

LEC 07

CSE 123

Runtime Analysis

BEFORE WE START

Talk to your neighbors:

*What was the latest Youtube
rabbit hole you went down?*

Instructor: James Wilcox

Questions during Class?

Raise hand or send here

sli.do #cse123



Announcements

- Resubmission Period 1 closes tonight at 11:59pm
- Programming Project 1 out now, due October 29 at 11:59pm

Runtime Analysis

- What's the “best” way to write code?
 - Depends on how you define best: Code quality, memory usage, speed, etc.
- Runtime = most popular way of analyzing solutions
 - Slow code = bad for business
- How do we figure out how long execution takes?
 - Stopwatch = human error
 - Computers = computer error (artifacts, operating systems, language)
 - Need a way to formalize abstractly...

Runtime Analysis

- We'll count simple operations as 1 unit
 - variable initialize / update `int x = 0;`
 - array accessing `arr[0] = 10;`
 - conditional checks `if (x < 10) {`
- Goal: determine how the number of operations scales w/ input size
 - Don't care about the difference between 2 and 4
 - Find the appropriate **complexity class**
- Result: evaluation tactic independent of OS, language, compiler, etc.
 - Simple operation = constant regardless of if it is truly 1

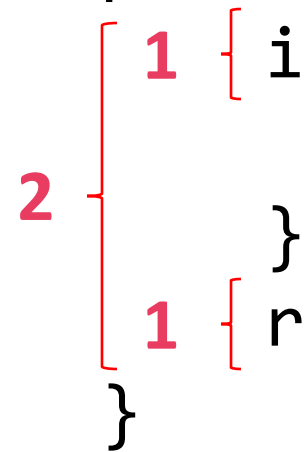
Complexity Classes

- Input will always be an array `arr` of length n
- Constant (1)
 - # Ops doesn't relate to n `return arr[0];`
- Linear (n)
 - # Ops proportional to n `for (int i = 0; i < arr.length; i++)`
- Quadratic (n^2)
 - # Ops proportional to n^2 `for (int i = 0; i < arr.length; i++)`
 `for (int j = 0; j < arr.length; j++)`
- Lets say # Ops = $n^2 + 100000n$
 - If n was really, really, really big, which term matters more?
 - Only care about the **dominating term** for complexity!

Complexity Classes

What's the complexity class of the following?

```
public static void mystery(int[] arr) {  
  1 { if (arr.length == 0) {  
    throw new IllegalArgumentException();  
  }  
  1 { return arr[arr.length - 1];  
}
```



Constant Complexity (1)

Complexity Classes

What's the complexity class of the following?

```
public static int mystery(int[] arr) {  
    1 { int sum = 0;  
    3n { for (int i = 0; i < arr.length; i++) {  
    3 { sum += arr[i];  
    }  
    1 { return sum;  
    }  
}
```

$3n + 2$

Linear Complexity (n)

Complexity Classes

What's the complexity class of the following?

```
public static int mystery(int[] arr) {  
    for (int i = 0; i < arr.length; i++) {  
        for (int j = 0; j < arr.length; j++) {  
            System.out.print(arr[i] + " ");  
        }  
        System.out.println();  
    }  
}
```

$n(2n + 1)$
 $= 2n^2 + n$

$2n$ {
 2 {
 System.out.print(arr[i] + " ");
 }
 1 {
 System.out.println();
 }
}

Quadratic Complexity (n^2)

Complexity Classes

What's the complexity class of the following?

```
public static int mystery(int[] arr) {  
    for (int i = 0; i < arr.length; i++) {  
        for (int j = i; j < arr.length; j++) {  
            System.out.print(arr[i] + " ");  
        }  
        System.out.println();  
    }  
}
```

Quadratic Complexity (n^2)

Complexity Classes

What's the complexity class of the following?

```
public static int mystery(int[] arr) {  
    int sum = 0;  
    for (int i = 0; i < 10000000000; i++) {  
        sum += arr[i];  
    }  
    return sum;  
}
```

Big-Oh Notation

- Programmers... are pessimists (or maybe realists)
 - Case in point: dominating term
- In the real world, best-case complexity isn't super useful
 - Want to make sure solutions work well in the worst possible situations
- We use Big-Oh notation to demonstrate worst-case complexity!

```
public static int indexOf(int[] arr, int x) {  
    for (int i = 0; i < arr.length; i++) {  
        if (arr[i] == x) return i;  
    }  
    return -1;  
}
```

***Worst-case
linear
 $O(n)$***

ArrayList vs LinkedList

Operation	ArrayList	LinkedList
size()	$O(1)$	$O(n)$
get(index)	$O(1)$	$O(n)$
add(val)	$O(1)$	$O(n)$
add(0, val)	$O(n)$	$O(1)$
add(index, val)	$O(n)$	$O(n)$
remove(0)	$O(n)$	$O(1)$
remove(n-1)	$O(1)$	$O(n)$
remove(index)	$O(n)$	$O(n)$

How should we implement a stack?

- With an `ArrayIntList`?
 - push = what?
 - pop = what?
- With a `LinkedIntList`?
 - push = what?
 - pop = what?

Is running time an implementation detail?

- Yes
- No
- Does that help? :D