Algorithmic complexity: Speed of algorithms

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UW CSE 160

Bonus Material - Winter 2020

How fast does your program run?

- Usually, this *does not matter*
- Correctness is more important than speed

- Computer time is much cheaper than human time
- The cost of your program depends on:
  – Time to write and verify it
    - High cost: salaries
  – Time to run it
    - Low cost: electricity
- An inefficient program may give you results faster

Sometimes, speed does matter

- Programs that need to run in real time
  - e.g. will my car crash into the car in front of me?
- Very large datasets
  - Even inefficient algorithms usually run quickly enough on a small dataset
  - Example large data set:

    Google:

    67 billion pages indexed (2014)

    5.7 billion searches per day (2014)

    Number of pages searched per day??

Program Performance

We'll discuss two things a programmer can do to improve program performance:

- Good Coding Practices – covered 2/28/2020
- Good Algorithm Choice

Good Algorithm Choice

- Good choice of algorithm can have a much bigger impact on performance than the good coding practices mentioned.
- However good coding practices can be applied fairly easily
- Trying to come up with a better algorithm can be a (fun!) challenge
- Remember:
  Correctness is more important than **speed!!**

How to compare two algorithms?

- Implement them both in Python
- Run them and time them

A Better Way to Compare Two Algorithms

- Hardware?
  - Count number of “operations” something independent of speed of processor
- Properties of data set? (e.g. almost sorted, all one value, reverse sorted order)
  - Pick the worst possible data set: gives you an upper bound on how long the algorithm will take
  - Also it can be hard to decide on what is and “average” data set
- Size of data set?
  - Describe running time of algorithm as a function of data set size

Asymptotic Analysis

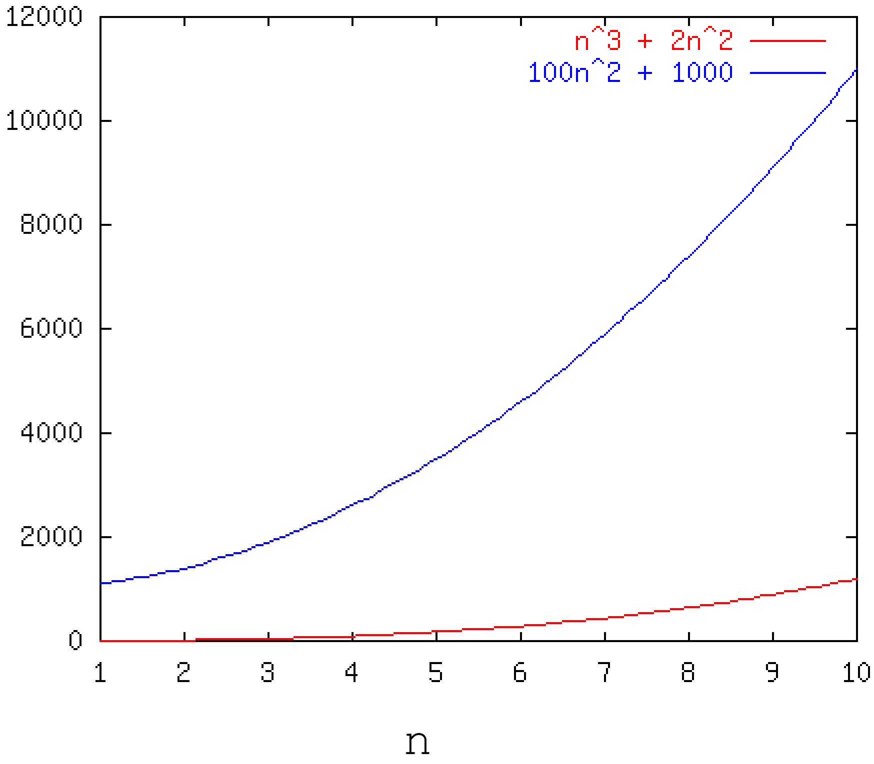
- Comparing "Orders of Growth"
- This approach works <u>when problem size is large</u>
  - When problem size is small, "constant factors" matter
- A few common Orders of Growth:

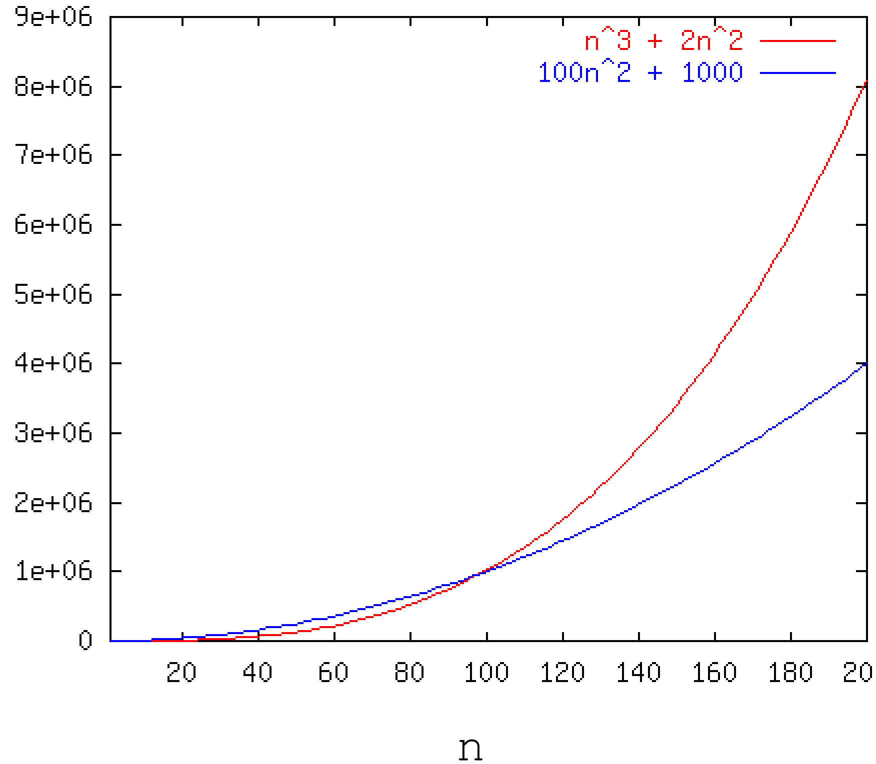
		Example:
– Constant	$O(1)$	integer + integer
– Linear	$O(n)$	iterating through a list
– Quadratic	$O(n^2)$	iterating through a grid

Which Function Grows Faster?

$O(n^3)$ $O(n^2)$

$n^3 + 2n^2$ vs. $100n^2 + 1000$





Running Times of Python Operations

Constant Time operations: O(1)

- Basic Math on numbers (+ - * /)
- Indexing into a sequence (eg. list, string, tuple) or dictionary
  - E.g. `myList[3] = 25`
- List operations: **`append`**, **`pop`**(at end of list)
- Sequence operation: **`len`**
- Dictionary operation: **`in`**
- Set operations: **`in`**, **`add`**, **`remove`**, **`len`**

Linear Time operations: O(n)

- **`for`** loop traversing an entire sequence or dictionary
- Built in functions: **`sum`**, **`min`**, **`max`**, slicing a sequence
- Sequence operations: **`in`**, **`index`**, **`count`**
- Dictionary operations: **`keys()`**, **`values()`**, **`items()`**
- Set operations: **`&`**, **`|`**, **`-`**
- String concatenation (linear in length of strings)

Note: These are general guidelines, may vary, or may have a more costly worst case. Built in functions (e.g. sum, max, min, sort) are often faster than implementing them yourself.

Example: Processing pairs

```
def make_pairs(list1, list2):
    """Return a list of pairs.
    Each pair is made of corresponding elements of list1 and list2.
    list1 and list2 must be of the same length."""
    …

assert make_pairs([100, 200, 300], [101, 201, 301]) == [[100, 101],
[200, 201], [300, 301]]
```

- 2 nested loops vs. 1 loop
- Quadratic (n^2) vs. linear (n) time

Example: Searching

```
def search(value, lst):
    """Return index of value in list lst.
    The value must be in the list."""
    …
```

- Any list vs. a sorted list
- Linear (n) vs. logarithmic (log n) time

Example: Sorting

```
def sort(lst):
    """Return a sorted version of the list lst.
    The input list is not modified."""
    …

assert sort([3, 1, 4, 1, 5, 9, 2, 6, 5]) == [1, 1,
2, 3, 4, 5, 5, 6, 9]
```

- selection sort vs. quicksort
- 2 nested loops vs. recursive decomposition
- time: quadratic (n^2) vs. log-linear (n log n) time

Note: Calling built in sorting methods sort or sorted in Python has O(n log n) time