Algorithm Design Strategies I

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Overview

- Python 3 – A quick review
- Algorithm Efficiency – Counting basic operations

[python.org]

PYTHON 3

Python – Main features

- Dynamic typing

- Simple, consistent syntax and semantics

- Multiplatform

- Highly modular

- Suited for rapid development and large-scale programming

Python – Main features

- Reasonably fast and easily extended with C or C++ modules for higher speeds

- Easy access to various GUI toolkits

- Built-in advanced features, such as advanced hash tables, …

- Powerful included libraries such as numeric processing, image manipulation, …

Python – Pros

- Easy to learn / use
  - Familiar constructs
  - Very simple rules
  - Types associated with objects, not variables

- Much higher level of abstraction
  - Extensive standard core library

- Well-suited for rapid application development

Python – Pros

- Expressive

  - Comparatively fewer lines of code

  - Faster development

  - Easier maintenance and debugging

```
var2, var1 = var1, var2
```

Python – Pros

- ## Readable

  - Use of indentation !!

```python
def pairwise_sum(list1, list2):
    result = []
    for i in range(len(list1)):
        result.append(list1[i] + list2[i])
    return result
```

Python - Pros

- **Complete**
  - "Batteries included" – Standard library
  - Everything you need to do real work

- **Cross-platform**

Python – Cons

- **Not the fastest language…**
  - ❑ Semicompiled to an internal byte-code form
  - ❑ Executed by a Python interpreter
  - ❑ BUT, computers have so much computing power

- **For most applications, running speed isn't as important as development speed**

Python – Cons

- ## Not the most libraries
  - Java and Perl have even larger library collections
  - BUT, Python is easy to expand

- ## Not checking variable types at compile time
  - Variables are not bound to particular types
  - Not catching variable type mismatches

Python 3 – Why?

- **More consistent, readable and less ambiguous than Python 2**

- **BUT, no full compatibility with older code**
  - ❑ Fairly small changes
  - ❑ Strategies for code migration

Python 3 – Numbers

- **Integers**
  - 1, –3, 42, 355, 888888888888888, –7777777777
- **Floats**
  - 3.0, 31e12, –6e–4
- **Complex numbers**
  - 3+2j, –4– 2j, 4.2+6.3j
- **Booleans**
  - True, False

Python 3 – Integers

```
>>> x = 5 + 2 - 3 * 2
>>> x
1
>>> 5 / 2
2.5
>>> 5 // 2
2
>>> 5 % 2
1
>>> 2 ** 8
256
>>> 1000000001 ** 3
1000000003000000003000000001
```

1

2

3
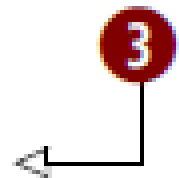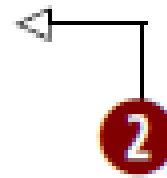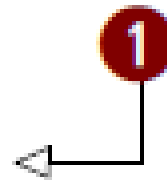
Python 3 – Lists

```
[]
[1]
[1, 2, 3, 4, 5, 6, 7, 8, 12]
[1, "two", 3L, 4.0, ["a", "b"], (5,6)]
```

Indexing and slicing

```
>>> x = ["first", "second", "third", "fourth"]
>>> x[0]
'first'                                    ❶
>>> x[2]
'third'
>>> x[-1]
'fourth'
>>> x[-2]                                  ❷
'third'
>>> x[1:-1]
['second', 'third']
>>> x[0:3]                                 ❸
['first', 'second', 'third']
>>> x[-2:-1]
['third']
```
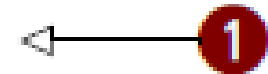
Python 3 – Tuples
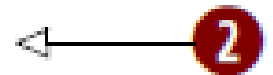
- **Tuples are immutable !!**

```
()
(1,)                                                    ◁───────── ①
(1, 2, 3, 4, 5, 6, 7, 8, 12)
(1, "two", 3L, 4.0, ["a", "b"], (5, 6))                 ◁───────── ②


>>> x = [1, 2, 3, 4]          >>> x = (1, 2, 3, 4)
>>> tuple(x)                  >>> list(x)
(1, 2, 3, 4)                  [1, 2, 3, 4]
```

Puthon 3 - Strings

- ■ Strings are also immutable !!

```
"A string in double quotes can contain 'single quote' characters."
'A string in single quotes can contain "double quote" characters.'
'''\This string starts with a tab and ends with a newline character.\n'''
"""This is a triple double quoted string, the only kind that can
    contain real newlines."""
```

- ■ The print function outputs strings

```
>>> e = 2.718
>>> x = [1, "two", 3, 4.0, ["a", "b"], (5, 6)]
>>> print("The constant e is:", e, "and the list x is:", x)

The constant e is: 2.718 and the list x is: [1, 'two', 3, 4.0,
['a', 'b'], (5, 6)]
>>> print("the value of %s is: %.2f" % ("e", e))
the value of e is: 2.72
```

❶

❷

Python 3 – Dictionaries

```
>>> x = {1: "one", 2: "two"}
>>> x["first"] = "one"
>>> x[("Delorme", "Ryan", 1995)] = (1, 2, 3)
>>> list(x.keys())
['first', 2, 1, ('Delorme', 'Ryan', 1995)]
>>> x[1]
'one'
>>> x.get(1, "not available")
'one'
>>> x.get(4, "not available")
'not available'
```

①

②

Python 3 – Sets

- A set is an unordered collection of objects

```
>>> x = set([1, 2, 3, 1, 3, 5])
>>> x
{1, 2, 3, 5}
>>> 1 in x
True
>>> 4 in x
False
```
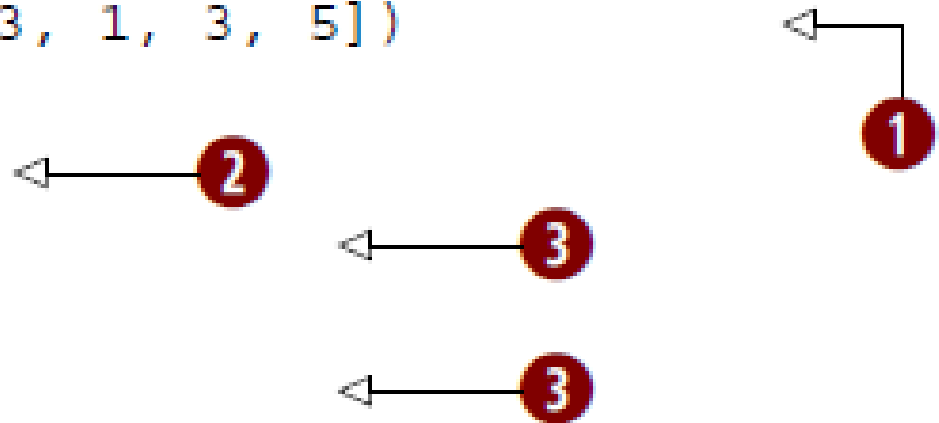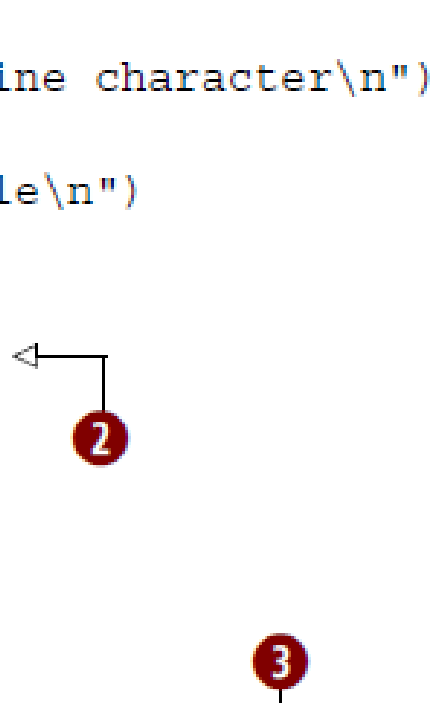
Python 3 – File objects

```
>>> f = open("myfile", "w")
>>> f.write("First line with necessary newline character\n")
44
>>> f.write("Second line to write to the file\n")
33
>>> f.close()
>>> f = open("myfile", "r")
>>> line1 = f.readline()
>>> line2 = f.readline()
>>> f.close()
>>> print(line1, line2)
First line with necessary newline character
Second line to write to the file
```
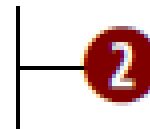
1

2
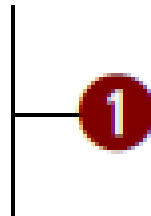
3

Python 3 – The os module

```
>>> import os
>>> print(os.getcwd())
c:\My Documents\test
>>> os.chdir(os.path.join("c:", "My Documents", "images"))
>>> filename = os.path.join("c:", "My Documents",
"test", "myfile")
>>> print(filename)
c:\My Documents\test\myfile
>>> f = open(filename, "r")
>>> print(f.readline())
First line with necessary newline character
>>> f.close()
```
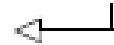
5

The if-elif-else statement

```python
x = 5
if x < 5:
    y = -1
    z = 5
elif x > 5:
    y = 1
    z = 11
else:
    y = 0
    z = 10
print(x, y, z)
```

① ②

The while loop
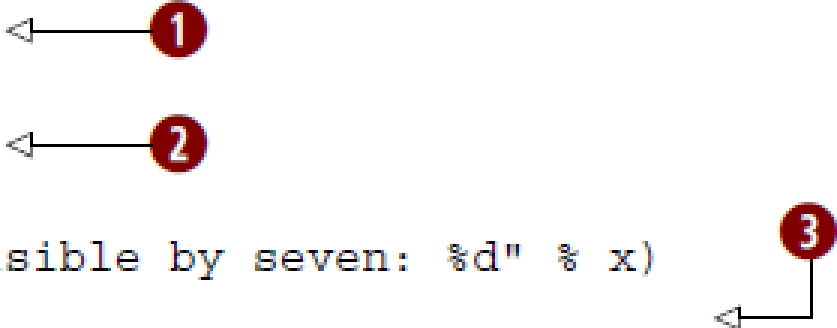
```
u, v, x, y = 0, 0, 100, 30
while x > y:
    u = u + y
    x = x - y
    if x < y + 2:
        v = v + x
        x = 0
    else:
        v = v + y + 2
        x = x - y - 2
print(u, v)
```
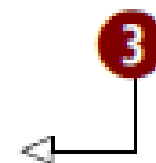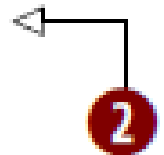
①

②

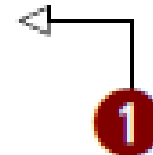# The for iterator

```
item_list = [3, "string1", 23, 14.0, "string2", 49, 64, 70]
for x in item_list:                              ◁————❶
    if not isinstance(x, int):
        continue                                 ◁————❷
    if not x % 7:
        print("found an integer divisible by seven: %d" % x)  ❸
        break                                    ◁—
```

Functions

```
>>> def funct1(x, y, z):
...       value = x + 2*y + z**2
...       if value > 0:
...             return x + 2*y + z**2
...       else:
...             return 0
...
>>> u, v = 3, 4
>>> funct1(u, v, 2)
15
>>> funct1(u, z=v, y=2)
23
```
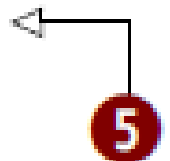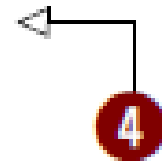
1

2

3

Functions

```
>>> def funct2(x, y=1, z=1):
...     return x + 2 * y + z ** 2
...
>>> funct2(3, z=4)
21
>>> def funct3(x, y=1, z=1, *tup):
...     print((x, y, z) + tup)
...
>>> funct3(2)
(2, 1, 1)
>>> funct3(1, 2, 3, 4, 5, 6, 7, 8, 9)
(1, 2, 3, 4, 5, 6, 7, 8, 9)
```

④

⑤

Module creation

```python
"""wo module. Contains function: words_occur()"""      1
# interface functions                          2
def words_occur():
    """words_occur() - count the occurrences of words in a file."""
    # Prompt user for the name of the file to use.
    file_name = input("Enter the name of the file: ")
    # Open the file, read it and store its words in a list.
    f = open(file_name, 'r')                        3
    word_list = f.read().split()
    f.close()
    # Count the number of occurrences of each word in the file.
    occurs_dict = {}
    for word in word_list:
        # increment the occurrences count for this word
        occurs_dict[word] = occurs_dict.get(word, 0) + 1
    # Print out the results.                          4
    print("File %s has %d words (%d are unique)" \
      % (file_name, len(word_list), len(occurs_dict)))
    print(occurs_dict)                               5
if __name__ == '__main__':
    words_occur()
```

Object-oriented programming

```python
"""sh module. Contains classes Shape, Square and Circle"""
class Shape:                                              ◁──── ①
    """Shape class: has method move"""
    def __init__(self, x, y):                             ◁──── ②
        self.x = x                                          ├─── ③
        self.y = y
    def move(self, deltaX, deltaY):                                    ◁──┐
        self.x = self.x + deltaX                                          │
        self.y = self.y + deltaY                                        ④
class Square(Shape):
    """Square Class:inherits from Shape"""
    def __init__(self, side=1, x=0, y=0):
        Shape.__init__(self, x, y)
        self.side = side                                          ⑤
```

Object-oriented programming

```
class Circle(Shape):
    """Circle Class: inherits from Shape and has method area"""
    pi = 3.14159
    def __init__(self, r=1, x=0, y=0):
        Shape.__init__(self, x, y)
        self.radius = r
    def area(self):
        """Circle area method: returns the area of the circle."""
        return self.radius * self.radius * self.pi
    def __str__(self):
        return "Circle of radius %s at coordinates (%d, %d)"\
                % (self.radius, self.x, self.y)
```

6

7

8

Object-oriented programming

```
>>> import sh
>>> c1 = sh.Circle()                              ◁── ❶
>>> c2 = sh.Circle(5, 15, 20)
>>> print(c1)
Circle of radius 1 at coordinates (0, 0)
>>> print(c2)
Circle of radius 5 at coordinates (15, 20)        ◁── ❷
>>> c2.area()
78.53974999999998
>>> c2.move(5,6)                                  ◁── ❸
>>> print(c2)
Circle of radius 5 at coordinates (20, 26)
```
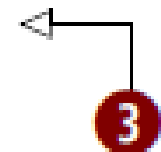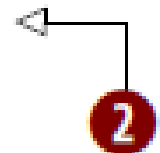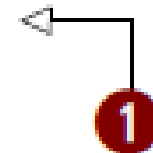
COMPUTATIONAL EFFICIENCY

Efficiency Analysis

- How fast does an algorithm run ?
  - Most algorithms run longer on larger inputs !

- How to relate running time to input size ?

- How to rank / compare algorithms ?
  - If there is more than one available…

- How to estimate running time for larger problem instances ?

Running Time vs. Operations Count

- **Running time is not (very) useful for comparing algorithms**
  - Speed of particular computers
  - Chosen computer language
  - Quality of programming implementation
  - Compiler optimizations

- **Evaluate efficiency in an independent way**
  - Count the "basic operations" !!
    - Contribute the most to overall running time

Input Size

- Relate operations count / running time to input size !!
  - Number of array / matrix / list elements
  - …

- Relate size metric to the main operations of an algorithm
  - Working with individual chars vs. with words
  - Number of bits in binary rep., when checking if n is prime
  - …

Formal Analysis – Pencil and paper

- **Understand algorithm behavior**
  - Count arithmetic operations / comparisons
  - Find a closed formula !!
  - Identify best, worst and average case situations, if that is the case

- **Iterative algorithms**
  - Loops : how many iterations ?
  - Set a sum for the basic operation counts

- **Recursive algorithms**
  - How many recursive calls ?
  - Establish and solve appropriate recurrences

TASK 1 : ITERATIVE ALGORITHMS

Return value? – Number of iterations?

```
int f1(int n) {
  int i,r=0;
  for(i = 1; i <= n; i++)
    r += i;
  return r;
}
```

```
int f2(int n) {
  int i,j,r=0;
  for(i = 1; i <= n; i++)
    for(j = 1; j <= n; j++)
      r += 1;
  return r;
}
```

```
int f3(int n) {
  int i,j,r=0;
  for(i = 1; i <= n; i++)
    for(j = i; j <= n; j++)
      r += 1;
  return r;
}
```

```
int f4(int n) {
  int i,j,r=0;
  for(i = 1; i <= n; i++)
    for(j = 1; j <= i; j++)
      r += j;
  return r;
}
```

Tasks – Closed formulas

- Result of each function ?

- Number of times the innermost instruction is executed ?

- Start by writing down summations !

- Use WolframAlpha to check your results !

WolframAlpha

https://www.wolframalpha.com/

Tasks

- **Implement** the functions of the previous slide in **Python**

- **Check** the correctness of the previously obtained **closed formulas**

TASK 2 :
RECURSIVE ALGORITHMS

Return value? – Number of calls?

```
unsigned int
r1(unsigned int n) {
    if(n == 0) return 0;
    return 1 + r1(n – 1);
}
```

```
unsigned int
r2(unsigned int n) {
    if(n == 0) return 0;
    if(n == 1) return 1;
    return n + r2(n – 2);
}
```

```
unsigned int
r3(unsigned int n) {
    if(n == 0) return 0;
    return 1 + 2 * r3(n – 1);
}
```

```
unsigned int
r4(unsigned int n) {
    if(n == 0) return 0;
    return 1 + r4(n – 1) + r4(n – 1);
}
```

Tasks – Closed formulas

- **Result** of each function ?

- Number of **recursive calls** ?

- Start by writing down **reccurrences** and solving them !

- Use [WolframAlpha](#) to check your results !

Tasks

- **Implement** the functions of the previous slide in **Python**

- **Check** the correctness of the previously obtained **closed formulas**

REFERENCES

References

- V. L. Ceder, *The Quick Python Book*, 2nd Ed., Manning, 2010
  - Chapter 1 + Chapter 2 + Chapter 3

- A. Levitin, *Introduction to the Design and Analysis of Algorithms,* 3rd Ed., Pearson, 2012
  - Chapter 1 + Chapter 2

- T. H. Cormen et al., *Introduction to Algorithms*, 3rd Ed., MIT Press, 2009
  - Chapter 1

Acknowledgment

- The Python overview slides are based on V. L. Ceder's book:
  - V. L. Ceder, *The Quick Python Book*, 2nd Ed., Manning, 2010

- The Python examples are from Chapter 1 and Chapter 3 of that book