CS2010: ALGORITHMS AND DATA STRUCTURES

Lecture 1: Module Overview & Introduction

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→ **Objective:** learn to solve computational problems *efficiently*

“Algorithms + Data Structures = Programs”

— Niklaus Wirth
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→ **Data Structures:** The methods to store the information needed for the algorithm.

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Are these good measures of a program’s efficiency?

→ How long it takes the program to run on my laptop
→ How long it takes the program to run on the fastest computer
→ How long it takes the program to run on the slowest computer
→ How long it takes the program to run with the largest input
→ How long it takes the program to run with the smallest input
WHAT ABOUT EFFICIENCY?

Established measure: how well the program scales to larger inputs

→ When I double the input size my program takes the same time to run on the same computer (constant running time).

→ When I double the input size my program takes twice the time to run on the same computer (linear running time).

→ ...

We also care about memory needed:

→ When I double the input size my program needs the same amount of memory to run (constant memory space).

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The Software Engineer’s toolbox

→ Learn the most common A&DS that every CS graduate must know.
  → Example algorithms: Merge Sort, Union-Find, Dijkstra’s Shortest Path Tree, …
IN CS2010 (1/2)

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→ **Identify which known algorithms/data structures best fit specific problems**
  → Example: What is the best algorithm for finding the median?
    - It depends: QuickSelect, MedianOfMedians, IntroSelect, using SoftHeaps
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→ Practice implementing A&DS

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The Computer Scientist’s toolbox

→ Learn to evaluate new algorithms
   → Efficiency: calculate the running time and memory usage
     → how well they scale
     → Measuring aspects: Worst-case, average-case, amortised, experimental performance
     → Measuring systems: big-O notation, tilde notation, cost models

→ Correctness: rigorous testing and some informal correctness arguments (see Unit Testing, test coverage)
CS2010 Logistics
Example Problem
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The engineer came up with two alternatives. The first is:

```java
boolean isContained1(int[] A, int[] B) {
    boolean AInB = true;
    for (int i = 0; i < A.length; i++) {
        boolean iInB = linearSearch(B, A[i]);
        AInB = AInB && iInB;
    }
    return AInB;
}
```
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The second is:

```java
boolean isContained2(int[] A, int[] B) {
    int[] C = new int[B.length];
    for (int i = 0; i < B.length; i++) { C[i] = B[i] }
    sort(C); // heapsort
    boolean AInC = true;
    for (int i = 0; i < A.length; i++) {
        boolean iInC = binarySearch(C, A[i]);
        AInC = AInC && iInC;
    }
    return AInC;
}
```
(a) Calculate the **worst-case running time** of each of the two implementations.

(b) For each implementation, how much **extra memory space** is it required to store copies of the elements in A and B? You should take into account any copies made within the methods `sort`, `linearSearch`, and `binarySearch`.

(c) Find an implementation which is more efficient than both of the engineer’s implementation.
Why?
http://www.youtube.com/embed/vSi6YoTPWLw?rel=0&start=8&end=165
→ To get a technology job
http://www.careercup.com
→ To create the “New Google”
http://en.wikipedia.org/wiki/PageRank
→ To make science

→ To win big on the stock market
http://www.theguardian.com/business/2012/oct/21/superstar-traders-lost-magic

One theory for the decline of the superstar trader is the rise of the analytical nerd and computerised algorithmic trading. Schmidt says: "The superstars are confronted with a changing market. The punting around is not working. You now need to be either a traditional long-term stock picker, a very short-term person working on algorithms, or a combination of both. There is no future for guys like Coffey."
→ To rule the world!

http://www.theguardian.com/science/2013/jul/01/how-algorithms-rule-world-nsa

How algorithms rule the world

The NSA revelations highlight the role sophisticated algorithms play in sifting through masses of data. But more surprising is their widespread use in our everyday lives. So should we be more wary of their power?
→ For fun!