CS2010: ALGORITHMS AND DATA STRUCTURES

Lecture 1: Module Overview & Introduction

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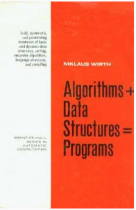
cs2010

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


lucid, systematic, and penetrating treatment of basic and dynamic data structures, sorting, recursive algorithms, language structures, and compiling
NIKLAUS WIRTH
Algorithms + Data Structures = Programs
PRENTICE-HALL SERIES IN AUTOMATIC COMPUTATION

"Algorithms + Data Structures = Programs"

— Niklaus Wirth

ALGORITHMS & DATA STRUCTURES

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ALGORITHMS & DATA STRUCTURES

- **Algorithm:** The steps to correctly perform a task that answers a general[1] computational problem
  - What is the median age of all people in Ireland?
  - What is the quickest path from here to Marrakech?
- **Data Structures:** The methods to store the information needed for the algorithm.

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WHAT ABOUT EFFICIENCY?

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*).
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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*).

→ When I double the input size my program takes twice the amount of memory to run (*linear memory space*).

→ …

IN CS2010 (1/2)

- → Learn the most common A&DS that every CS graduate must know.
  - → Example algorithms: Merge Sort, Union-Find, Dijstra's Shortest Path Tree, ...

in cs2010 (1/2)

- Learn the most common A&DS that every CS graduate must know.
  - Example algorithms: Merge Sort, Union-Find, Dijstra's Shortest Path Tree, ...
- Identify which known algorithms/data structures best fit specific problems
  - Example: What is the best algorithm for finding the median?
    – It depends:[2] QuickSelect, MedianOfMedians, IntroSelect, using SoftHeaps

[2] https://www.quora.com/What-is-the-most-efficient-algorithm-to-find-the-kth-smallest-element

IN CS2010 (2/2)

- Learn to evaluate new algorithms
  - Efficiency: **calculate** the running time and memory usage
    - We are interested mostly on **how well they scale**
    - Worst-case, average-case, best-case, amortised performance
    - Experimentally measure performance
    - Calculate performance using mathematical methods (big-O notation, tilde notation, cost models, …)
  - Correctness: **rigorous testing** and some informal correctness arguments

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- → Learn to use Abstract Data Types: the interfaces of Data Structures
- → Practice implementing A&DS in Java

CS2010 Logistics

cs2010 logistics

https://www.scss.tcd.ie/Vasileios.Koutavas/teaching/cs2010/

Example Problem

A software engineer was asked to design an algorithm which will input two **unsorted** arrays of integers, A (of size *N*) and B (also of size *N*), and will output `true` when all integers in A are present in B. The engineer came up with **two** alternatives:

```
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;
}
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;
  }
```

(a) Calculate the worst-case running time of each of the two implementations using the asymptotic Θ notation.

(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?

VIDEO

`http://www.youtube.com/embed/vSi6YoTPWLw?rel=0&start=8&end=165`

WHY?

→ To get a technology job
`http://www.careercup.com`

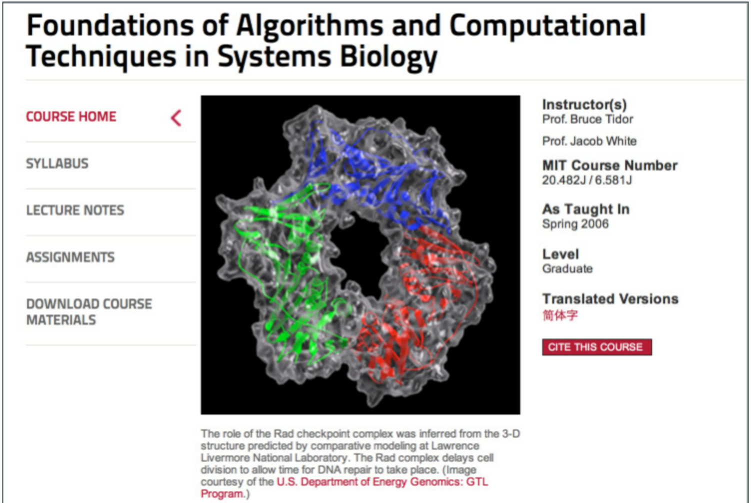
WHY?

→ To create the “New Google”
`http://en.wikipedia.org/wiki/PageRank`

WHY?

→ To make science

`http://ocw.mit.edu/courses/biological-engineering/`
`20-482j-foundations-of-algorithms-and-computational-techniques-in`



Foundations of Algorithms and Computational Techniques in Systems Biology

Instructor(s)
Prof. Bruce Tidor
Prof. Jacob White

MIT Course Number
20.482J / 6.581J

As Taught In
Spring 2006

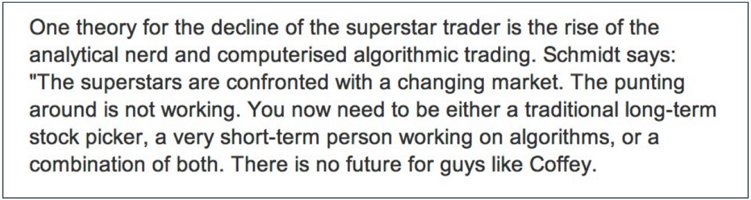
Level
Graduate

Translated Versions
简体字

The role of the Rad checkpoint complex was inferred from the 3-D structure predicted by comparative modeling at Lawrence Livermore National Laboratory. The Rad complex delays cell division to allow time for DNA repair to take place. (Image courtesy of the U.S. Department of Energy Genomics: GTL Program.)

WHY?

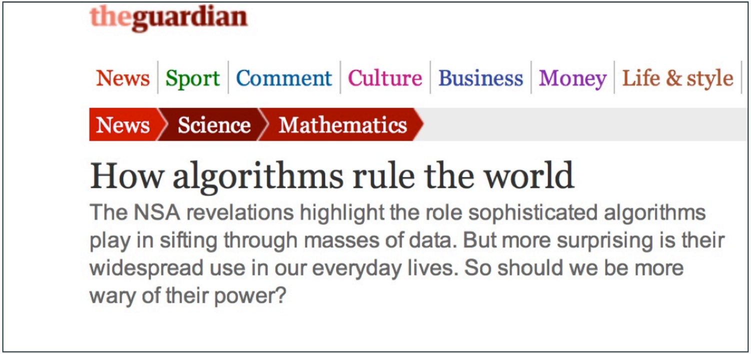
→ To play the stock market
`http://www.theguardian.com/business/2012/oct/21/superstar-traders-lost-magic`



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.

WHY?

→ To rule the world!
`http://www.theguardian.com/science/2013/jul/01/how-algorithms-rule-world-nsa`



theguardian

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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?

WHY?

→ For fun!

`http://en.wikipedia.org/wiki/Tower_of_Hanoi`