

ITCS 4101

Intro to Natural Language Processing

Python for Programming, NLP, ML

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Python Programming Stack

- Python = object-oriented, interpreted, scripting language.
 - imperative programming, with functional programming features.
- NumPy = package for powerful N-dimensional arrays:
 - sophisticated (broadcasting) functions.
 - useful linear algebra, Fourier transform, and random number capabilities.
- SciPy = package for numerical integration and optimization.
- Matplotlib = comprehensive 2D and 3D plotting library.

Python Programming Stack

- PyTorch = a wrapper of NumPy that enables the use of GPUs and automatic differentiation:
 - **Tensors** similar to NumPy's ndarray, but can also be used on GPU.
- Jupyter Notebook = a web app for creating documents that contain live code, equations, visualizations and markdown text.
- Anaconda = an open-source distribution of Python and Python packages:
 - Package versions are managed through Conda.
 - Install all packages above using Anaconda / Conda install.

Anaconda Install

- **Anaconda:** Installation instructions for various platforms can be found at: <https://docs.anaconda.com/anaconda/install>
 - For Mac and Linux users, the system PATH must be updated after installation so that ‘conda’ can be used from the command line.
 - Mac OS X:
 - For bash users: `export PATH=~/.opt/anaconda3/bin:$PATH`
 - For csh/tcsh users: `setenv PATH ~/.opt/anaconda3/bin:$PATH`
 - For Linux:
 - For bash users: `export PATH=~/.opt/anaconda3/bin:$PATH`
 - For csh/tcsh users: `setenv PATH ~/.opt/anaconda3/bin:$PATH`
 - It is recommend the above statement be put in the `~/.bashrc` or `~/.cshrc` file, so that it is executed every time a new terminal window is open.
 - To check that conda was installed, running “*conda list*” in the terminal should list all packages that come with Anaconda.

Installing Packages with Conda / Anaconda

- Tools and libraries that can be configured from Anaconda:
 - Python 3, **NumPy**, SciPy, Matplotlib, **Jupyter Notebook**, Ipython, Pandas, **Scikit-learn**.
 - **PyTorch** can be installed with ‘conda’ from the command line:
 - The actual command line depends on the platform as follows:
 - Using the GUI on pytorch.org, choose the appropriate OS, conda, Python 3.6, CUDA or CPU version.

NLP/ML APIs in Python

- spaCy: <https://spacy.io/usage>
- Scikit-learn: <https://scikit-learn.org/stable/>
- Hugging Face: <https://huggingface.co/docs>
- OpenAI: <https://platform.openai.com/docs/introduction>

Install spaCy

Operating system: **macOS / OSX** Windows Linux

Package manager: pip **conda** from source

Hardware: **CPU** GPU

Configuration: virtual env train models

Trained pipelines: Chinese Danish Dutch English French German Greek Italian
 Japanese Lithuanian Macedonian Multi-language Norwegian Bokmål Polish
 Portuguese Romanian Russian Spanish

Select pipeline for: **efficiency** accuracy

```
$ conda install -c conda-forge spacy
$ python -m spacy download en_core_web_sm
```

Python

- Designed by Guido van Rossum in the early 1990s.
 - Current development done by the Python Software Foundation.
 - Python facilitates multiple programming paradigms:
 - imperative programming.
 - object oriented programming.
 - functional programming.
- ⇒ **multi-paradigm programming language.**

Python: Important Features

- Python = **object-oriented** **interpreted** “**scripting**” language:
 - **Object oriented:**
 - modules, classes, exceptions.
 - dynamically typed, automatic garbage collection.
 - **Interpreted**, interactive:
 - rapid edit-test-debug cycle.
 - **Extensible:**
 - can add new functionality by writing modules in C/C++.
 - **Standard library:**
 - extensive, with hundreds of modules for various services such as regular expressions, TCP/IP sessions, etc.

Scripting Languages

- **Scripts vs. Programs:**
 - interpreted vs. compiled
 - one script = a program
 - many {*.c, *.h} files = a program
- **Higher-level “glue” language:**
 - glue together larger program/library components, potentially written in different programming languages.
 - orchestrate larger-grained computations.
 - vs. programming fine-grained computations.
 - `grep -i programming *.txt | grep -i python | wc -l`

The Python Interpreter: Terminal

```
(base) rbunescu@CCI5CFQ05NALT code % python
```

```
Python 3.10.9 (main, Mar 1 2023, 12:33:47) [Clang 14.0.6 ] on darwin
```

```
Type "help", "copyright", "credits" or "license" for more information.
```

```
>>> □
```

```
(base) rbunescu@CCI5CFQ05NALT code % ipython
```

```
Python 3.10.9 (main, Mar 1 2023, 12:33:47) [Clang 14.0.6 ]
```

```
Type 'copyright', 'credits' or 'license' for more information
```

```
IPython 8.10.0 -- An enhanced Interactive Python. Type '?' for help.
```

```
In [1]: □
```

The Python Interpreter: Help()

```
>>> help()
```

Welcome to Python 3.10's help utility!

If this is your first time using Python, you should definitely check out the tutorial on the Internet at <https://docs.python.org/3.10/tutorial/>.

Enter the name of any module, keyword, or topic to get help on writing Python programs and using Python modules. To quit this help utility and return to the interpreter, just type "quit".

To get a list of available modules, keywords, symbols, or topics, type "modules", "keywords", "symbols", or "topics". Each module also comes with a one-line summary of what it does; to list the modules whose name or summary contain a given string such as "spam", type "modules spam".

```
help>
```

The Python Interpreter: Keywords

help> keywords

Here is a list of the Python keywords. Enter any keyword to get more help.

| | | | |
|----------|---------|----------|--------|
| False | def | if | raise |
| None | del | import | return |
| True | elif | in | try |
| and | else | is | while |
| as | except | lambda | with |
| assert | finally | nonlocal | yield |
| break | for | not | |
| class | from | or | |
| continue | global | pass | |

The Python Interpreter: Keywords

```
help> lambda
```

```
Lambdas
```

```
*****
```

```
lambda_expr ::= "lambda" [parameter_list]: expression
```

```
lambda_expr_nocond ::= "lambda" [parameter_list]: expression_nocond
```

Lambda expressions (sometimes called lambda forms) have the same syntactic position as expressions. They are a shorthand to create anonymous functions; the expression "lambda arguments: expression" yields a function object. The unnamed object behaves like a function object defined with

```
def <lambda>(arguments):  
    return expression
```

See section **Function definitions** for the syntax of parameter lists. Note that functions created with lambda expressions cannot contain statements or annotations.

The Python Interpreter: Modules

help> modules

commands:

execute shell commands via `os.popen()` and return status, output.

compiler:

package for parsing and compiling Python source code.

gzip:

functions that read and write gzipped files.

HTMLParser:

a parser for HTML and XHTML (defines a class `HTMLParser`).

math:

access to the mathematical functions defined by the C standard.

exceptions:

Python's standard exception class hierarchy.

The Python Interpreter: Modules

help> modules

os:

OS routines for Mac, NT, or Posix depending on what system we're on.

re:

support for regular expressions (RE).

string:

a collection of string operations (most are no longer used).

sys:

access to some objects used or maintained by the interpreter and to functions that interact strongly with the interpreter:

sys.argv: command line arguments.

sys.stdin, *sys.stdout*, *sys.stderr*: standard input, output, error file objects.

threading:

thread modules emulating a subset of Java's threading model.

The Python Interpreter: Integer Precision

```
>>> def fib(n):
```

```
...     a, b, i = 0, 1, 0
```

```
...     while i < n:
```

```
...         a,b,i = b, a+b, i+1
```

```
...     return a
```

```
..
```

```
>>> fib(10)
```

```
55
```

```
>>> fib(100)
```

```
354224848179261915075
```

```
>>> fib(1000)
```

```
4346655768693745643568852767504062580256466051737178040248172908953655541
```

```
4905189040387984007925516929592259308032263477520968962323987332247116164
```

```
996440906533187938298969649928516003704476137795166849228875
```

Built-in Types: Basic

- **integers**, with unlimited precision – `int()`.
 - decimal, octal and hex literals.
- **floating point numbers**, implemented using double in C – `float()`.
- **complex numbers**, real and imaginary as double in C – `complex()`.
 - `10+5j`, `1j`
 - `z.real`, `z.imag`
- **boolean values**, `True` and `False` – `bool()`.
 - False is: `None`, `False`, `0`, `0L`, `0.0`, `0j`, `''`, `()`, `[]`, `{}`,
 - user defined class defines methods `nonzero()` or `len()`.
- **strings** – `str()`, **class**, **function**, ...
 - `"Hello world"`, `'Hello world'`

Built-in Types: Composite

- **lists:**
 - [], [1, 1, 2, 3], [1, “hello”, 2+5j]
- **tuples:**
 - (), (1,), (1, 1, 2, 3), (1, “hello, 2+5j)
- **dictionaries:**
 - {“john”: 12, “elaine”: 24}
- **sets:**
 - {1, 2, 3}
- **files**

Integers

```
>>> int
<class 'int'>
>>> 1024
1024
>>> int(1024)
1024
>>> repr(1024)
'1024'
>>> eval('1024')
1024
>>> str(1111)
'1111'
>>> int('1111')
1111
```

```
>>> a = 100
>>> b = 200
>>> a + 1, b + 1 #this is a tuple
(101, 201)
>>> print(a, b + 1)
100 201
>>> int(3.6), abs(-10), 11%3, 11//3, 11/3, 2**3
(3, 10, 2, 3, 3.6666666666666665, 8)
>>> int('1110',2), int('170',8), int('40',16)
(14, 120, 64)
>>> [170, 0170, 0x40] #this is a list
[170, 120, 64]
>>> float(8), 2**3, pow(2,3)
(8.0, 8, 8)
```

Booleans

```
>>> bool
<class 'bool'>
>>> [bool(0), bool(0.0), bool(0j),bool([]), bool(()), bool({}), bool(''), bool(None)]
[False, False, False, False, False, False, False, False]
>>> [bool(1), bool(1.0), bool(1j), bool([1]), bool((1,)), bool({1:'one'})], bool('1')]
[True, True, True, True, True, True, True]
>>> str(True), repr(True)
('True', 'True')
>>> True and True, True and False, False and False
(True, False, False)
>>> True or True, True or False, False or False
(True, True, False)
>>> not True, not False
(False, True)
```

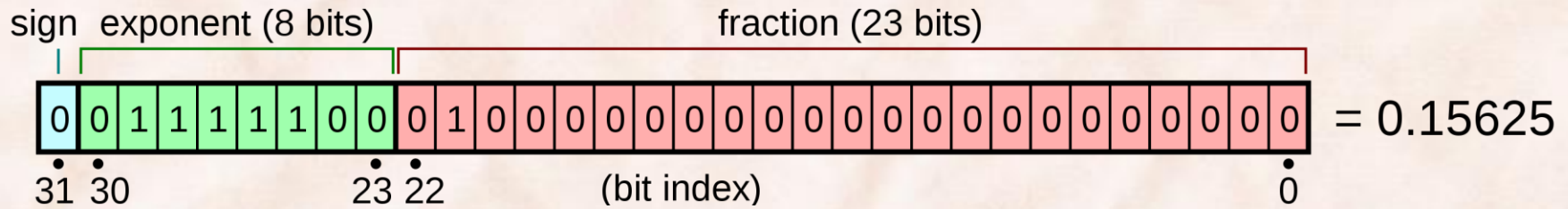
Floating Point

```
>>> float
<class 'float'>
>>> 3.14, 3.1400000000000001
(3.14, 3.14)
>>> repr(3.1400000000000001)
3.14
>>> 3.14/2, 3.14//2
(1.5, 1.0)
>>> 1.9999999999999999
2.0
>>> import math
>>> math.pi, math.e
(3.1415926535897931, 2.7182818284590451)
>>> help('math')
```

```
===== Python =====
>>> sum = 0.0
>>> for i in range(10):
...     sum += 0.1
...
>>> sum
0.99999999999999989
===== C++ =====
float sum = 0.0;
for (int i = 0; i < 10; i++)
    sum += 0.1;
cout.precision(17);
cout << sum << endl;
⇒ 1.0000001192092896
```

<http://docs.python.org/3/tutorial/introduction.html#numbers>

IEEE 754 Standard



- Use **decimal.Decimal** to represent 0.1 exactly (fixed point representation).
 - >>> from decimal import Decimal
 - >>> zpo = Decimal('0.1')
 - vs.
 - >>> zpo = Decimal(0.1)

Strings (Immutable)

- Immutable Sequences of Unicode Characters:

```
>>> str
<class 'str'>
>>> str.upper('it'), 'it'.upper()
('IT', 'IT')
>>> ',', ""
(',', '')
>>> "functional {0} lang".format('programming')
'functional programming lang'
>>> "object oriented " + "programming"
'object oriented programming'
>>> 'orient' in 'object oriented', 'orient' in 'Object Oriented'
(True, False)
```

```
>>> s = "object oriented"
```

```
>>> len(s), s.find('ct'), s.split()
(15, 4, ['object', 'oriented'])
```

```
>>> s[0], s[1], s[4:6], s[7:]
('o', 'b', 'ct', 'oriented')
```

```
>>> s[7:100]
'oriented'
```

```
>>> help('str')
```

<http://docs.python.org/3/tutorial/introduction.html#strings>

(Fancy) String Formatting

```
>>> n, x, s = 10, math.pi, 'charlotte'
>>> 'We live in {city}'.format(city = s)
>>> 'We live in {}'.format(s)
>>> 'There are {num} bears living in {city}'.format(city = s, num = n)
>>> 'There are {1} bears living in {0}'.format(s, n)
>>> 'The approximate value of pi is {:.2f}'.format(math.pi)
>>> 'The approximate value of pi is {math.pi:.2f}.'
>>> 'The approximate value of pi is {math.pi:.2f}.'
>>> 'The value of pi is approximately {x:.2f}.'
>>>          VS.
>>> f'The approximate value of pi is {x:.2f}.'
```

Read more here:

<https://docs.python.org/3/tutorial/inputoutput.html>

List (Mutable)

```
>>> [] #empty list
[]
>>> x = [3.14, "hello", True]
[3.14, 'hello', True]
>>> x + [10, [], len(x)]
[3.14, 'hello', True, 10, [], 3]
>>> x.append(0.0)
>>> x.reverse()
>>> x
[0.0, True, 'hello', 3.14]
>>> x * 2
[0.0, True, 'hello', 3.14, 0.0, True, 'hello', 3.14]
```

```
>>> x.sort()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unorderable types: str() < bool()
```

```
>>> x = [0.0, 3.14, True]
>>> sorted(x)
[0.0, True, 3.14]
>>> x
[0.0, 3.14, True]
>>> x.sort()
>>> x
[0.0, True, 3.14]
```

```
>>> help('list')
```

Tuple (Immutable)

```
>>> tuple
<class 'tuple'>
>>> () # empty tuple
()
>>> (10) # not a one element tuple!
10
>>> (10,) # a one element tuple
(10,)
>>> (1, 2) + (3, 4)
(1, 2, 3, 4)
>>> (1, 2) * 2
(1, 2, 1, 2)
>>> x = (0, 1, 'x', 'y')
```

```
>>> x[0], x[1], x[:-1]
(0, 1, (0, 1, 'x'))
>>> y = (13, 20, -13, -5, 0)
>>> temp = list(y)
>>> temp.sort()
>>> y = tuple(temp)
>>> y
(-13, -5, 0, 13, 20)
>>> help('tuple')
```

Immutable types are hashable!

Set (Mutable) & Frozenset (Immutable)

```
>>> set, frozenset
(<class 'set'>, <class 'frozenset'>)
>>> set() # empty set
set()
>>> type(set())
<class 'set'>
>>> {} # not an empty set!
{}
>>> type({})
<class 'dict'>
>>> s = {1, 3, 3, 2}
>>> s
{1, 2, 3}
>>> frozenset({1, 3, 3, 2})
frozenset({1, 2, 3})
```

```
>>> 3 in s, 4 in s
(True, False)
>>> s = set('yellow')
>>> t = set('hello')
>>> s
{'e', 'o', 'l', 'w', 'y'}
>>> t
{'h', 'e', 'l', 'o'}
>>> s - t, s | t
({'w', 'y'}, {'h', 'e', 'o', 'l', 'w', 'y'})
>>> s & t, s ^ t
({'e', 'l', 'o'}, {'h', 'w', 'y'})
>>> {1, 3} <= {1, 2, 3, 2}
True
>>> help(set) >>> help(frozenset)
```


Mutable Operations on Sets

```
>>> s = set(['abba', 'dada', 'lola', 'bama'])
```

```
>>> s
```

```
{'abba', 'bama', 'dada', 'lola'}
```

```
>>> s |= {'bama', 'lily'}
```

```
>>> s
```

```
{'abba', 'bama', 'dada', 'lily', 'lola'}
```

```
>>> s -= {'lola', 'abba', 'mama'}
```

```
>>> s
```

```
{'bama', 'dada', 'lily'}
```

```
>>> s &= {'lily', 'dodo', 'bama'}
```

```
>>> s
```

```
{'bama', 'lily'}
```

```
>>> s = {[1]}
```

```
TypeError: unhashable type: 'list'
```

How can we prove the actual set object changes and not a new one is created?

Hint: are $s -= t$ and $s = s - t$ equivalent for sets? How about strings?

Dictionaries (Mutable)

```
>>> dict
<class 'dict'>
>>> {} # empty dictionary
{}
>>> d = {'john':23, 'alex':25, 'bill':99}
>>> d['alex']
25
>>> d['alex'] = 26
>>> del d['john']
>>> d['tammy'] = 35
>>> d
{'alex':26, 'bill':99, 'tammy':35}
>>> for key in d:
>>> ... print(key, end = ' ')
'alex' 'bill' 'tammy'
```

```
>>> d.items() # this is a view
dict_items([('alex',26), ('bill',99), ('tammy',35)])
>>> d.keys() # this is a view
dict_keys['alex', 'bill', 'tammy']
>>> d.values() # this is a view
dict_values[26, 99, 35]
>>> for x, y in d.items():
>>> ... print (x, y)
'alex' 26
'bill' 99
'tammy' 35
>>> d.keys() | ['alex', 'john'] # set ops.
{'alex', 'bill', 'john', 'tammy'}
>>> d['mary'] = 10
>>> d.keys()
dict_keys['alex', 'bill', 'tammy', 'mary']
```

Dictionaries (Mutable)

```
>>> dict
<class 'dict'>
>>> {}
{}
>>> d = dict(abba=1, dada=2)
>>> d[frozenset({1, 2, 3})] = 3
25
>>> d
{'abba':1, 'dada':2, frozenset({1, 2, 3}):3}
>>> del d[frozenset({1, 2, 3})]
>>> d
{}
>>> d[{1, 2, 3, 4}] = 4
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unhashable type: 'set'
>>> ... print(key, end = ' ')
'alex' 'bill' 'tammy'
>>> d.items() # this is a view
dict_items[('alex',26), ('bill',99), ('tammv',35)]
>>> d['mary'] = 10
>>> d.keys()
dict_keys['alex', 'bill', 'tammy', 'mary']
```

Files

```
>>> file
<type 'file'>
>>> output = open('/tmp/output.txt', 'w') # open tmp file for writing
>>> input = open('/etc/passwd', 'r') # open Unix passwd file for reading
>>> s = input.read() # read entire file into string s
>>> line = input.readline() # read next line
>>> lines = input.readlines() # read entire file into list of line strings
>>> output.write(s) # write string S into output file
>>> output.write(lines) # write all lines in 'lines'
>>> output.close()
>>> input.close()

>>> from urllib import urlopen
>>> html = urlopen('http://www.ohio.edu')
>>> lines = [line[:-1] for line in html.readlines()]

>>> help('file')
```

Statements & Functions

- Assignment Statements
- Compound Statements
- Control Flow:
 - Conditionals
 - Loops
- Functions:
 - Defining Functions
 - Lambda Expressions
 - Documentation Strings
 - Generator Functions

Assignment Forms

- Basic form:
 - `x = 1`
 - `y = 'John'`
- Tuple positional assignment:
 - `x, y = 1, 'John'`
 - `x == 1, b == 'John' ==> (True, True)`
- List positional assignment:
 - `[x, y] = [1, 'John']`
- Multiple assignment:
 - `x = y = 10`

Compound Statements

- Python does not use block markers (e.g. ‘begin .. end’ or ‘{ ... }’) to denote a compound statements.
 - Need to indent statements at the same level in order to place them in the same block.
 - Can be annoying, until you get used to it; intelligent editors can help.
 - Example:

```
if n == 0:  
    return 1  
else:  
    return n * fact(n - 1)
```

Conditional Statements

```
if <bool_expr_1>:  
    <block_1>  
elif <bool_expr_2>:  
    <block_2>  
...  
else:  
    <block_n>
```

- There can be zero or more elif branches.
- The else branch is optional.
- “Elif “ is short for “else if” and helps in reducing indentation.

Else If vs. Elif

```
if a == 0:
    print('nothing')
else:
    if a == 1:
        print('one thing')
    else:
        if a == 2:
            print('two things')
        else:
            if a == 3:
                print('three things')
            else:
                print('many things')
```

```
if a == 0:
    print('nothing')
elif a == 1:
    print('one thing')
elif a == 2:
    print('two things')
elif a == 3:
    print('three things')
else:
    print('many things')
```

Conditional Statements

- [Python 3.10](#) added a `match ... case` statement.
- Same behavior can be achieved using:
 - `if ... elif ... elif` sequences.
 - dictionaries:

```
name = 'John'
dict = {'Mary': 'female', 'John': 'male',
        'Alex': 'either', 'Paris': 'either'}
if name in dict:
    print(dict[name])
else:
    print('unknown')
```


While Loops

```
x = 'university'  
while x:  
    print(x, end = ' ')  
    x = x[1:]
```

```
a, b = 1, 1  
while b <= 23:  
    print(a, end = ' ')  
    a, b = b, a + b
```

For Loops

```
sum = 0
for x in [1, 2, 3, 4]
    sum += x
print(sum)
```

```
D = {1:'a', 2:'b', 3:'c', 4:'d'}
for x, y in D.items():
    print(x, y)
```

Names and Scopes

- Static scoping rules.
 - if x is a variable name that is only read, its variable is found in the closest enclosing scope that contains a defining write.
 - a variable x that is written is assumed to be local, unless it is explicitly imported.
 - use **global** and **nonlocal** keywords to override these rules.
- Example:

Functions

```
def mul(x, y):  
    return x * y
```

`mul(2, 5) => ?`

`mul(math.pi, 2.0) => ?`

`mul([1, 2, 3], 2) => ?`

`mul(('a', 'b'), 3) => ?`

`mul('ou', 5) => ?`

Parameter Correspondence

```
def f(a, b, c): print(a, b, c)
```

```
f(1, 2, 3) => 1 2 3
```

```
f(b = 1, c = 2, a = 3) => 3 1 2
```

```
def f(*args): print(args)
```

```
f("one argument") => ('one argument')
```

```
f(1, 2, 3) => (1, 2, 3)
```

```
def f(**args): print(args)
```

```
f(a=2, b=4, c=8) => {'a':2, 'b':4, 'c':8}
```


Lambda Expressions

- **Scheme:**

```
>(define (make-adder (num)
  (lambda (x)
    (+ x num))))
```

- **Python:**

```
>>> def make_adder(num):
...     return lambda x: x + num
...
>>> f = make_adder(10)
>>> f(9)
19
```

Lambda Expressions

```
>>> formula = lambda x, y: x *x + x*y + y*y
>>> formula
<function <lambda> at 0x2b3f213ac230>
>>> apply(formula, (2,3))
19
>>> list(map(lambda x: 2*x, [1, 2, 3]))
[2, 4, 6]
>>> list(filter(lambda x: x>0, [1, -1, 2, -2, 3, 4, -3, -4]))
[1, 2, 3, 4]
>>> from functools import reduce
>>> reduce(lambda x,y:x*y, [1, 2, 3, 4, 5])
120
>>> def fact(n): return reduce (lambda x, y: x*y, range(1, n+1))
>>> fact(5)
120
```

Iterators

- An **iterator** is an object representing a stream of data:
 - to get the next element in the stream:
 - call `__next__()` method.
 - pass the iterator to the built-in function `next()`.
 - to create an iterator:
 - call `iter(collection)`.
 - some functions create iterators/iterables instead of collections:
 - `map()`, `filter()`, `zip()`, ...
 - `range()`, `dict.keys()`, `dict.items()`, ...
 - **why create iterators/iterables instead of collections?**
- Examples:

Iterators

```
for x in range(5):  
    print(x)
```

an **iterable** (provides the `__iter__()` method)

Internally, this is implemented as:

```
it = iter(range(5))  
while True:  
    try:  
        x = next(it)  
        print(x)  
    except StopIteration:  
        break
```

A Convenient Shortcut to Building Iterators: Generator Functions/Expressions

```
def squares(n):  
    for i in range(n):  
        yield i*i
```

Equivalent generator expression:

```
>>> (i * i for i in range(n))
```

```
>>> for i in squares(5):  
...     print(i, end = ' ')  
0 1 4 9 16
```

```
>>> s = squares(5)  
>>> next(s) => 0  
>>> next(s) => 1  
>>> next(s) => 4
```


Generator Functions

```
def fib(): # generate Fibonacci series
    a, b = 0, 1
    while 1:
        yield b
        a, b = b, a+b
```

```
>>> it = fib()
>>> next(it) => 1
>>> next(it) => 1
>>> next(it) => 2
```

List/Set/Dict Comprehensions

- Mapping operations over sequences is a very common task in Python coding:
 - ⇒ introduce a new language feature called *list comprehensions*.

```
>>> [x**2 for x in range(5)]
```

```
[0, 1, 4, 9, 25]
```

```
>>> [x for x in range(5) if x % 2 == 0]
```

```
[0, 2, 4]
```

```
>>> [x+y for x in [1, 2, 3] for y in [-1,0,1]]
```

```
[0,1,2,1,2,3,2,3,4]
```

```
>>> [(x,y) for x in range(5) if x%2 == 0 for y in range(5) if y%2=1]
```

```
[(0,1), (0,3), (2,1), (2,3), (4,1), (4,3)]
```

List/Set/Dict Comprehensions

*['expression for target₁ in iterable₁ [if condition]
for target₂ in iterable₂ [if condition]
...
for target_n in iterable_n [if condition] ']*

```
>>> [line[:-1] for line in open('myfile)]
```

```
>>> {x for x in 'ohio' if x not in 'hawaii'}
```

```
>>> {x:2*x for x in 'ohio'}
```

```
>>> {x:y for x in [1, 2] for y in [3, 4]}
```

Errors & Exceptions

- **Syntax errors:**

```
while True print `True`  
File "<stdin>", line 1  
    while True print `True`  
                        ^
```

```
SyntaxError: invalid syntax
```

- **Exceptions: errors detected during execution:**

```
1 / 0
```

```
Traceback ( most recent call last):
```

```
File "<stdin>", line 1, in ?
```

```
ZeroDivisionError: integer division or modulo  
by zero
```

Handling Exceptions

```
for arg in sys.argv[1:]:
    try:
        f = open(arg, 'r')
    except IOError:
        print('cannot open', arg)
    else:
        print(arg, 'has', len(f.readlines()), 'lines')
        f.close()
```


Modules

- Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter.
- A **module** is a file containing Python definitions and statements.
- The file name is the module name with the suffix **.py** appended.
- Within a module, the module's name (as a string) is available as the value of the global variable **__name__**

fibonacci.py

```
# Fibonacci numbers module
def fib(n): # write Fibonacci series up
    to n
    a, b = 0, 1
    while b < n:
        print b,
        a, b = b, a+b
```

```
>>> import fibo
```

```
>>> fibo.fib(100)
```

```
1 1 2 3 5 8 13 21 34 55 89
```

How to write and run Python code

- Interactively:
 1. Terminal: run **python**, type code at the interpreter prompt `>>>`.
 2. Browser: run **jupyter-notebook**, type code and markdown.
 - Can File / Download as Python (.py) source code.
- Editor or IDE:
 1. **emacs, vi, ...**
 2. **VSCode, Spyder, PyCharm, ...**
 - Smart editors and IDE can also offer interactive features in parallel with code development.

How to write and run Python code

- Explicit interpreter invocation:

> **python main.py arg₁ ... arg_n**

- Implicit interpreter invocation:

> **./main.py arg₁ ... arg_n**

- Need to specify the path to the `python` interpreter on the first line of `main.py`:

`#!/opt/anaconda3/bin/python`

- Need to give execution rights to `main.py`:

> **chmod 0755 main.py**

Readings

- More about Python:
 - <https://docs.python.org/3/tutorial>
 - <https://docs.python.org/3/tutorial/classes.html#iterators>
 - <https://docs.python.org/3/tutorial/classes.html#generators>
 - <https://docs.python.org/3/library/functions>
 - <https://docs.python.org/3/library/stdtypes>
 - <https://docs.python.org/3/whatsnew/3.0.html>
 - <https://docs.python.org/3/howto/regex.html>
- Matplotlib and NumPy:
 - <https://matplotlib.org/3.1.1/tutorials/index.html>
 - <https://docs.scipy.org/doc/numpy/user/quickstart.html>