fields

```
class Shape():
    def area(self):
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```

```
class Circle():
    def __init__(self, r):
        self.r = r
    def area(self):
        return (3.14 * self.r
                * self.r)
```

Classes: object-oriented programming

Class consists of

- fields: class local variables
- methods: functions to operate on the fields

```
class Shape():
    def area(self):
        return 0
```

```
class Circle():
    def __init__(self, r):
        self.r = r
    def area(self):
        return (3.14 * self.r
                * self.r)
```

```
class Rectangle():
    def __init__(self, w, h):
        self.w = w
        self.h = h
    def area(self):
        return self.w * self.h
```

project organization

- modules & files

lib.py
```python
def area(r):
    pi = 3.14
    return pi * r * r
def perimeter(r):
    pi = 3.14
    return 2 * r * pi
```

project organization

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lib.py

```python
def area(r):
    pi = 3.14
    return pi * r * r
def perimeter(r):
    pi = 3.14
    return 2 * r * pi
```

use.py

```python
from lib import area
from lib import perimeter
r = 10
print('Area: ', area(r))
print('Perimeter: ',
      perimeter(r))
```

Python standard library [1]

- numerical: `math`, `random`
- File IO: `os`, `io`
- dataset: `pickle`, `sqlite3`
- GUI: `tkinter`
- multi-thread: `threading`, `subprocess`
- network: `socket`, `asyncio`
- web: `html`, `xml`, `http`

[1] https://docs.python.org/3/library/

Recap: program components

Basic ingredients

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TOC

Early days (50s-60s)

- 1957: FORTRAN 

- 1958: Lisp-1.5: code is data
- 1958 ALGOL
  - ALGOL 58
  - ALGOL 60
  - ALGOL 68
- 1959 COBOL
- 1964 BASIC
- 1966 APL

Early days (50s-60s)

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Lisp is worth learning for the profound enlightenment experience you will have when you finally get it; that experience will make you a better programmer for the rest of your days, even if you never actually use Lisp itself a lot.

– Eric Raymond, in *How to Become a Hacker*

1970s: Establishing fundamental paradigms

- 1970: Pascal, in ALGOL family
- 1972: C
    - 1973: Unix V4 rewritten in C
- 1972: Smalltalk
- 1972: Prolog
- 1973: ML, "Lisp with types"
- 1975 Scheme: cleanly designed Lisp
    - proper lexical scoping
    - hygenic macros
- 1978 SQL

1980s

- 1980: C++
  - add object-oriented to C
- 1980: Ada
- 1984: Common Lisp
- 1984: Matlab
- 1986: Erlang
- 1986: Labview
  - graphical programming
- 1986: Perl
- 1988: Tcl

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Philip Greenspun:

> *Any sufficiently complicated C or Fortran program contains an ad hoc informally-specified bug-ridden slow implementation of half of Common Lisp.*

1990s: the Internet age, developer productivity

- 1990: Haskell
    - pure-functional language
    - Monad
- 1991: Python
    - scripting made easier
- 1991: Visual Basic
- 1993: Lua
- 1993: R
- 1995: Ruby
- 1995: Java
    - most popular for 2 decades
- 1995: PHP
- 1995: Javascript

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Atwood's Law: any application that can be written in JavaScript, will eventually be written in JavaScript.

2000-2010

- 2001: C#
- 2001: D
- 2002: scratch Demo: `https://scratch.mit.edu`
- 2003: scala
- 2005: F#
- 2007: Clojure
- 2009: Go

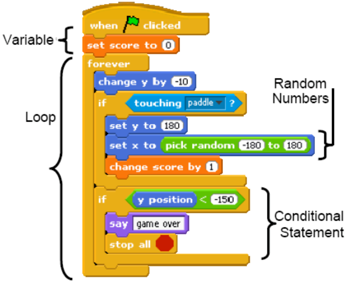

Figure: a Scratch program

2010+

- 2010: Rust: memory safety
- 2011: Dart: cross platform (Apple, Android, Web)
- 2011: Kotlin: can we fix Java?
- 2011: Elixir
- 2012: Julia: machine learning, the new R
- 2012: Typescript: Javascript with static typing
- 2014: Swift

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What will be the new python in 5 years?

Lisp family

- 1958: lisp 1.5
  - 1975: scheme
    - 1995: R5RS
    - 2005: R6RS
    - 2010: R7RS
  - 1984: common lisp, 1994 ANSI CL with CLOS
  - 1985: Emacs Lisp
  - 1993: GNU guile
  - 1995: racket
  - 2007: Clojure

TOC

TIOBE Index [2]

Aug 2019	Aug 2018	Programming Language	Ratings
1	1	Java	16.028%
2	2	C	15.154%
3	4	Python	10.020%
4	3	C++	6.057%
5	6	C#	3.842%
6	5	Visual Basic .NET	3.695%
7	8	JavaScript	2.258%
8	7	PHP	2.075%
9	14	Objective-C	1.690%
10	9	SQL	1.625%
24		Dart	0.715%
28		Rust	0.450%
29		Scratch	0.448%
34		Lisp	0.362%
39		Julia	0.279%
49		Haskell	0.174%

[2] Data from search engine. `https://www.tiobe.com/tiobe-index/`.

TIOBE Index history

PL	2019	2014	2009	2004	1999	1994	1989
Java	1	2	1	1	14	-	-
C	2	1	2	2	1	1	1
Python	3	7	5	7	24	21	-
C++	4	4	3	3	2	2	2
VB .NET	5	9	-	-	-	-	-
C#	6	5	6	6	19	-	-
JavaScript	7	8	8	8	16	-	-
PHP	8	6	4	5	-	-	-
SQL	9	-	-	89	-	-	-
Objective-C	10	3	31	38	-	-	-
Perl	16	11	7	4	3	10	22
Lisp	32	13	19	13	12	5	3
Pascal	220	16	14	88	6	3	20

github language stats [3]

Ranking	PL	Percentage	change
1	JavaScript	19.922%	(-2.425%)
2	Python	17.803%	(+1.519%)
3	Java	10.482%	(+0.591%)
4	Go	7.916%	(+0.295%)
5	C++	7.253%	(+0.167%)
6	Ruby	6.296%	(-0.249%)
7	PHP	5.515%	(-0.285%)
8	TypeScript	5.415%	(+0.641%)
9	C#	4.001%	(+0.659%)
10	C	3.190%	(+0.248%)
14	Rust	0.714%	(-0.062%)
15	Kotlin	0.656%	(+0.113%)
20	Dart	0.376%	(+0.055%)
24	Clojure	0.271%	(-0.091%)
28	Haskell	0.190%	(-0.071%)
37	Julia	0.068%	
48	Common Lisp	0.024%	

[3] https://madnight.github.io/githut/

TOC

Python

Table: Python language feature

Features	Option 1	Option 2
Compilation model	interpreted	compiled
Typing checking	strong	weak
Variable typing	static	dynamic
Scoping	lexical	dynamic
Paradigm	procedual	functional
Pure-functional	pure	impure
Memory model	manual	garbage collected
Object-Oriented	Yes	No

Compiler vs. Interpreter

Compiler

source code compiled to object code then runs

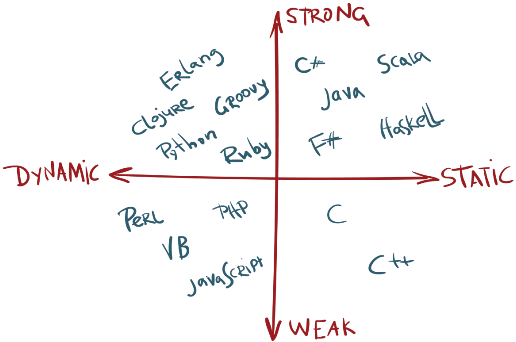
- check errors during compilation
- whole-program optimization, thus run fast

Interpreter

source code, directly run

- Interactive
- Incremental development, thus develop fast

strong/weak & static/dynamic Typing



- Strong/Weak typing: Whehter type safety is enforced on values.
- Static/Dynamic typing: Whether variables are typed.

strong typing & weak typing

Whehter type safety is enforced on values.

Strong typing: python

```
1 + "hello"
```

strong typing & weak typing

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TypeError: unsupported operand type(s) for +: 'int' and 'str'

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Weak typing: Javascript

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```

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Whehter type safety is enforced on values.

Strong typing: python

```
1 + "hello"
```

TypeError: unsupported operand type(s) for +: 'int' and 'str'

Weak typing: Javascript

```
1 + "hello"
```

"1hello"

static & dynamic typing

Whether variables are typed.

static typing: C

```
int var;
var = 8;
var = "hello";  // compile error
```

static & dynamic typing

Whether variables are typed.

static typing: C

```c
int var;
var = 8;
var = "hello";   // compile error
```

dynamic typing: python

```python
var = 8
var = "hello"
```

memory safety & management

- manual memory management
- automatic memory management: gabbage collection
- ownership (Rust)

memory safety & management

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Manual memory management: C

```c
int *var;
var = (int*) malloc(sizeof(int));
*var = 5;
free(var);
```

memory safety & management

- manual memory management
- automatic memory management: gabbage collection
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Manual memory management: C

```c
int *var;
var = (int*) malloc(sizeof(int));
*var = 5;
free(var);
```

Gabbage collected: python

```python
l = [1,2,3]
l.append(4)
print(l)      # => [1,2,3,4]
```

functional & procedual programming

functional:

- function is a first-class citizen
  - *first-class* means a function can appear anywhere value can occur
  - can be assigned to variable, pass to a function, or returned by a function
- function in *mathmatical sense*: given input, compute output. There is no side effect.

```python
var = 8
def bad_square(a):
    global var
    var = a
    return a * a
```

```python
print(var) # => 8
print(bad_square(3))
# => 9
print(var) # => 3
```

TOC

Prime number

A prime number (or a prime) is a natural number greater than 1 that cannot be formed by multiplying two smaller natural numbers.

- composite number: 6 is not prime, because 6 = 2 * 3
- list of prime numbers: 2, 3, 5, 7, 11, 13, ...

```python
def is_prime(n):
  for i in range(2, round(n/2)+1):
    if n % i is 0:
      return False
  return True

for i in range(2, 10):
  if is_prime(i):
    print(i)
```

Fibonacci number

$$
\begin{aligned}
F_0 &= 1 \\
F_1 &= 1 \\
F_n &= F_{n-1} + F_{n-2} \qquad \text{for n} > 1
\end{aligned}
$$

Example: 1, 1, 2, 3, 5, 8, 13

Fibonacci number

$$F_0 = 1$$
$$F_1 = 1$$
$$F_n = F_{n-1} + F_{n-2} \qquad \text{for n} > 1$$

Example: 1, 1, 2, 3, 5, 8, 13

```
def fib(n):
  if n is 0: return 1
  if n is 1: return 2
  return fib(n-1) + fib(n-2)

for i in range(10):
  print(fib(i))
```

Trainning a neural network classifier

Online runtime: `https://colab.research.google.com`
Import libraries:

```
import keras
from keras.layers import Input, Dense, Flatten
from keras.models import Model
from keras.datasets import mnist
import random
import matplotlib.pyplot as plt
import numpy as np
```

Trainning a neural network classifier

Setup model:

```
inputs = Input(shape=(28,28,))
x = Flatten()(inputs)
x = Dense(64, activation='relu')(x)
x = Dense(64, activation='relu')(x)
predictions = Dense(10, activation='softmax')(x)
model = Model(inputs, predictions)
model.compile(optimizer='rmsprop',
              loss='categorical_crossentropy',
              metrics=['accuracy'])
```

Trainning a neural network classifier

Load MNIST data and train the model:

```
(x_train, y_train), (x_test, y_test) = mnist.load_data()
y_train = keras.utils.to_categorical(y_train, 10)
y_test = keras.utils.to_categorical(y_test, 10)

model.fit(x_train, y_train, epochs=10)
model.evaluate(x_test, y_test)
```

Trainning a neural network classifier

Visualization:

```
index = random.randint(0, 1000)
plt.imshow(x_train[index])
plt.savefig("image.jpg")
pred = np.argmax(
    model.predict(
        np.array([x_train[index]]))[0])
print("prediction: ", pred)
```