COT 6936: Topics in Algorithms

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Purpose of this class

- First course in algorithms is inadequate preparation for most PhD students
  - Learn standard techniques
  - Solve standard problems
  - Learn basic analysis techniques
  - Need to go beyond that!
- This course
  - Model/formalize a problem
  - Leverage existing solutions
  - Create your own solutions

Expectations

- Attend class
- Participate in class discussions
- Team work; discussion groups
- Solve practical research problems
- Make a presentation; write a report
  - need a research component; may implement
- Write research paper
- No cell phones, SMS, or email during class

Evaluation

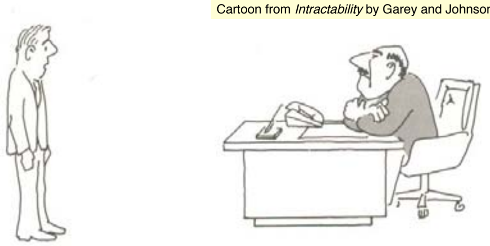
• Exam (1)	20%
• Quizzes	5%
• Homework Assignments	15%
• Semester Project	40%
• Class Participation	20%

Semester Schedule

- Milestones:
  - By Jan 18: Meet with me and discuss project
  - By Jan 25: Send me email with project team information and topic
  - Feb 3rd week: Short presentation (15 minutes) giving intro to project, problem definition, notation, and background
  - March 2nd week: Take-home Exam
  - Starting March last week: Full length presentation of project (1 hour)
  - April 15: Written report on project

Why should I care about Algorithms?

Cartoon from *Intractability* by Garey and Johnson



"I can't find an efficient algorithm, I guess I'm just too dumb."

Why are theoretical results useful?

"I can't find an efficient algorithm, because no such algorithm is possible!"

Cartoon from *Intractability* by Garey and Johnson

Why are theoretical results useful?

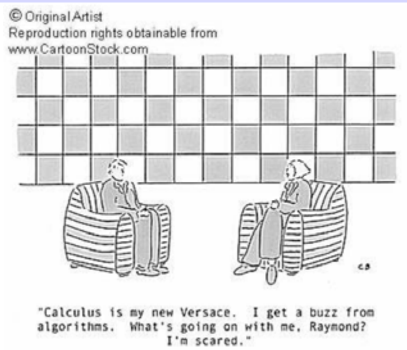
"I can't find an efficient algorithm, but neither can all these famous people."

Cartoon from *Intractability* by Garey and Johnson

What if efficient algorithms don't exist

- Find good approximation algorithms
  - Quality of the solution is guaranteed
- Find good heuristic algorithms
- Understand nature of inputs in practice
- Perform many experiments after implementing

If you like Algorithms, nothing to worry about!



Classical (Theoretical) Algorithmic Model

- Input-output description provided
- Input provided & stored in memory
- Output computed & stored or output immediately
- Entire program stored in memory
- Algebraic Computation-Tree Model (Variants: indirection, floor function, square root)
- Space (?) and time (?) efficiency
- Deterministic and Sequential algorithms
- Worst-case analysis
- No other factors to consider

Find a "good" student

- President Rosenberg says to you: "Find me a good FIU student."
- You ask: "What do you mean by good?"
- President says: "S/he must be better than at least half of our current student body."

Probabilities

- Prob of failure: $\frac{1}{2}$
- Prob of failure: $(1/2)^r$

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Randomized algorithms

- Useful when you can tolerate failure
- 2 kinds of randomized algorithms
  - Always fast, sometimes wrong (Monte Carlo)
  - Always correct, sometimes slow (Las Vegas)
  - Complexity classes: RP, BPP, ZPP, …
- Focus of study
  - Design
  - Analysis
    - Time, Failure probability, Performance, Tradeoffs

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Facility Location

- Given: Location of all fire-stations in Miami
- Output: Optimal location of next fire-station
- Strategy: find largest empty region

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Heights of Students

- Given: Heights of all students in class
- Problem:
  - To achieve diversity in heights by adding one more student
  - Find biggest empty height range
- Variant:
  - To remove a student and achieving diversity in heights
  - Find smallest empty height range

Heights of Students: What we know

- One problem is harder than the other!
- Which one and why?
- One has a lower bound!
  - Relationship to EUP?
- The other can be solved faster with a different computational model!

Updating a Binary Counter

- How many bits are changed when a binary number is incremented?
  - Worst-case?
  - Average-case?
  - Amortized analysis? Average cost over a worst-case sequence of operations.

Binary Counter: What we know

- Worst case per increment = O(# bits)
- Average case per increment = O(# bits)
- Amortized complexity = ??

Other Algorithmic Models

- Practical problems
  - Making spot decisions: ON-LINE Algorithms
    - Often randomized
    - Use current state
    - Sophisticated: use past history
  - Not having enough memory or computing power: STREAMING Algorithms

Practical Algorithmic Models

- Sequential Algorithms
  - Worst-case / average-case analysis
  - Amortized Analysis
- Parallel Algorithms
- On-line algorithms
- Randomized Algorithms
- Streaming Algorithms
- External Memory Algorithms
- Limited space/time/power Algorithms
- Making use of cache

Experimental Algorithms

- How to do good experiments in practice?
  - Testing for correctness
  - Testing for performance
    - Modeling inputs in practice
    - Trying different input distributions
    - Optimizing performance for special input distributions

Additional Topics

- Approximation Algorithms
- Computational Geometry
- Computational Biology
  - String Algorithms
- Computational Finance
- Combinatorial Optimization
- Algorithmic Game Theory
- Heuristic Algorithms
- Problem Modeling and Transformations

Paging Algorithms

Here are 3 well-known paging algorithms

- Least Recently Used (LRU): evict item whose most recent request was furthest in the past
- First-in, First-out (FIFO): evict item that was brought in furthest in the past
- Least Frequently Used (LFU): evict item that has been requested least often

Which ones are good algorithms and why?

What is an optimal algorithm?

Robot Challenge Problem

- Homework #1 – here it is!
- I know 2 ways of solving it.
  1. By modeling it as a known problem
  2. With a standard algorithmic technique
- Write pseudo-code to solve this problem.

Drunken sailors and cabins

- A ship arrives at a port. 40 sailors go ashore for revelry. They return to the ship rather inebriated. Being unable to remember their cabin location, they find a random unoccupied cabin to sleep the night. How many sailors are expected to sleep in their own cabins?
- Variants? Generalizations?