AP CS A and AB: New/Experienced A Tall Order?

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Schedule

- 8:30 – 10:00
  - Intro, resources, what's new
- 10:15 - 12:00
  - Design
  - Inheritance, Interfaces & Abstract Classes
- 12:45 – 3:30
  - Collections -> Analysis -> Big O
  - Reading sample questions and their rubrics

Intro

- A v. AB?
- Years teaching?
- Java experience?
- The cards (years teaching A/AB, 2 things)
- Materials (AB q/ref, A2 & AB1 samples, role play)

Resources

- AP Central
  - Course descriptions
  - Java subset
  - Sample syllabi
- AP list-serve
- JETT workshops
  - 8/6 & 7 at Florida International

What's new?

- 2-D arrays to AB
- Well, Java…
  - No reference parameters
  - Collections
- But also…
  - Design
  - Analysis
  - Priority Queues

Design

- Interfaces – proscribe a set of behaviors
  - methods are public by default
  - NO implementation can be provided
  - NO instance variables can be declared
  - cannot, therefore, be instantiated
    - what does that mean?
  - examples: stack and queue
- Classes realize interfaces by implementing all methods

Design…

- vs. Abstract classes
  - some methods implemented
  - others designated as abstract (which forces the class to be abstract) – these must be implemented by class(es) that extend this abstract class (ultimately)
  - can have instance variables

Design…

- Let's look at A2

- Let's look at some other classes

Collections

- Lists, Sets, Maps
- Raises the level of design (and discourse)
- But, then, what is (are) the issue(s)?

Collections…

- What do they do?
  - List
    - ordered (positionally) – a sequence
    - duplicates?
  - Set
    - unordered collection
    - duplicates?
  - Map
    - Maps (unique) keys to values

Collections…

- How do they do it?
  - Analyze their algorithms
  - But what does that mean?

Algorithm Analysis (kudos to ola)

- How do you measure performance?
  - It's faster! It's more elegant! It's safer! It's cooler!
- Use mathematics to analyze the *algorithm* (performance as function of input size)
- Implementation is another matter
  - cache, compiler optimizations, OS, memory,…

What do we need?

- Need empirical tests and mathematical tools
  - Compare by running
    - 30 seconds vs. 3 seconds,
    - 5 hours vs. 2 minutes
    - Two weeks to implement code

- We need a vocabulary to discuss tradeoffs

What is big-Oh about?

- **Intuition: avoid details when they don't matter, and they don't matter when input size (N) is big enough**
  - **For polynomials, use only leading term, ignore coefficients: linear, quadratic**

$y = 3x$ $\quad y = 6x-2$ $\quad y = 15x + 44$

$y = x^2$ $\quad y = x^2-6x+9$ $\quad y = 3x^2+4x$

O-notation, family of functions

- first family is `O(n)`, the second is $O(n^2)$
  - Intuition: family of curves, same shape
  - More formally: `O(f(n))` is an *upper-bound*, when n is large enough the expression `cf(n)` is larger
  - Intuition: linear function: double input, double time, quadratic function: double input, quadruple the time

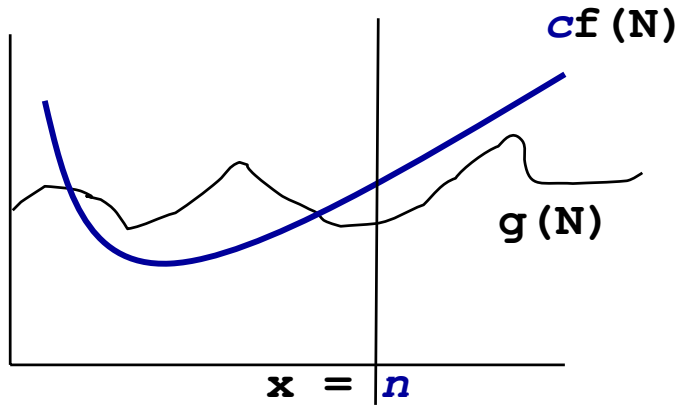
Reasoning about algorithms

- **We have an O(n) algorithm,**
  - **For 5,000 elements takes 3.2 seconds**
  - **For 10,000 elements takes 6.4 seconds**
  - **For 15,000 elements takes ….?**

- **We have an $O(n^2)$ algorithm**
  - **For 5,000 elements takes 2.4 seconds**
  - **For 10,000 elements takes 9.6 seconds**
  - **For 15,000 elements takes …?**

More formal definition

- O-notation is an upper-bound, this means that N is O(N), but it is also $O(N^2)$; we try to provide *tight* bounds. Formally:
  - A function g(N) is O(f(N)) if there exist constants *c* and *n* such that g(N) < cf(N) for all N > *n*



Other definitions

- g(n) is O(f(n)) if lim g(n)/f(n) = c as n -> inf
- Informally, think of O as "<="
- Similarly, there's a notation for lower bounds…

Big-Oh calculations from code

- **Search for element in array:**
  - **What is complexity (using O-notation)?**
  - **If array doubles, what happens to time?**

```
for(int i=0; i < a.length; i++) {
   if (a[i].equals(target)) return true;
}
return false;
```

- **Best case? Average case? Worst case?**

Measures of complexity

- **Worst case**
  - Good upper-bound on behavior
  - Never get worse than this
- **Average case**
  - What does average mean?
  - Averaged over all inputs? Assuming uniformly distributed random data?

Some helpful mathematics

- $1 + 2 + 3 + 4 + \ldots + N$
  - $N(N+1)/2 = N^2/2 + N/2$ is $O(N^2)$
- $N + N + N + \ldots + N$ (total of N times)
  - $N*N = N^2$ which is $O(N^2)$
- $1 + 2 + 4 + \ldots + 2^N$
  - $2^{N+1} - 1 = 2 \times 2^N - 1$ which is $O(2^N)$

The usual suspects

- O(1)
- O(log n)
- O(n)
- O(n log n)
- $O(n^2)$
- $O(n^3)$
- …
- $O(2^n)$

Multiplying and adding big-Oh

- Suppose we do a linear search then we do another one
  - What is the complexity?
  - If we do 100 linear searches?
  - If we do n searches on an array of size n?

Multiplying and adding

- Binary search followed by linear search?
  - What are big-Oh complexities? Sum?
  - 50 binary searches? N searches?

- What is the number of elements in the list (1,2,2,3,3,3)?
  - What about (1,2,2, …, n,n,…,n)?
  - How can we reason about this?

Analysis for AP collections

- ListQueue
- ArrayStack (where's the top?)

- Lists, Maps, Sets

Priority Queues

- **Idea**

- **Implementation(s)**

Language details

- No reference parameters
  - All passes are by value (primitives/objects)
- How do you change something
  - Through "modifier" methods
  - Through returning a reference to a modified object (x = "changed x")