Welcome to Analysis of Algorithms (CS483 - 001)

Amarda Shehu

Spring 2017
Class Information

Outline of Today's Class

The Importance of Designing and Analyzing Algorithms

Tentative Syllabus

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<tr>
<th>Date</th>
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<tr>
<td>Jan 23</td>
<td>Course Overview and introduction to</td>
<td>C1-3, D0, D2.0-3</td>
<td>Self-eval. quizz</td>
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<td>Analysis of Algorithms</td>
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<td>Jan 30</td>
<td>Algorithm Analysis</td>
<td>C3-5, D2.0-3</td>
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Sorting

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<tr>
<td>Feb 6</td>
<td>Algorithm Analysis</td>
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<td>Feb 13</td>
<td>Heapsort, Quicksort, Linear-Time Sorting</td>
<td>C6-8, D2.3</td>
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<td>Feb 20</td>
<td>Order Statistics</td>
<td>C9, C11, D1.5, D2.4</td>
<td>Quiz, Hw1 Out</td>
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Data Structures for Searching and Mapping

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<tr>
<td>Feb 27</td>
<td>Hash Tables</td>
<td>C11, C12, D2.4</td>
<td>Hw1 Due</td>
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<td>Mar 06</td>
<td>Balanced Search Trees, Binomial Heaps</td>
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Optimization and Advanced Analysis

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<tr>
<td>Mar 20</td>
<td>Dynamic Programming, Greedy Algorithms</td>
<td>C15-16, D5-6</td>
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Graph Algorithms

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<td>Amortized Analysis, Graph Representation</td>
<td>C17, C22, D3, D6</td>
<td>Hw2 Out [pdf]</td>
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<td>Apr 10</td>
<td>Elementary Graph Algorithms, Applications of DFS</td>
<td>C22-23, D3, D4.1-3</td>
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<td>Topological Sorting, SCCs, Minimum Spanning Trees</td>
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<td>Apr 24</td>
<td>All Pairs Shortest Paths and Maximum Flow</td>
<td>C25-26, D4.4-7</td>
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Complexity Theory

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<td>May 01</td>
<td>NP-completeness</td>
<td>C34, D8 [pdf]</td>
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<tr>
<td>May 08</td>
<td>Exam 2</td>
<td>Robinson Hall B113</td>
<td>4:30 pm – 7:15 pm</td>
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Instructor: Amarda Shehu
Office: ENG #4452
Email: amarda AT gmu.edu
Web: cs.gmu.edu/~ashehu

CS483 Hours

Class: MW 9:00 - 10:15 am
Place: Robinson Hall A111
Office Hours: MW 1:30 - 2:30 pm

TA: Xiaosheng Li
Email: xli22 AT gmu.edu
ENG#5321, W 3:00 - 5:00 pm
1 Class Information

2 Outline of Today’s Class

3 The Importance of Designing and Analyzing Algorithms
   - The Pervasiveness of Algorithms in Our Society
   - What does It Take to Design Useful Algorithms?
Why are we Here?

- In *Calculation with Hindu Numerals*, 825 A.D., Muhammad ibn Musa al-Khwarizmi introduced Indian decimal system.
- The book was translated into Latin in 12th century as *Algoritmi de numero Indorum*.
- *Algorithm* was introduced to refer to a procedure for calculations with numbers.
- Short answer: We are here to design and analyze algorithms - procedures to solve useful problems.

*Figure:* Soviet stamp for al-Khwarizmi’s 1200th birthday. ©wikipedia.
The Importance of Designing and Analyzing Algorithms

The Pervasiveness of Algorithms in Our Society

What does it take to design useful algorithms?

- Pattern matching algorithms and information searching algorithms are fundamental to our ability to parse through an overwhelming amount of information.
- Google was founded on the ability of two Stanford University Ph.D. students, Sergey Brin and Larry Page, to design a fast information searching algorithm, BackRub. They quit school after that.

Figure: Searched for algorithms for life sciences in text in the web.
The Importance of Designing and Analyzing Algorithms

Orientation Software: Google maps, GPS navigators

- Path from Rice University, Houston, Texas to George Mason University, Fairfax, Virginia
- Path finding algorithms can be found in portable GPS navigators
- Most versions of the algorithm work with a static map (static conditions on the ground)

Figure: Output of a path finding algorithm.
The Importance of Designing and Analyzing Algorithms

The Pervasiveness of Algorithms in Our Society
What does it take to design useful algorithms?

Exploration, Search and Rescue, and Motion Planning

Figure: Ron Li and his research team are developing algorithms to help the rovers, Spirit and Opportunity, to navigate and find a safe path to a winter resting area. ©NASA.

Figure: Erion Plaku at Rice University is developing algorithms that plan paths for car-like robots in cluttered environments. ©E. Plaku.
Simulating Molecular Properties for Drug Design

Figure: Successful docking of HIV protease with a small inhibitor ligand. ©A. R. Leach.

Figure: Simulating the ability of proteins like ubiquitin to change shape as needed to accommodate and dock with different partner molecules. ©A. Shehu.
What is an Algorithm?

- Recipe, computational procedure that transforms input into output, tool to solve well-defined problems, sequence of instructions

**Figure:**

- An algorithm is a finite sequence of unambiguous instructions for completing a task, that:
What is an Algorithm?

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**Figure:**

- An algorithm is a finite sequence of unambiguous instructions for completing a task, that:
  - when given an initial state (≥ 0 inputs),
  - proceeds through a well-defined series of successive states,
  - eventually terminating in an end-state (≥ outputs)
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Figure:

- An algorithm is a finite sequence of unambiguous instructions for completing a task, that:
  - when given an initial state ($\geq 0$ inputs),
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  - eventually terminating in an end-state ($\geq$ outputs)

Examples of algorithms?
What is an Algorithm?

- Recipe, computational procedure that transforms input into output, tool to solve well-defined problems, sequence of instructions

![Diagram: INPUT → What's in the box? → OUTPUT]

Figure:

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Examples of algorithms?
Why do we Write Algorithms?

Given a real problem:

- Model it as a well-defined computational problem
- Is the solution to the problem *computable*?
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Given a real problem:

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How do we Write Algorithms?

- Are there any useful paradigms from which we can choose?
- How do we know the algorithm we have written is correct?
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    - Less space? Storage Concerns?
    - Shorter running time? Faster is always better.
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  - Use a simpler data structure?
  - Allow developers to extend and generalize?
  - Aesthetics concerns?
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    • Allow developers to extend and generalize?
    • Aesthetics concerns?
Paradigms we Will See in this Class

- Brute force
- Divide and conquer
- Decrease and conquer
- Transform and conquer
- Space and time tradeoffs
- Dynamic Programming
- Greedy Approach
- Iterative improvement
- Backtracking
- Branch and bound