

CSE 417: Algorithms and Computational Complexity

I: Organization & Overview

Winter 2007
Larry Ruzzo

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University of Washington
Computer Science & Engineering

CSE 417, WI '07: Algorithms & Computational Complexity

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Assignments

Solutions

Lecture Notes

1: Overview & Example (06)

2-3: Analysis (06)

4-6: Graphs, BFS/DFS (06)

7-11: Greedy

Scheduling (06)

Huffman (06)

12-15: Dyn. Prog.

Fibonacci (06)

Stamps (06)

RNA Structure (06)

Scheduling (06)

16-19: Divide & Conquer

20-25: P & NP

Lecture: [Low 101](#) MWF 2:30- 3:20

Office Hours

Phone

Instructor: Larry Ruzzo, luzzo@cs.washington.edu MF 12:00-1:00? CSE 554 206-543-6298

TA: Zizhen Yao, yizizhen@cs.washington.edu at cs TBA

Course Email: cse417a_wi07@u.washington.edu. Use this list to ask and/or answer questions about homework, lectures, etc. The instructor and TA are subscribed to this list. All messages are automatically archived. Questions not of general interest may be directed to the instructor and TA: cse417-staff@cs.washington.edu or just to the instructor: ruzzo@cs.washington.edu. You can (and perhaps should) change your subscription options.

Catalog Description: Design and analysis of algorithms and data structures for manipulating graphs and strings. Fast Fourier Transform, dynamic programming, Turing machines. Time and space complexity.

Prerequisite: CSE 373

Credits: 3

Assignments: A mix of paper & pencil exercises and programming assignments. Homework turns are due at the start of class on the due date. 10% off for up to one day late (Monday for Friday due dates); additional 20% per day thereafter.

- *Algorithm Design* by Jon Kleinberg and Eva Tardos. Addison Wesley, 2006. (Available from [U Book Store](#), [Amazon](#), etc.)

Based on past experience, we will probably have little if any time to cover the "computability" material outlined in the catalog description. If you want additional material on these topics, as well as an alternative presentation of the computational complexity/NP-completeness topics, I recommend:

<http://www.cs.washington.edu/417>

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What you'll have to do

Homework (~55% of grade)

Programming

Several small projects

Written homework assignments

English exposition and pseudo-code

Analysis and argument as well as design

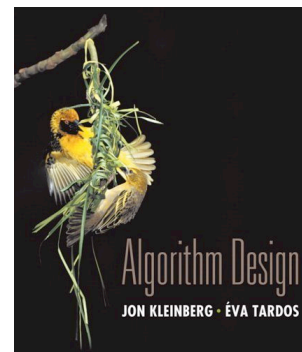
Midterm / Final Exam (~15% / 30%)

Late Policy:

Papers and/or electronic turnins are due at the start of class on the due date. 10% off for one day late (Monday, for Friday due dates); 20% per day thereafter.

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Textbook



Algorithm Design by Jon Kleinberg and Eva Tardos. Addison Wesley, 2006.

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What the course is about

Design of Algorithms

- design methods
- common or important types of problems
- analysis of algorithms - efficiency
- correctness proofs

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What the course is about

Complexity, NP-completeness and intractability

- solving problems in principle is not enough
 - algorithms must be *efficient*
- some problems have *no efficient solution*
- NP-complete problems
 - important & useful class of problems whose solutions (seemingly) cannot be found efficiently, but *can* be checked easily

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Very Rough Division of Time

Algorithms (7 weeks)

- Analysis of Algorithms
- Basic Algorithmic Design Techniques
- Graph Algorithms

Complexity & NP-completeness (3 weeks)

Check online
schedule page for
(evolving) details



University of Washington
Computer Science & Engineering
CSE 417, WI '06: Approximate Schedule

| | Due | Lecture Topic | Reading |
|---------------------|-----|------------------------------|--------------|
| Week 1 1/10-16 | M | Holiday | |
| | W | Intro, Examples & Complexity | Ch. 1, Ch. 2 |
| | F | Intro, Examples & Complexity | |
| Week 2 1/16-1/23 | M | Intro, Examples & Complexity | |
| | W | Graph Algorithms | Ch. 3 |
| | F | Graph Algorithms | |

Complexity Example

Cryptography (e.g. RSA, SSL in browsers)

- Secret: p, q prime, say 512 bits each
- Public: n which equals $p \times q$, 1024 bits

In principle

- there is an algorithm* that given n will find p and q :
try all 2^{512} possible p 's, an astronomical number

In practice

- no efficient algorithm* is known for this problem
- security of RSA depends on this fact

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Algorithms versus Machines

We all know about Moore's Law and the exponential improvements in hardware...

Ex: sparse linear equations over 25 years

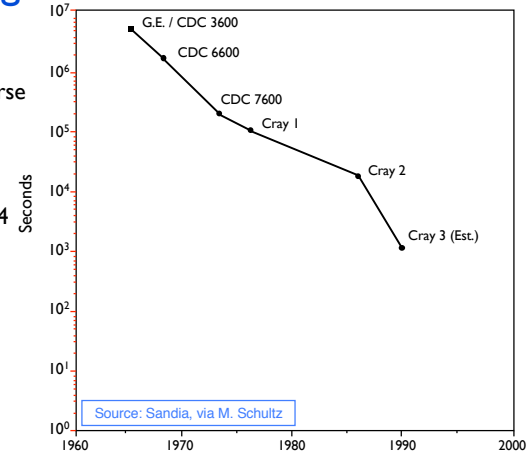
10 orders of magnitude improvement!

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Algorithms or Hardware?

25 years
progress
solving sparse
linear
systems

hardware: 4
orders of
magnitude

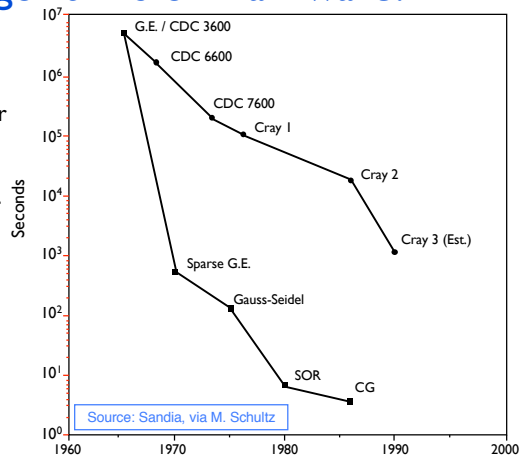


Algorithms or Hardware?

25 years
progress
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hardware: 4
orders of
magnitude

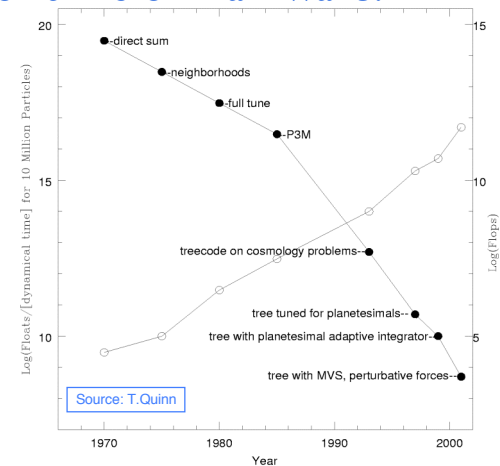
software: 6
orders of
magnitude



Algorithms or Hardware?

The
N-Body
Problem:

in 30 years
 10^7 hardware
 10^{10} software



Algorithm: definition

Procedure to accomplish a task or solve a well-specified problem

Well-specified: know what all possible inputs look like and what output looks like given them

“accomplish” via simple, well-defined steps

Ex: sorting names (via comparison)

Ex: checking for primality (via $+$, $-$, $*$, $/$, \leq)

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Algorithms: a sample problem

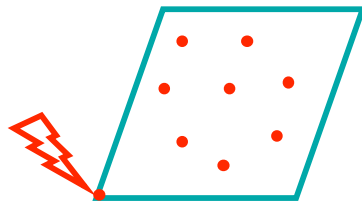
Printed circuit-board company has a robot arm that solders components to the board

Time: proportional to total distance the arm must move from initial rest position around the board and back to the initial position

For each board design, find best order to do the soldering

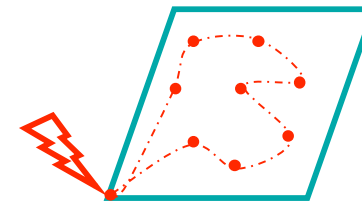
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Printed Circuit Board



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Printed Circuit Board



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A Well-defined Problem

Input: Given a set S of n points in the plane

Output: The shortest cycle tour that visits each point in the set S .

Better known as “TSP”

How might you solve it?

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Nearest Neighbor Heuristic

heuristic: A rule of thumb, simplification, or educated guess that reduces or limits the search for solutions in domains that are difficult and poorly understood. May be good, but usually *not* guaranteed to give the best or fastest solution.

Start at some point p_0

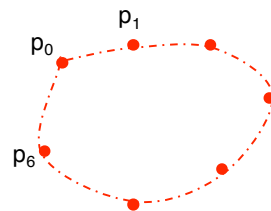
Walk first to its nearest neighbor p_1

Repeatedly walk to the nearest unvisited neighbor p_2 , then p_3, \dots until all points have been visited

Then walk back to p_0

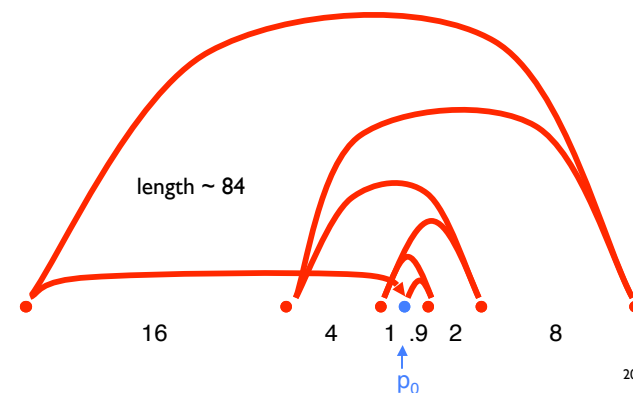
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Nearest Neighbor Heuristic



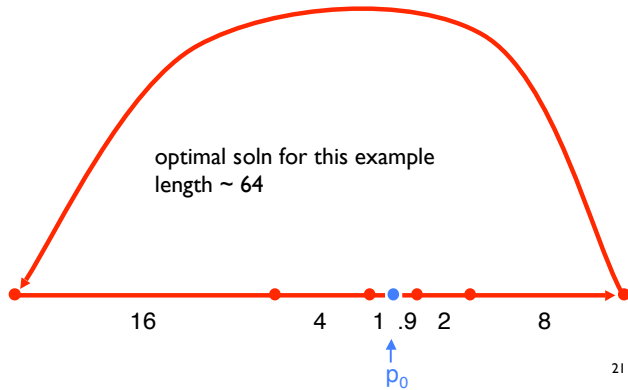
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An input where it works badly



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An input where it works badly



Revised idea - Closest pairs first

Repeatedly join the closest pair of points

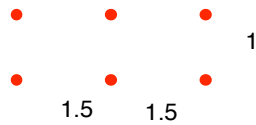
(s.t. result can still be part of a single loop in the end. I.e., join endpoints, but not points in middle, of path segments already created.)



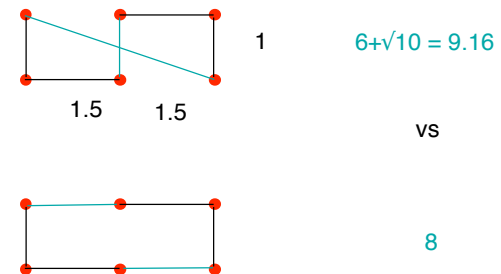
How does this work on our bad example?



Another bad example



Another bad example



Something that works

For each of the $n! = n(n-1)(n-2)\dots 1$ orderings of the points, check the length of the cycle you get
Keep the best one

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Two Notes

The two *incorrect* algorithms were greedy

Often very natural & tempting ideas

They make choices that look great “locally” (and never reconsider them)

When greed works, the algorithms are typically efficient

BUT: often does not work - you get boxed in

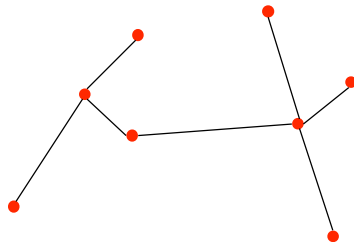
Our correct alg avoids this, but is incredibly slow

$20!$ is so large that checking one billion per second would take 2.4 billion seconds (around 70 years!)

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Something that “works” (differently)

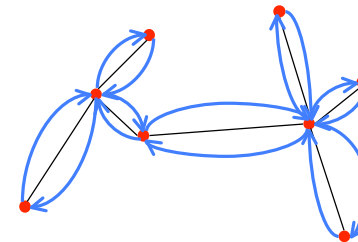
1. Find Min Spanning Tree



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Something that “works” (differently)

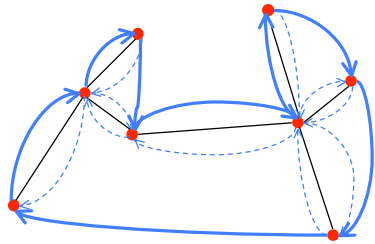
2. Walk around it



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Something that “works” (differently)

3. Take shortcuts (instead of revisiting)



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Something that “works” (differently): Guaranteed Approximation

Does it seem wacky?

Maybe, but it's *always* within a factor of 2 of the best tour!

deleting one edge from best tour gives a spanning tree, so *Min* spanning tree < best tour

best tour \leq wacky tour $\leq 2 * \text{MST} < 2 * \text{best}$

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The Morals of the Story

Simple problems can be hard

Factoring, TSP

Simple ideas don't always work

Nearest neighbor, closest pair heuristics

Simple algorithms can be very slow

Brute-force factoring, TSP

Changing your objective can be good

Guaranteed approximation for TSP

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