6.100A
Final Review

Type of knowledge

Declarative knowledge - a statement of fact

- Stata is building 32

Imperative knowledge - a recipe, ‘how-to’ knowledge

1. Start at Student Center
2. Walk down Mass Ave, towards Vassar St
3. Make a right on Vassar
4. Walk until you see a funky-looking building

Programming is about writing recipes to generate facts!

Expressions and Statements

Expression - combination of objects and operators, and can be evaluated to a value

- 3 + 5
- a or (True and b)

Statements - instructs the interpreter to perform some action

- print(3 + 5)
- return a or (True and b)

Primitive Types

1) Boolean → True, False
2) Strings → “abc”, “123”, “@#%!$&@*”
3) Numbers:
    a) ints: 0, 1, 2, 3
    b) floats: 1., 1.46, 8.76, 1.1111
4) None

Type Issues

a. 1 // 2 = 0 (integer division)
b. 1.0 // 2 = 0.0 (integer division casted (implicitly) to float)
c. 1 / 2 = 0.5 (float division)
d. int(1 / 2) = 0 (casting)

NOTE: integer division truncates the answer – it does NOT round to nearest int (use round for that)

7 / 3 = 2.33333333

7 // 3 = 2

7 / 4 = 1.75

7 // 4 = 1

Operations

- Arithmetic operations (follow order of operations / PEMDAS rules)
  - +, -, *, /
  - ** for exponents
  - % modulo to get remainder
- String operations
  - + for concatenation
  - * to repeat
- Boolean comparators
  - >, >=, <, <=, ==, !=
- Logical operators
  - and, or, not

Representing Numbers - Binary

Integers are represented in **base 2**, also known as binary:

$$1 \quad 0 \quad 1 \quad 1 \quad 0 \quad 1 \quad 0 \quad 1 = 181$$

$$2^7 \quad 2^6 \quad 2^5 \quad 2^4 \quad 2^3 \quad 2^2 \quad 2^1 \quad 2^0$$

$$128 + 0 + 32 + 16 + 0 + 4 + 0 + 1$$

Representing Numbers - Floats

Two parts, the **mantissa** and the **exponent**, both represented in **binary**

$$M * 2^p \rightarrow (M, p)$$

mantissa exponent

$$1.25 = 5 * 2^{-2} = (101, -10)$$

T/F Question!

T/F Question: The value of ‘math.sqrt(2.0)*math.sqrt(2.0) == 2.0’ is True.

False! 2.0000000000000004 != 2.0

Approximation - Floats

```
In [1]: import math

In [2]: math.sqrt(2.0) * math.sqrt(2.0) == 2.0
Out[2]: False

In [3]: print(math.sqrt(2.0) * math.sqrt(2.0))
2.0000000000000004

In [4]: abs((math.sqrt(2.0) * math.sqrt(2.0)) - 2.0) < 1e-9
Out[4]: True
```

Questions?

Swap Variables: Question

```
x = 1
y = 2
y = x
x = y
```

Swap Variables

```
x = 1
y = 2
y = x
x = y
```

```
x = 1
y = 2
temp = y
y = x
x = temp
```

```
x = 1
y = 2
y, x = x, y
```

Very pythonic!

Control: IF

if condition 1:

    # some code to run

if condition 2:

    # other code to be run

else:

    # some code to run if **condition 2** was not met

Control: IF

if condition 1:

    # some code to run

elif condition 2:

    # some other code to run **instead**

else:

    # some more conditions to run if the other conditions weren't met

Control: Loops

for

- Repeat this block of code once per element in the given iterable

- for *var* in *iterable*:

      #code

while

- Repeat this block of code until a given condition is False

- while *condition*:

      #code

Control: For Loops

```
>>> word = 'hello'
>>> for letter in word:
        print(letter)

>>> |
```

```
>>> word = 'hello'
>>> for i in range(len(word)):
        print(word[i])

>>> |
```

Think about if you want the element in the iterable itself, or just its index

```
>>> char_list = ['a', 'b', 'c']
>>> for char in char_list:
        print(char)

>>> |
```

```
>>> char_list = ['a', 'b', 'c']
>>> for i in range(len(char_list)):
        print(char_list[i])

>>> |
```

Example Question

What is going to be printed?

```
T = (0.1, 0.1)
x = 0.0

for i in range(len(T)):

    for j in T:
        x += i + j
        print (x)

print( i )
```

Example Question

```
T = (0.1, 0.1)
x = 0.0

for i in range(len(T)):

    for j in T:
        x += i + j
        print (x)

print( i )
```

What is going to be printed?

Behind the scenes (bolded text is what is printed):
Remember, x += i + j is the equivalent of x = x + i + j

i = 0
    j = 0.1
        x = x + i + j → x = 0.0 + 0 + 0.1 = **0.1**
    j = 0.1
        x = x + i + j → x = 0.1 + 0 + 0.1 = **0.2**
i = 1
    j = 0.1
        x = x + i + j → x = 0.2 + 1 + 0.1 = **1.3**
    j = 0.1
        x = x + i + j → x = 1.3 + 1 + 0.1 = **2.4**

Last value of i was 1 → **1**

Guess and Check

- Guess a value for the solution
- Check if the solution is correct
- Keep guessing until solution is good enough

Process is exhaustive enumeration, can take really long to find answer

Example of Guess & Check: Finding Square Roots

```
number = int(input("Enter a number: ") )
answer = 0
steps = 0
while answer**2 < abs(number):
    answer = answer + 1
    steps+=1
#if square of ans is not equals to actual number, then x is not a perfect square
if answer**2 != abs(number):
    print(str(number) + ' is not a perfect square')
else:
    print('Square root of ' + str(number) + ' is ' + str(answer))
    print('The steps it took to reach the ans are:  ' + str(steps))
```

Questions?

Lists

- Ordered sequence of elements
- Initialized with square brackets
- Mutable

```
>>> myList = [3,5,2,7]
>>> myList[0]
3
>>> myList[1] = 6
[3, 6, 2, 7]
>>> myList[:2]
[3, 6]
```

T/F Question :

Given a list L = ['f', 'b'] the statement L[1] = 'c' will mutate list L. True

T/F Question :

Let L be a list, each element of which is a list of ints. In Python, the assignment statement L[0][0] = 3 mutates the list L. False

List Functions

```
>>> letters = ['a','b','d']
>>> len(letters)
3
>>> letters.append([‘e’])
['a', 'b', 'd', ['e']]
>>> letters.extend(['b', 'a'])
['a', 'b', 'd', ['e'], 'b', 'a']
>>> letters.insert(2, 'c')
['a', 'b', 'c', 'd', ['e'], 'b', 'a']
```

```
>>> letters.remove('a')
['b', 'c', 'd', ['e'], 'b', 'a']
>>> letters.reverse()
['a', 'b', ['e'], 'd', 'c', 'b']
>>> letters.pop()
'b'
>>> letters
['a', 'b', ['e'], 'd', 'c']
```

List Indexing

```
>>> letters = ['a', 'b', 'c', 'd', 'e']
>>> letters[:]
['a', 'b', 'c', 'd', 'e']
>>> letters[2:]
['c', 'd', 'e']
>>> letters[:2]
['a', 'b']
>>> letters[:-2]
['a', 'b', 'c']
```

```
>>> letters[::2]
['a', 'c',  'e']
>>> letters[::-1]
['e', 'd', 'c', 'b', 'a']
>>> letters[1:4:2]
['b', 'd']
```

List Comprehensions

A fast, pythonic trick!

Create a **new** list using the values in an existing one:

```
L1 = [0, 4, 8, 16]
L2 = [x ** 2 for x in L1]
print(L1)
print(L2)
```

```
>>> [0, 4, 8, 16]
>>> [0, 16, 64, 256]
```

Tuples

Like lists, but immutable

t1 = (1, 2, 3, “abc”)

t2 = (5, 6, t1)

Operations:

Concatenation: t1 + t2 `(1,2,3,'abc',5,6,(1,2,3,'abc'))`

Indexing: (t1+t2) [3] `‘abc’`

Slicing: (t1+t2) [1:3] `(2,3)`

- You can iterate over tuples
- You cannot mutate tuples
- Can be used as keys in the dictionary (lists can’t) - **why?**

Dictionaries

- Key, value pairs
- Keys can be integers, strings, tuples, etc. (anything **immutable**)
- Keys can't be lists, dictionaries, etc. (anything mutable)
- Keys are unique, values don't have to be

True

T/F Question: In Python, the keys of a dict must be immutable.

T/F Question: The dictionary {'a':'1', 'b':'2', 'c': '3'} has a mapping of string:int

False

Using Dictionaries

```
>>> zoo = {'elephant' : 3, 'giraffe' : 4}
>>> len(zoo)
2
>>> zoo['elephant']
3
>>> zoo['frog']
KeyError: 'frog'
>>> zoo.get('frog', 'Frog is not in zoo')
    'Frog is not in zoo'
>>> if 'cheetah' not in zoo:
    zoo['cheetah'] = 5
```

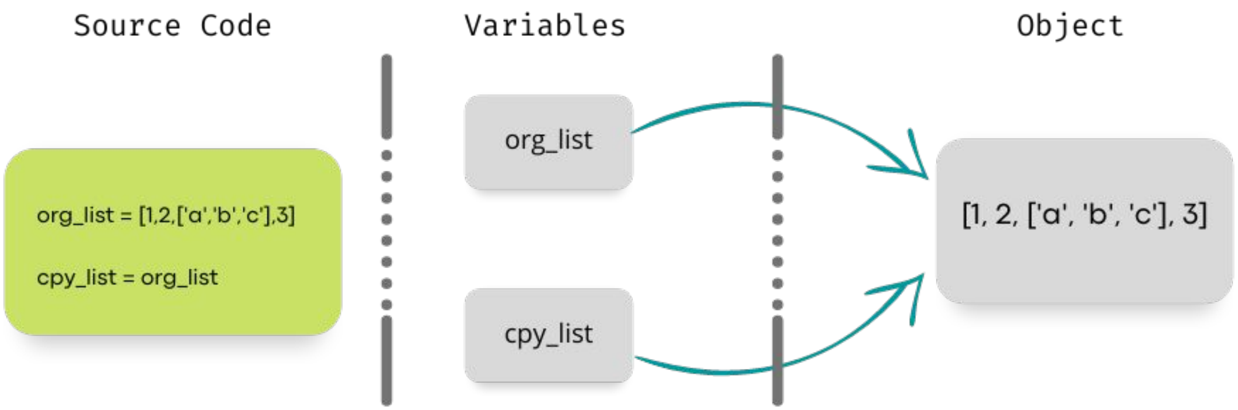
```
>>> zoo
{'cheetah': 5, 'giraffe': 4, 'elephant': 3}
>>> list(zoo.keys())
['cheetah', 'giraffe', 'elephant']
>>> list(zoo.values())
[5, 4, 3]
>>> del zoo['elephant']
>>> zoo
{'cheetah': 5, 'giraffe': 4}
```

Mutability & Aliasing

Mutable: Lists, Dictionaries, Sets
Immutable: Strings, int, float, bool, tuples

Aliasing: Two variables bound to the same object

```
>>> a = [1]
>>> b = a
>>> a.append(2)
>>> print (a)
[1, 2]
>>> print (b)
[1, 2]
```



Mutability: Lists

```
L1 = ['a', 'b', 'c']
L2 = [ [ ], L1, 1]
L3 = [ [ ], ['a', 'b', 'c'], 1]
L4 = [L1]+L1
L2[1][2]='z'
print( 'L1 = ', L1 )
print( 'L2 = ', L2 )
print( 'L3 = ', L3 )
print( 'L4 = ', L4 )
```

What is going to be printed?

```
L1 =  ['a', 'b', 'z']
L2 =  [[], ['a', 'b', 'z'], 1]
L3 =  [[], ['a', 'b', 'c'], 1]
L4 =  [['a', 'b', 'z'], 'a', 'b', 'c']
```

Cloning

```
L1 = ['a', 'b', 'c']
L2 = L1[:]

print( 'L1 = ', L1 )
print( 'L2 = ', L2 )

L1.append('d')

print( 'L1 = ', L1 )
print( 'L2 = ', L2 )
```

What is going to be printed?

L1 = ['a', 'b', 'c']
L2 = ['a', 'b', 'c']
L1 = ['a', 'b', 'c', 'd']
L2 = ['a', 'b', 'c']

Questions?

Abstraction & Decomposition

How to think about and solve complex systems at a high-level:

- **break up** a problem into simpler building blocks
- give each block a **name**, forget about the details of how it’s built, just know its **inputs** and **outputs**

Abstraction & Decomposition

Why abstract and decompose?

- better code organization
- fewer lines of code
- can test small units (testing full system may be unmanageable)

Abstraction & Decomposition

How do we abstract and decompose?

Functions !!!

the most basic unit of code abstraction

<u>Variables</u> abstract <u>values</u>

<u>Functions</u> abstract <u>blocks of code</u>

Functions

1. name

2. Inputs (parameters)

3. Promises a certain behavior (if given proper inputs)

```
def function_name(arg1, arg2, …, argN):
    '''
    docstring here (can specify the function's promise)
    '''
    #some code
    #some more code
    return something
```

Functions

Calling a function ⇒ running it, with specific parameters

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Calling a function ⇒ running it, with specific parameters

How to call a function:

- specify name
- *pass* the parameters
- optionally, save the returned output

```
out = function_name(x1,x2,…,xn)
```

Functions examples

function definition

```
def even_or_odd(number):
    '''
    Returns True if number is even, False otherwise
    '''
    if number % 2 == 0 :
        return True
    else:
        return False
```

function call

```
three_is_even = even_or_odd(3)
```

Question: what's the difference between **even_or_odd()** and **even_or_odd** in code?

Functions examples

```
def mult_by_five(number):
    print(number * 5)
```

```
mult_by_five("hi")
```

what does this do? **Prints: hihihihihi**

what is returned by **mult_by_five** ? **None !**

Lambda functions

A way to define a short function in one line, often to be used as an argument to another function:

```python
def run_function_twice(a_function, param1, param2):
    """
    a_function: A function with one parameter
    param1: The input to the function to run the first time
    param2: The input to the function to run the second time
    """
    print(a_function(param1))
    print(a_function(param2))

func = lambda x: x ** 2 + 2 * x + 1

run_function_twice(func, 2, 3) # prints 9, 16
```

Questions?

Scope

scope dictates what parts of a program can see each variable’s value

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- a scope is a table, mapping variable names to values
  - assignment (<variable> = <expression>) adds an item to the table

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Scope

scope dictates what parts of a program can see each variable's value

- a scope is a table, mapping variable names to values
  - assignment (<variable> = <expression>) adds an item to the table
- when your program starts, there's one scope called *global* scope
- when you call a function, a new scope is created
  - the scope is destroyed when the function returns

Scope

How is scope used?

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Scope

How is scope used?

- when a variable is used in an expression, the variable is looked up in the current scope
    - if not found, the variable is looked up in the scope where the function was defined
    - if not found there, repeat until found or we hit global scope and still not found

Scope

global

```
x = 5
y = 8

def my_function(x):
    y = 10
    print(y)    10
    return x * y

print(my_function(9))    90

print(x)    5
print(y)    8
```

Exam Question

```
def testprog(x, y):
    temp = x
    x = y
    y = temp
    print(x)


x = 3
y = -3
print(x)
testprog(x, y)
print(x)
```

What is going to be printed?

3
-3
3

Scope

```
def f(x):
    print('In f(x): x =', x)
    print('In f(x): y =', y)
    def g():
        print('In g(): x =', x)
    g()


x = 3
y = 2
f(1)
```

in f (x) : x = 1
in f (x) : y = 2

in g () : x = 1

Questions?

Recursion

a *recursive* function is any function that calls itself

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Two crucial structural characteristics:

- *Base case*: a simplest version of the input
    - no recursive calls in base case

Recursion

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Two crucial structural characteristics:

- *Base case*: a simplest version of the input
  - no recursive calls in base case
- *Recursive case*: makes one or more recursive calls with a simpler input
  - recursive calls **must** bring us closer to the base case
  - some basic computation is done in addition to the recursive calls

Recursion

When to use recursion?

Recursion

When to use recursion?

when a problem can be solved easily *if*

we have the answer to a <u>subproblem of the same form</u>

Recursion examples

Integer multiplication

$$a*b = a + a*(b-1)$$

Factorial

$$n! = n * (n-1)!$$

Fibonacci

$$fib(n) = fib(n-1) + fib(n-2)$$

Recursion examples

Integer multiplication **a*b = a + a*(b-1)**

```
def recurMul(a, b):
    if b == 1:
        return a
    else:
        return a + recurMul(a, b-1)
```

Recursion examples

Factorial **n! = n * (n-1)!**

```
def factR(n):
    """assumes that n is
 an int > 0
       returns n!"""
    if n == 1:
        return n
    return n*factR(n-1)
```

Recursion examples

Fibonacci $fib(n) = fib(n-1) + fib(n-2)$

```
def fib(x):
    """assumes x an int >= 0
       returns Fibonacci of x"""
    assert type(x) == int and x >= 0
    if x == 0 or x == 1:
        return 1
    else:
        return fib(x-1) + fib(x-2)
```

Final Review Session Part 2

Complexity

- An algorithm might be useless if it takes too long to get an answer
- We need a notion to measure how long an algorithm takes
- We would like our notion to be independent of the machine it runs on

Big O? Θ? Ω?

O(g(n)**)**

Describes an **upper bound** on the runtime complexity

Ω(g(n)**)**

Describes a **lower bound** on the runtime complexity

Θ(g(n)**)**

Describes the **tight (upper and lower) bound** on the runtime complexity

Big Θ Notation

- Describes the runtime of an algorithm as a function of its input size
- Typically describes the worst case runtime
  - "In the worst case, how much time will it take for this algorithm to run?"
- When describing an algorithm, choose the tightest bound

Examples

I have a function $f(x) = 3x^2 + 2x + 1$

O(g(n)**)**

Can be $O(n^2)$, because there exists $g(n) = 4x^2$ that will surpass $f(x)$

But could also be $O(n^3)$, for example, since it will always surpass $f(x)$

Ω(g(n)**)**

Could be $\Omega(n)$, meaning the complexity will always surpass $g(n) = n$

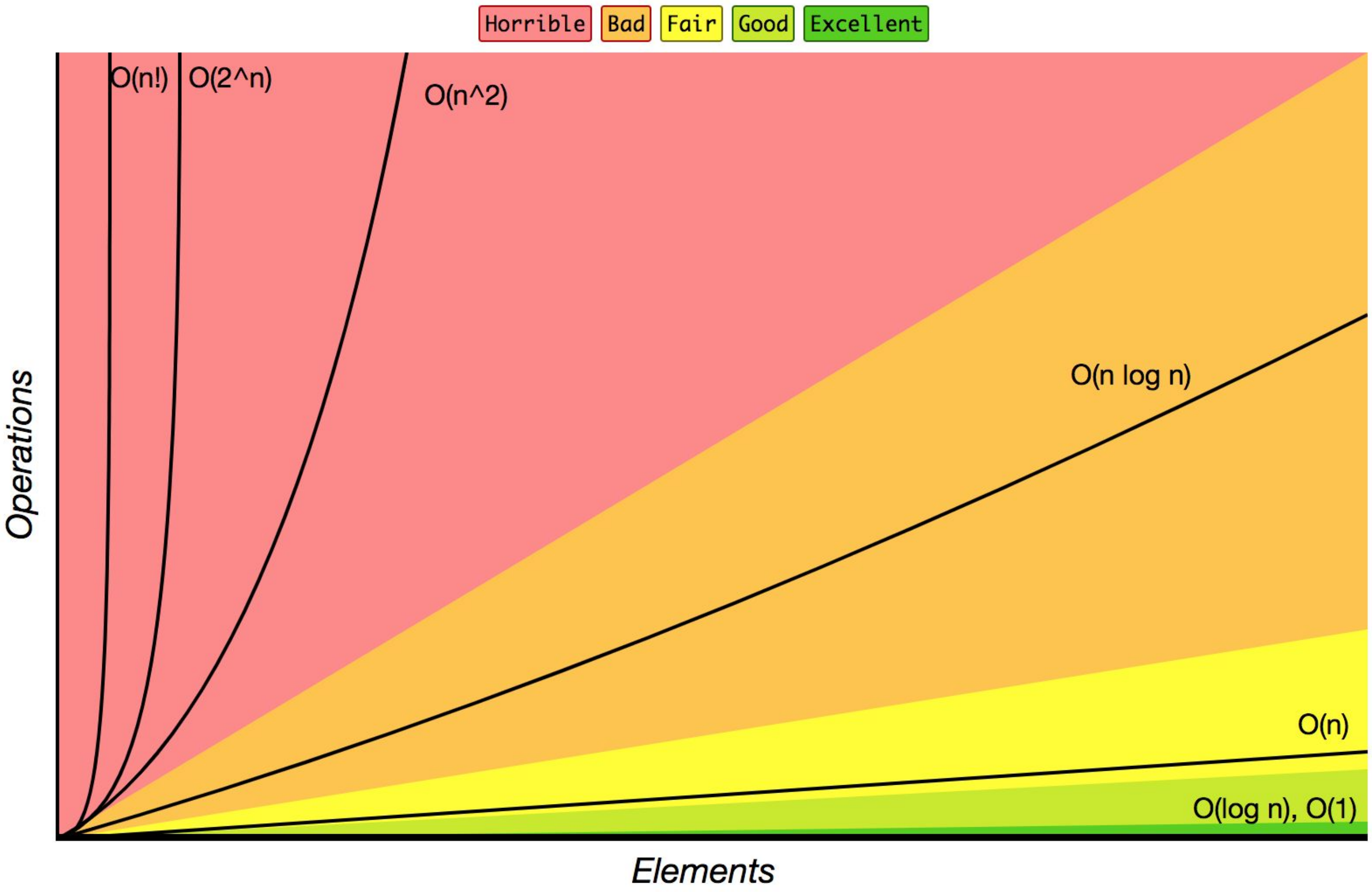
Θ(g(n)**)**

Must be $\Theta(n^2)$, because it is both an upper and lower bound

i.e. $4x^2$ and x^2

bigocheatsheet.com

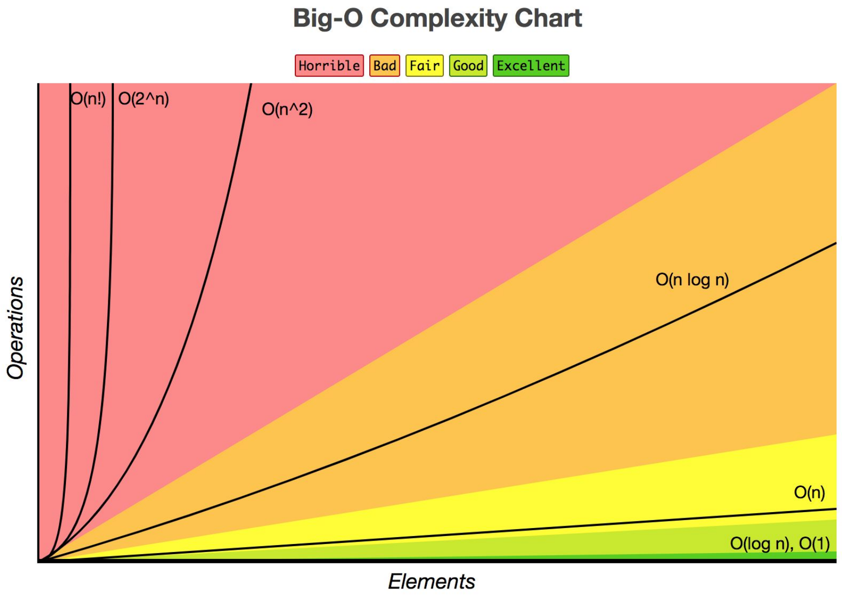
Big-O Complexity Chart



Big Θ Notation Mechanics

Fastest growing term dominates:

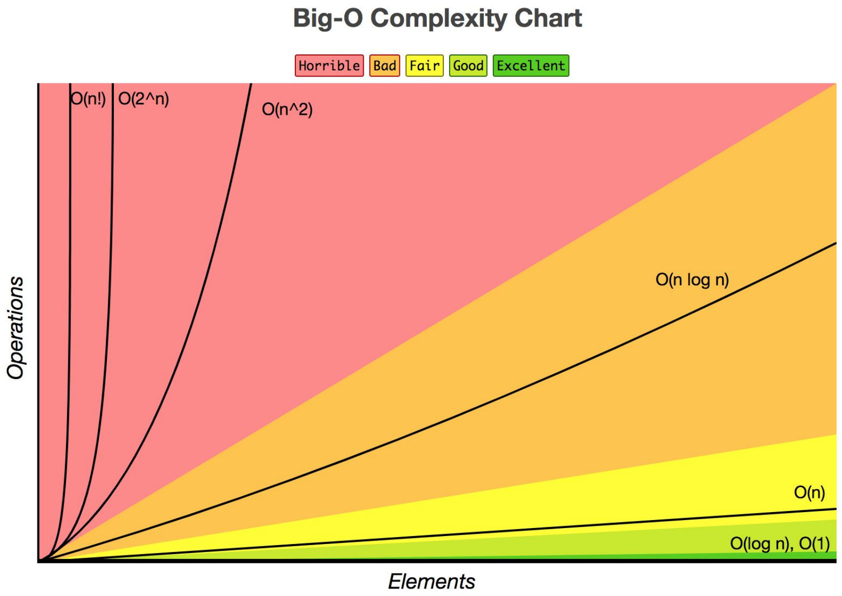
n^2 + 100n + 1000 log(n)



Big Θ Notation Mechanics

Fastest growing term dominates:

$n^2 \cancel{+ 100n + 1000 \log(n)} = \Theta(n^2)$



Big Θ Notation Mechanics

Fastest growing term dominates:

$n^2 + 100n + 1000 \log(n) = \Theta(n^2)$

Constant factors do not affect complexity:

$1000000000n$ $\quad$ $0.0000001n$

Big Θ Notation Mechanics

Fastest growing term dominates:

n^2 + 100n + 1000 log(n) = Θ(n^2)

Constant factors do not affect complexity: **<- WHY??**

~~1000000000~~n = Θ(n) = ~~0.0000001~~n

Commonly Used Complexities in Algorithms

$\Theta(1)$ - Constant

$\Theta(\log n)$ - Logarithmic

$\Theta(n)$ - Linear

$\Theta(n \log n)$ - Log-Linear

$\Theta(n^k)$ - Polynomial

$\Theta(k^n)$ - Exponential

Complexity of built-in methods

- **Constant-time, Θ(1)**
  - Assignment, x=2
  - Basic operations, + - * / > <
- **Dictionary**
  - Look-up: Θ(1)
  - Length: Θ(1)
  - Insert: Θ(1)
  - Delete: Θ(1)
  - dictionary.keys(): Θ(n) - because a list is generated
  - Check if a key is in the dictionary: Θ(1)

Complexity of built-in methods

- **List**
  - Append: Θ(1)
  - Length: Θ(1)
  - Insert: Θ(n)
  - Delete: Θ(n)
  - Copy: Θ(n)
  - Sort: Θ(n log n)
  - Check if an item is in the list: Θ(n)
    - “if elt in a_list:”

Strategies for analyzing complexity

- Loops
  - # of iterations in the loop
  - Amount of work within each loop
- Recursive calls
  - # of recursive calls that are made
  - Amount of work done for each recursive call

Total Time = Time per Iteration * # of Iterations

or Time per Call * # of Calls

What is the complexity?

```
def beep(n):
    tot = 0
    while n >= 2:
        tot += n
        n = n // 2
    return tot
```

Complexity: $\Theta(\log n)$

What is the complexity?

```
def is_palindrome_iterate(s):
    ``` input size, n = len(s) ```
    string_len = len(s)
    i = 0
    while i < string_len//2 +1:
        if s[i] != s[-i-1]:
            return False
        i+=1
    return True
```

Number of iterations: Θ(n)
Number of operations in each iteration: constant
Complexity: Θ(n)
```

What is the complexity?

```
def is_palindrome_recursive(s):
    if len(s) == 0: return True

    if len(s) == 1: return True

    else:
        first_char = s[0]
        last_char = s[-1]
        if first_char == last_char:
            return is_palindrome_recursive(s[1:-1])
        else:
            return False
```

n/2 recursive calls: Θ(n)
Slicing strings: Θ(n)
Complexity: Θ(n^2)

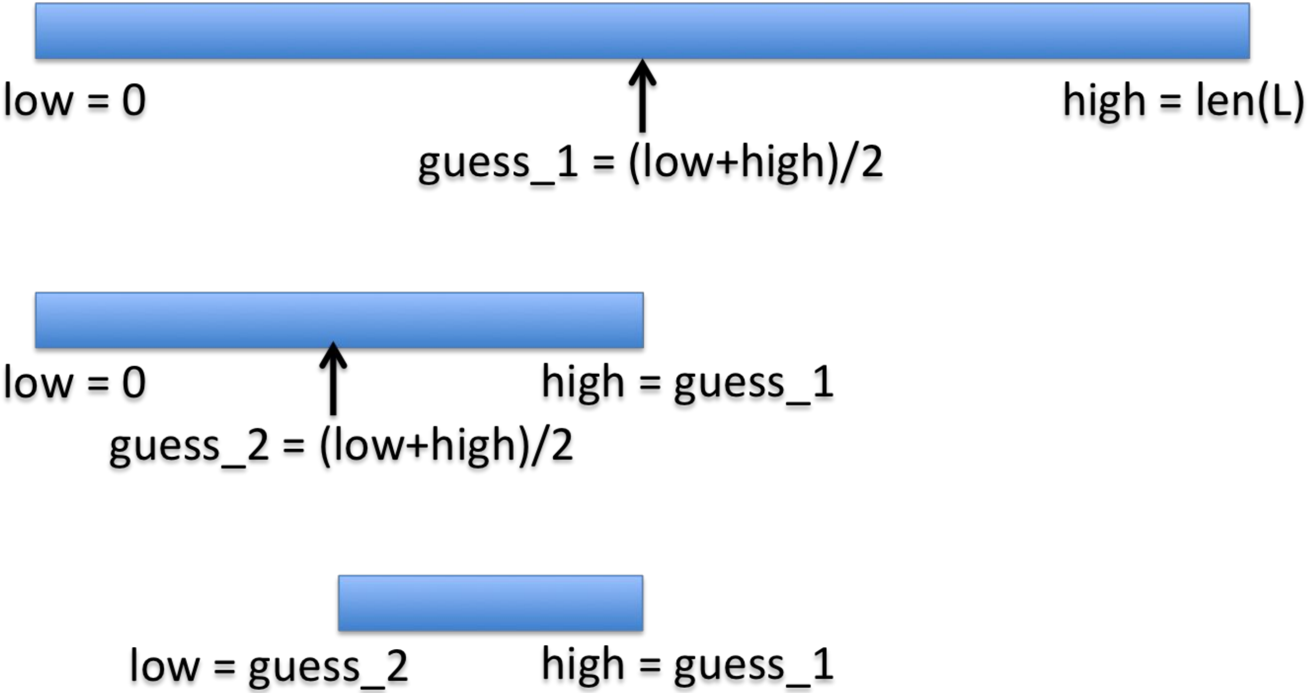
Slicing a string = O(n)

Questions?

Search

- Linear search
  - Brute force search
  - List doesn’t have to be sorted
  - $\Theta(n)$
- Bisection search
  - List must be sorted to give correct answer
  - $\Theta(\log n)$

Bisection search



Complexity of searching unsorted list

- Linear search
  - $\Theta(n)$
  - One time search

- Bisection search
  - complexity(sort) + complexity(bisection search)
  - complexity(sort) + $\Theta(\log n)$
  - complexity(sort) > $\Theta(n)$, always

Sorting Methods: Bubble Sort

- Each step, for i = 0, 1, ... , len(L)-2, swap L[i], L[i+1] such that smaller is first
- Checks every adjacent pair in list to see if it is sorted
- n steps to put everything in order, building right to left
- Up to n passes

First Pass

(**5 1** 4 2 8) –> (**1 5** 4 2 8)
(1 **5 4** 2 8) –> (1 **4 5** 2 8)
(1 4 **5 2** 8) –> (1 4 **2 5** 8)
(1 4 2 **5 8**) –> (1 4 2 **5 8**)

Second Pass

(**1 4** 2 5 8) –> (**1 4** 2 5 8)
(1 **4 2** 5 8) –> (1 **2 4** 5 8)
(1 2 **4 5** 8) –> (1 2 **4 5** 8)
(1 2 4 **5 8**) –> (1 2 4 **5 8**)

Third Pass

(**1 2** 4 5 8) –> (**1 2** 4 5 8)
(1 **2 4** 5 8) –> (1 **2 4** 5 8)
(1 2 **4 5** 8) –> (1 2 **4 5** 8)
(1 2 4 **5 8**) –> (1 2 4 **5 8**)

Sorting Methods: Bubble Sort

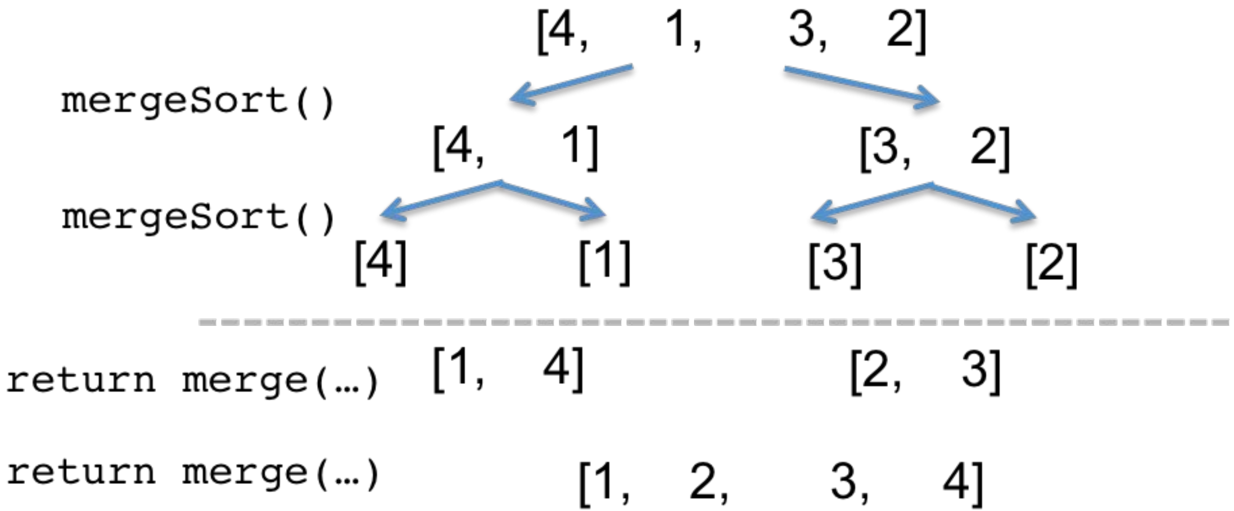
- How many steps?
- Each step, how many operations?
- Complexity?

Sorting Methods: Bubble Sort

- How many steps? $\Theta(n)$
- Each step, how many operations? $\Theta(n)$
- Complexity? $\Theta(n^2)$

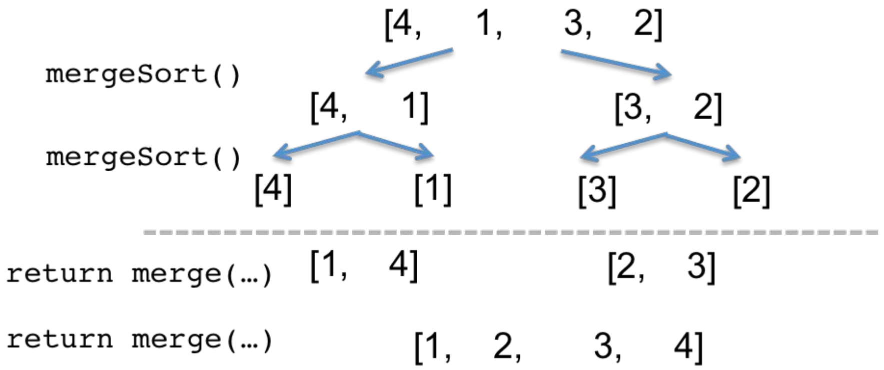
Sorting Methods: Merge Sort

- Break list in half
- Recursively sort both halves
- Merge the sorted halves



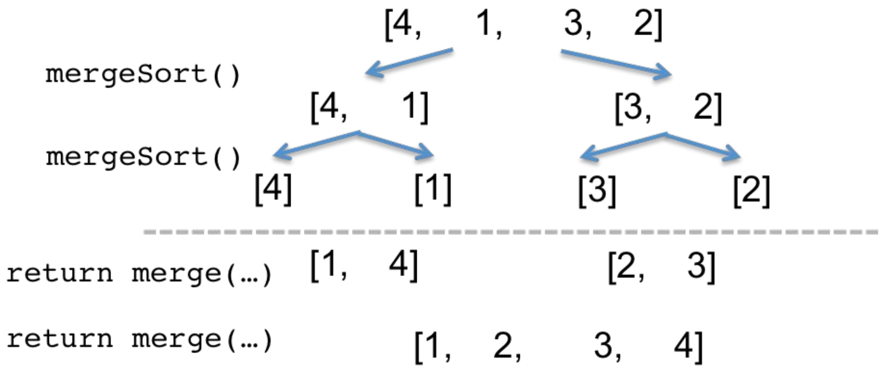
Sorting Methods: Merge Sort

- How many levels of the recursive tree?
- How much computation of each level of the tree?
- Complexity?



Sorting Methods: Merge Sort

- How many levels of the recursive tree? O(log n)
- How much computation of each level of the tree? O(n)
- Complexity? O(n log n)



Questions?

Debugging

- Assertions

```
assert <boolean condition>
assert <boolean condition>, <argument>
```

- Exception

```
try:
    <code>
except <exception_type>:
    <other code to run if try block encounters an exception>
finally:
    <always executed after try, else, and except clauses>
```

Assertion Error

```
x = 3
assert x == 4, 'x is not 4’
```

throws an AssertionError, stops all further computation

Exception Types

- NameError: access a name to a variable
  - ex. NameError: name 'variable_name' is not defined
- ValueError: concatenating a non-string with a string
- IndexError: accessing beyond the limits of a list
  - ex. IndexError: list index out of range
- KeyError: attempting to use a key in a dict that doesn't exist
  - ex. KeyError: 'key_name'
- TypeError: converting an inappropriate type
  - ex. TypeError: unsupported operand type(s) for +: 'int' and 'str'
- AttributeError: trying to append to a string
  - ex. AttributeError: 'str' object has no attribute 'append'

Input Space Partitioning

```
def search_odd(a, b):
    """
    Inputs
        a, b: integers or booleans
    Outputs
        True if either input is equal to True or odd, and False otherwise
    """
    if type(a) == bool:
        if a:
            return True
    else:
        if a%2 == 1:
            return True
    if type(b) == bool:
        if b:
            return True
    else:
        if b%2 == 1:
            return True
    return False
```

Characterizing all types of input a program might allow based on its specification

Input Space Partitioning

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        True if either input is equal to True or odd, and False otherwise
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    if type(a) == bool:
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    else:
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    if type(b) == bool:
        if b:
            return True
    else:
        if b%2 == 1:
            return True
    return False
```

Inputs: {bools}, {ints}

Can subdivide each of those sets:
{bools} → {True}, {False}
{ints} → {evens}, {odds}

Classes

- Classes provide a means of bundling data and functionality together

- They have **attributes** and **methods** specific to themselves

```
class Vehicle(object):
    def __init__(self, name):
        self.name = name # a variable
    def honk(self): # a method
        print(self.name, “says HONK”)
```

Classes

- You can use classes to instantiate **objects**

```
>>> my_vehicle = Vehicle("batmobile")
>>> print(my_vehicle.name)
batmobile
>>> my_vehicle.honk()
batmobile says HONK
```

```
class Vehicle:
    def __init__(self, name):
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    def honk(self): # a method
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```

Classes

- Calling class methods

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batmobile
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batmobile says HONK
>>> my_vehicle.honk
<bound method Vehicle.honk of <__main__.Vehicle instance at
0x1010748c0>>
```

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Classes

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What does this mean?

Classes

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class Vehicle:
    def __init__(self, name):
        self.name = name  # a variable
    def honk(self):  # a method
        print(self.name, “says HONK”)
```

- Calling class methods

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<bound method Vehicle.honk of <__main__.Vehicle instance at
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>>> Vehicle.honk
<unbound method Vehicle.honk>
```

Classes

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class Vehicle:
    def __init__(self, name):
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- Calling class methods

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what??

Classes

- Calling class methods

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<unbound method Vehicle.honk>
>>> Vehicle.honk()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unbound method honk() must be called with Vehicle instance as
first argument (got nothing instead)
>>> Vehicle.honk(my_vehicle)
batmobile says HONK
```

Classes

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class Vehicle:
    def __init__(self, name):
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- Calling class methods

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>>> Vehicle.honk(my_vehicle)
batmobile says HONK
```

WHAT

Classes

```
class Vehicle:
    def __init__(self, name):
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```

- You can use classes to instantiate objects

```
>>> my_vehicle = Vehicle("batmobile")
>>> print(my_vehicle.name)
batmobile
>>> my_vehicle.honk()
batmobile says HONK
>>> my_vehicle.honk -> Bound method: part of a specific object
<bound method Vehicle.honk of <__main__.Vehicle instance at 0x1010748c0>>
>>> Vehicle.honk
<unbound method Vehicle.honk>  -> Unbound method: not part of an object
>>> Vehicle.honk()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unbound method honk() must be called with Vehicle instance as
first argument (got nothing instead)  -> we get an error because
>>> Vehicle.honk(my_vehicle)             there is no data for the
batmobile says HONK                      method to operate on
```