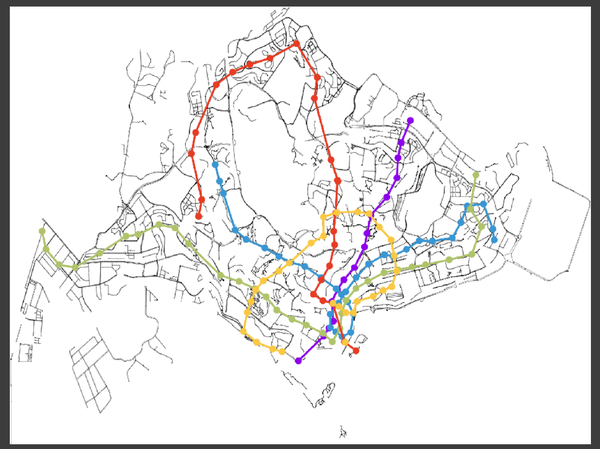
Spring 2022

CSCI 357: Algorithmic Game Theory

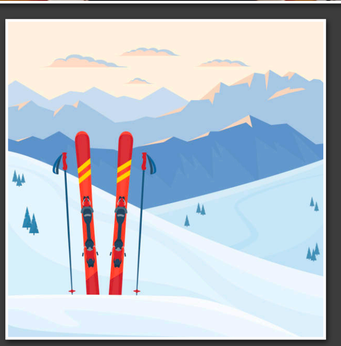
Lecture 1A: Overview & Logistics

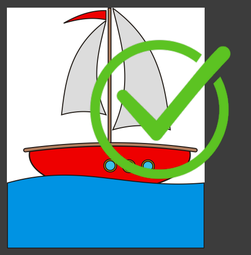
Shikha Singh



About Me

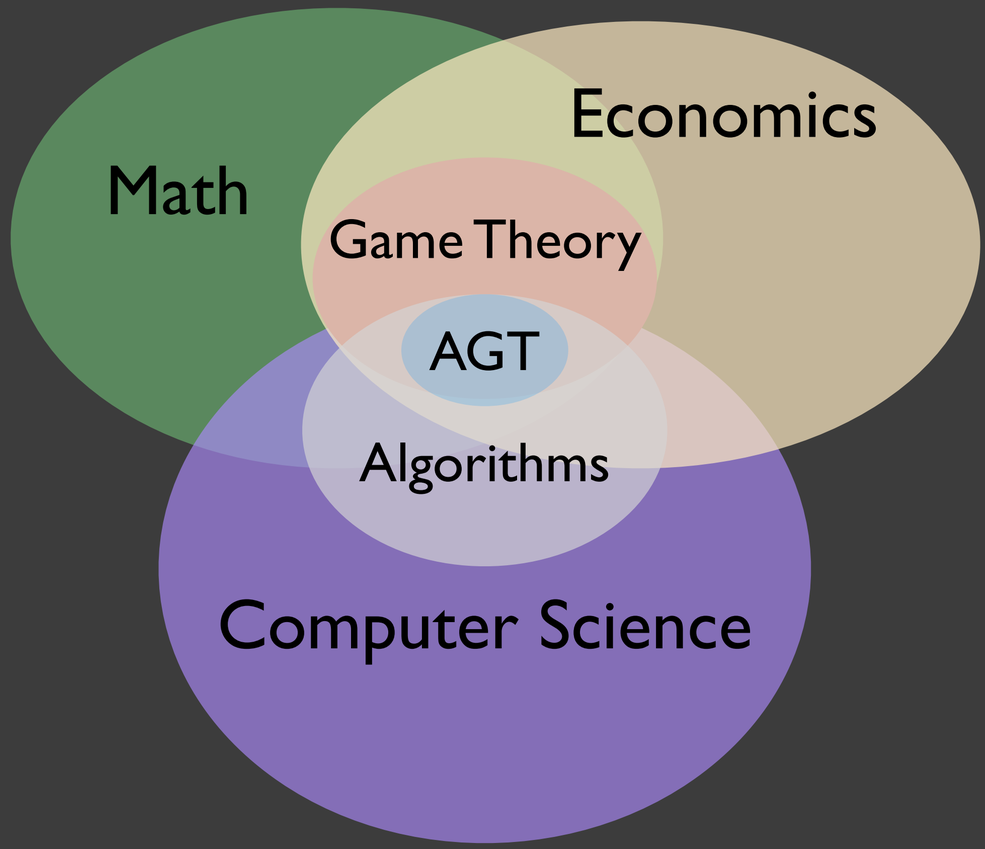
- Instructor: **Shikha Singh** (she/her)
- Can call me Shikha or Prof. Shikha or Prof. Singh
- Pronunciation tips:
    - “Shi” is like in ship not sheep
    - Shikha is like Chica in Chica-ago
- Webpage: http://cs.williams.edu/~shikha/
- Research: Algorithms and Algorithmic Game Theory
- Contact: shikha@cs.williams.edu
- Office: TCL 304



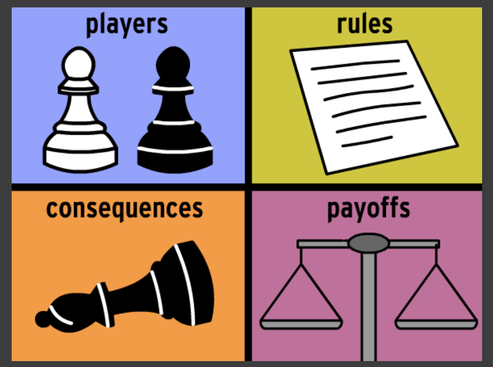


Algorithmic Game Theory

- Relatively new field (~15 years or so)
- Gained momentum due to the Internet & e-commerce
- Also called ***Economics and Computation***
- Economic to CS:
    - Incentives in resource allocation, online advertising, file sharing, etc
- CS to Econ:
    - Efficiency
    - Approximations
    - Complexity



Game Theory

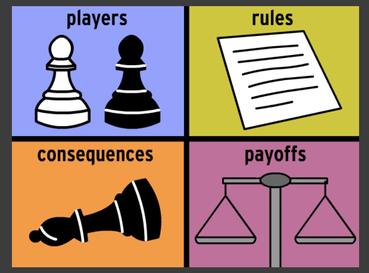


- Study of **strategic interactions** between rational agents
- Players play to maximize their utility in the game
- Pre-existing rules
- Goal is to analyze rational behavior

Algorithms

- Specify rules that given an input, produce a desired **output/outcome**
- Design goals:
  - Optimize an objective function
  - Efficiency and simplicity
  - Quality of outcome

Algorithmic Game Theory



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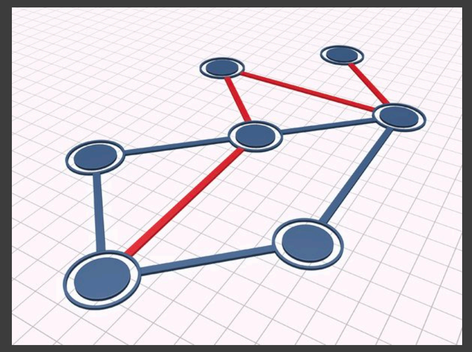
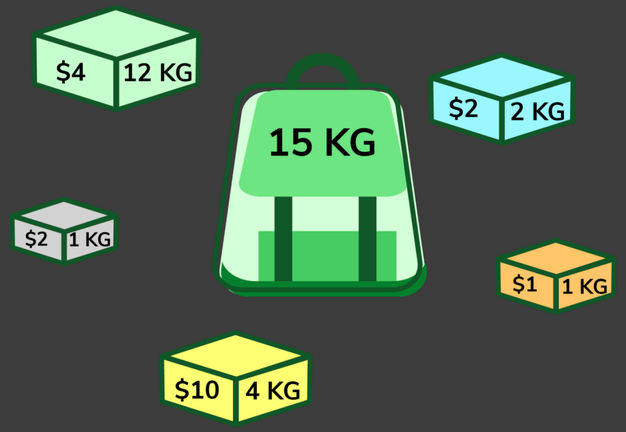
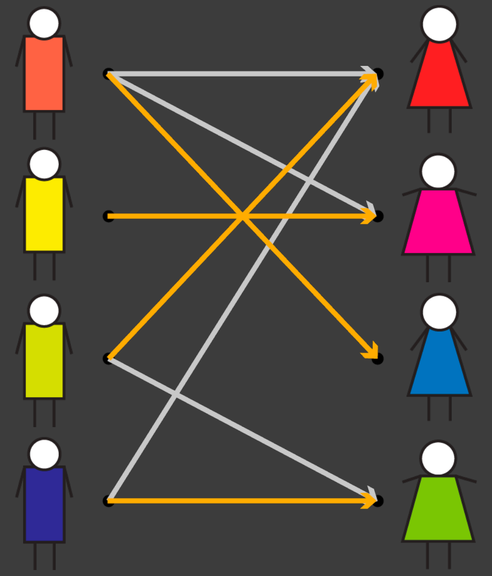
CS357: How does strategic behavior affect the outcome of an algorithm?



Routing in Networks



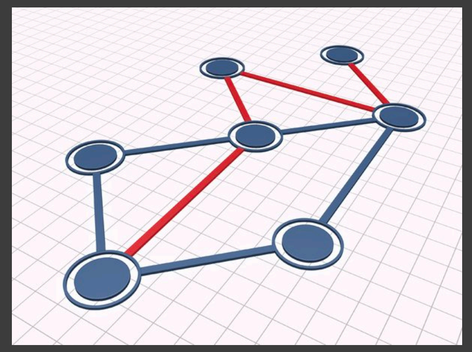
Resource allocation



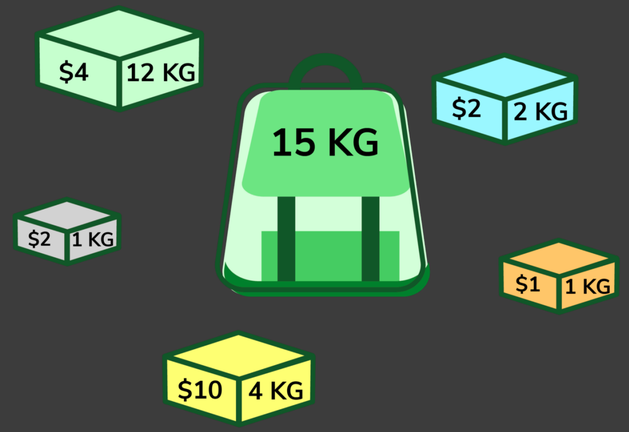
Matching problems

Algorithmic Game Theory

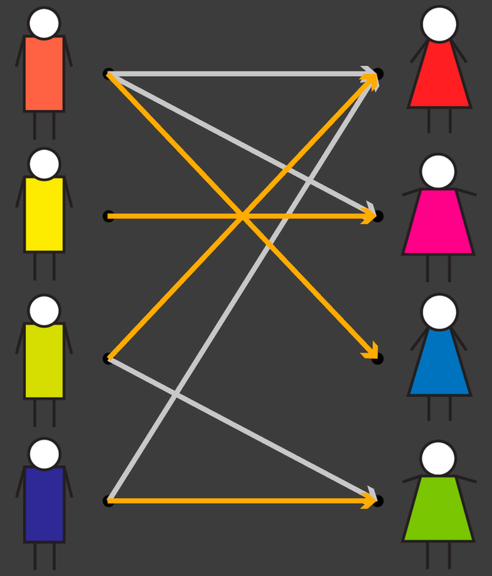
Often the system designer's (global) objective does not necessarily align with that of the participants (local).



Routing in Networks



Resource allocation

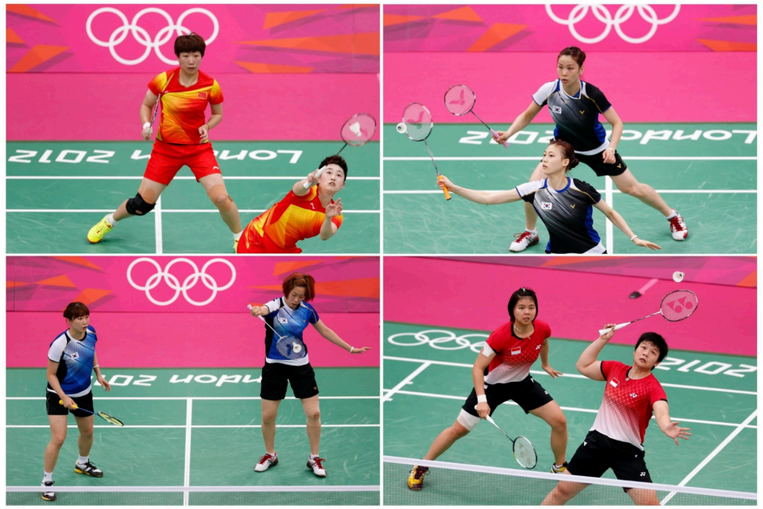


Matching problems

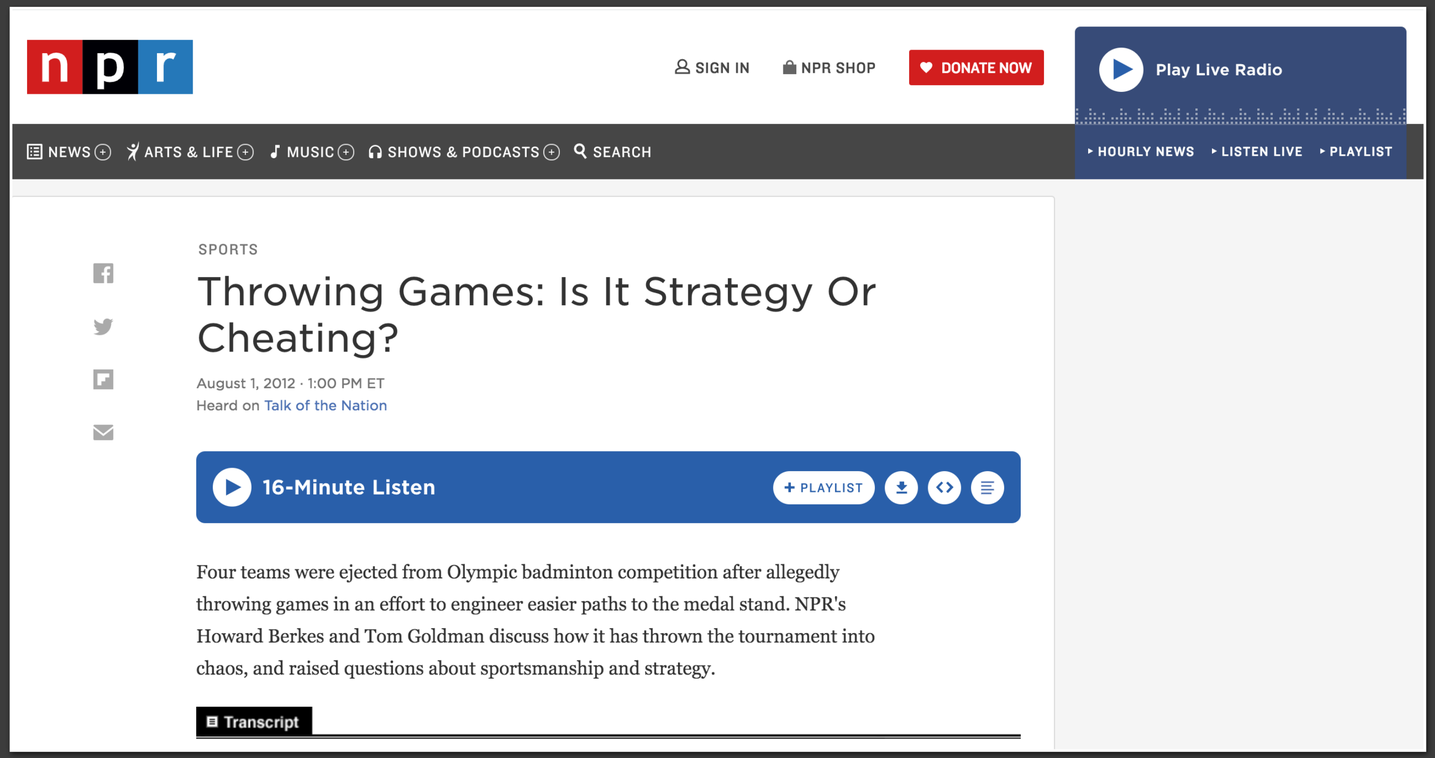
Why Should We Care About Incentives?

- When we don't, things may go wrong unexpectedly...
- Classic example: **2012 Olympics**

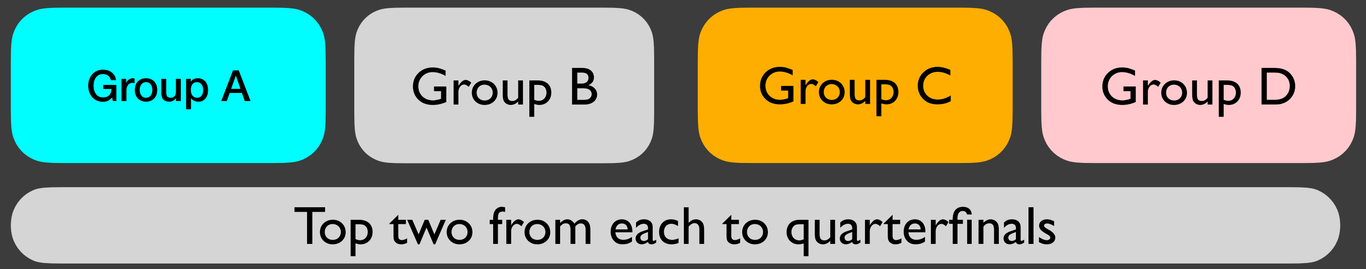
Olympic Ideal Takes Beating in Badminton



Clockwise from top left, the women's badminton doubles pairs: China's Wang Xiaoli, left, and Yu Yang; South Korea's Jung Kyung-eun, top, and Kim Ha-na; Indonesia's Greysia Polii and Meiliana Jauhari; and South Korea's Ha Jung-eun and Kim Min-jung during matches in London. The players were charged with misconduct by the World Badminton Federation. Bazuki Muhammad/Reuters



Rules of the Game



- Four groups of four teams each
- First phase: **round-robin** within each group
- Top two teams advance to knockout stage
    - Four **quarter finals:** losers eliminated
    - Two semifinals (losers play for bronze)
    - One final (winner: gold, loser: silver)

Rules of the Game

A
B
C
D

Four Quarter finals

1st A 2nd C

1st B 2nd D

1st C 2nd A

1st D 2nd B

- How are teams paired in knockouts?
  - Best from A plays second-best team from C in the 1st quarterfinal
  - Best from C plays the second-best from group A in the 3rd quarterfinal.
  - Top two teams from B and D are paired up analogously in the 2nd and 4th quarterfinals.

What do players want?

Rules of the Game

A
B
C
D

1st A 2nd C

1st B 2nd D

1st C 2nd A

1st D 2nd B

- How are teams paired in knockouts?
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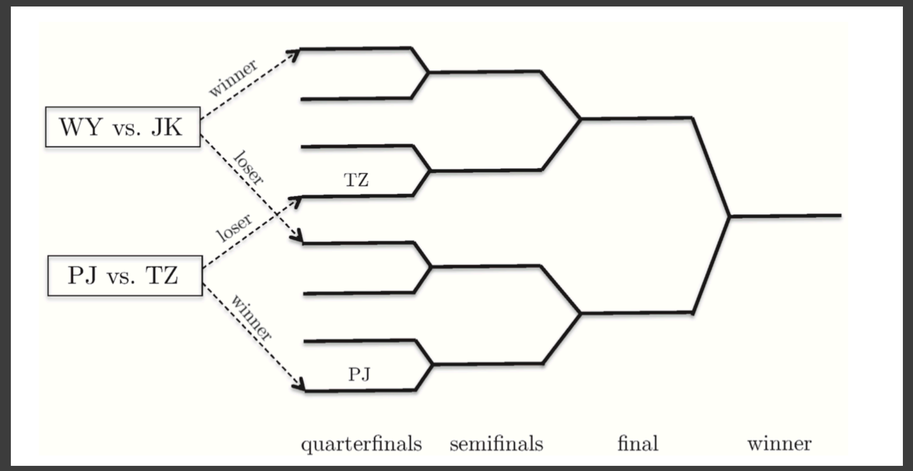
What do organizers want?

What Went Wrong

- Chinese team Tian and Zhao (TZ): favored team to win
- Last day of round-robin: shocking upset
  - Danish team Pedersen and Juhl (PJ) beat the TZ
- First controversial match between Chinese team Xiaoli & Yang (XY) and S Korean team Kyung-eun & Ha-na (KH)
  - Both teams were guaranteed to move to knockouts
  - Winner: faces TZ in semifinals (can win bronze)
  - Loser: faces TZ in finals (silver guaranteed)
  - So... both teams tried to deliberately lose the game
- Video: https://youtu.be/7mq1ioqiWEo?t=791



"*The next time we bemoan people exploiting loopholes to subvert the intent of the rule makers, instead of asking 'What's wrong with these people?" let's instead ask, `What's wrong with the rules?' and then adopt a scientifically principled approach to fixing them*" — *Hartline and Kleinberg*

Incentives Matter: Voting

- System designer's goal: to elicit truthful preferences over candidates
- Why voters may not vote truthfully?
  - **Tactical voting**: May not want to "waste their vote" if their favorite candidate does not have a chance to win
- Bush vs Gore 2000 US Presidential Election
  - Nader traders: https://slate.com/news-and-politics/2000/10/nader-s-traders.html
- Tactical voting can be reduced by instant-runoff voting, a system where voters cast ballots ranking the candidates

HIGH CONCEPT

Nader's Traders

How to save Al Gore's bacon by swapping votes on the Internet.

By JAMIN RASKIN

OCT 25, 2000 • 3:00 AM

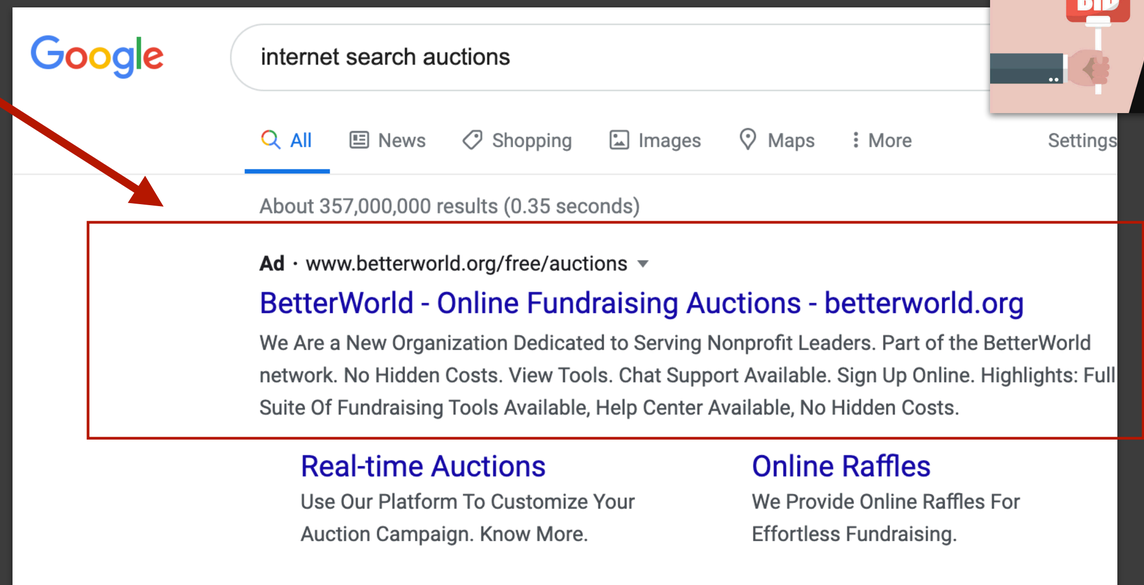
Classroom exercise:

Can you come up with examples of procedures/algorithms in your life where the rules do not necessarily lead to desirable behavior or have unintended consequences?

Or on the flip side: examples of well-incentivized algorithms?

Mechanism Design

- In this course we will learn how to **design and analyze mechanisms** that incentivize rational participants to act in a desired way
- **Goal:** align the goals of system designer and participants
- Often called **reverse game theory**
- **Many applications** in everyday life:
  - Internet search auctions
  - Wireless spectrum auctions
  - Matching markets
    - Students to school
    - Patients to kidneys
    - Hospitals to doctors



In mechanism design, we try to carefully design rules and centralized systems to obtain good guarantees.

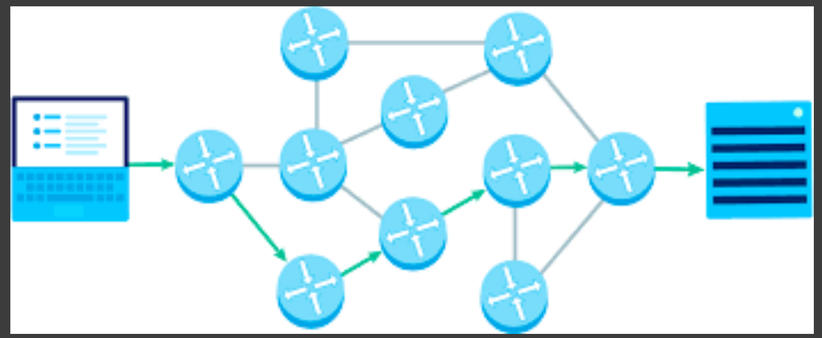
Question. But, how bad is selfish behavior anyway?

Fundamentals of Game Theory

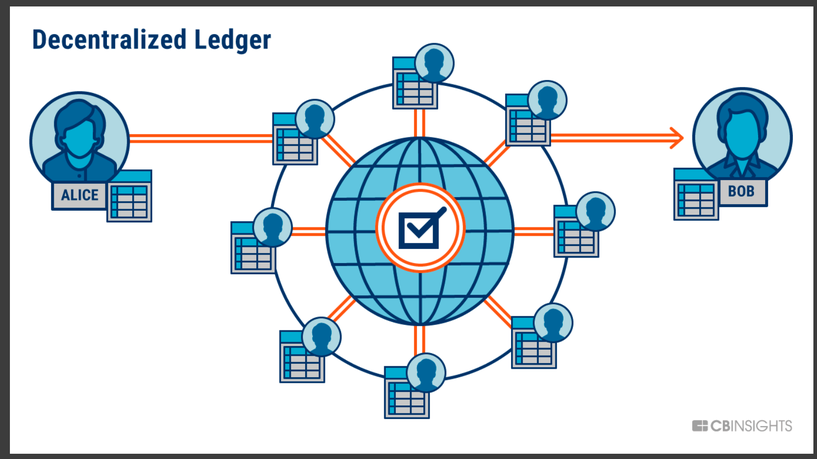
- In this course, we will learn how to analyze selfish behavior
- We will use concepts from game theory:
  - Dominant strategy equilibrium
  - Nash equilibrium
  - Bayes' Nash equilibrium
  - Subgame perfect equilibrium
- Some of you may have taken Game Theory in Math/Econ
  - Our focus is very different
  - We will cover all concepts that we need
- **Goal**: Analyze when selfish behavior (what is good for one) is also good for the group

Incentives in Computer Science

- Finally, in this course we will learn how lessons from game theory and mechanism design **apply to CS system design**:
  - Incentives in computer networks
  - Incentives in P2P systems such as file sharing (torrents), inter-AS routing, blockchains, etc.
  - Incentives in resource-allocation algorithms, scheduling algorithms
  - Incentives in matching, or consensus/aggregation algorithms



BitTorrent™



Course Logistics

Course Components

- Weekly **problem sets** **(35 %)**
    - Problems involving theoretical analysis (**proofs**)
    - Type in LaTeX, submit on Gradescope
    - Occasional programming assignments (Python)
- Two take-home **midterm exams** **(20 + 20 %)**
    - Tentatively ~ March 12 & April 23
- **Final project** on a topic of your choice **(20 %)**
    - Can be theoretical or empirical study
    - Project proposal + class presentation + final paper
- **Class participation** and **attendance** **(5 %)**
    - Attendance is required: contact me if you must miss class

Class Participation

- I like interaction in our classes!
- Many ways to participate:
    - Ask questions! (there are no bad questions!)
    - Answer questions (there are no wrong answers!)
    - Laugh at my jokes… (no guarantees here)
    - Talk to me after class/come to office hours
- Class participation does not mean dominating classroom discussions or interrupting your peers

Bottom line. *Help create a vibrant, positive and inclusive classroom environment!*

Problem Sets

- Must be typeset in **LaTeX** using template provided
- Goal: Practice formalizing concepts we introduce in class
- PDF must be submitted via **Gradescope**
    - Register on Gradescope using course code: **KYERN3**
- Released on Thursdays & due the following Thursday at 10 pm
- Each student is allowed **two late days** (at most one per assignment)
    - Beyond that, any late work is penalized 20% per day
- If you need extensions for (mental or physical) health -related reasons, please reach out to me

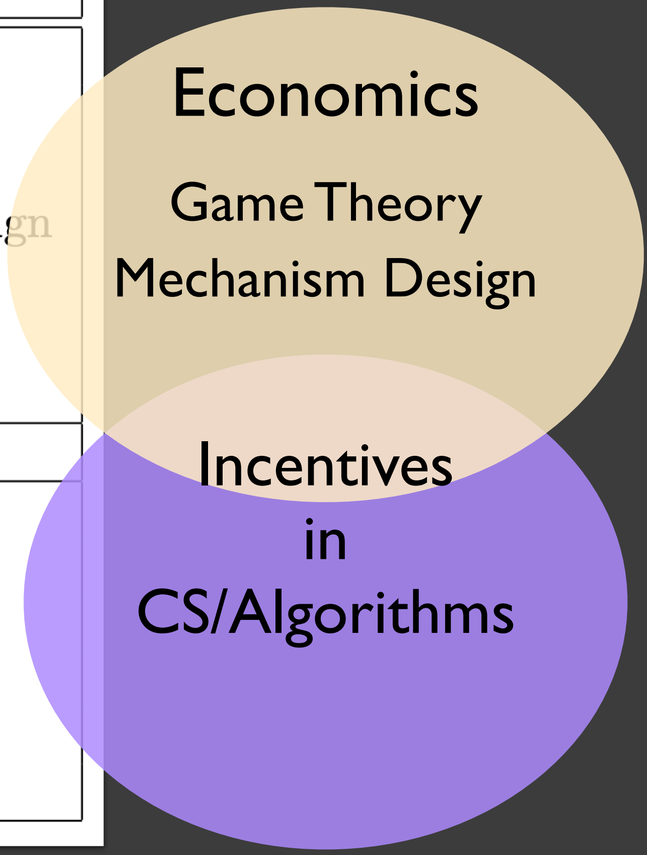
Final Project

- Goal is for you to dig deeper on a topic of your interest
- Can be theoretical or programming based
- Must involve significant depth on a topic that is not covered in course
- Deliverables
  - Short project proposal meetings with instructor
  - Short class presentation during last week
  - Final paper due during finals period
- I will provide project ideas but encourage you to pick your own

F21 Project **“Strategic Behavior in Voting”** by Sam Gilman ’21 & Peter Zhao ’21 won the **Ward Prize for Best Project in Computer Science!**

Tentative Course Plan

Week	Monday	Thursday
2/2	—	1. Welcome
7/2	2. Game Theory I	3. Game Theory II
14/2	4. Auctions I	5. Auctions II
21/2	6. Sponsored Search Auctions	7. Algorithmic Mechanism Design
28/2	8. Incomplete Information Games	9. BNE in Auctions
7/3	10. Revenue Maximization	11. Matching Markets
14/3	12. Stable Matchings 1	13. Stable Matchings 2
	Spring Break	Spring Break
4/4	14. Top Trading Cycles & Kidney Exchange	15. Voting 1
11/4	16. Voting 2	17. Sequential Games
18/4	18. Repeated Games & BitTorrent	19. BGP Routing
25/4	—	20. Spectrum Auctions
2/5	21. Incentives in Blockchains	22. Complexity of Equilibrium
9/5	23. Project Presentations	24. Project Presentations



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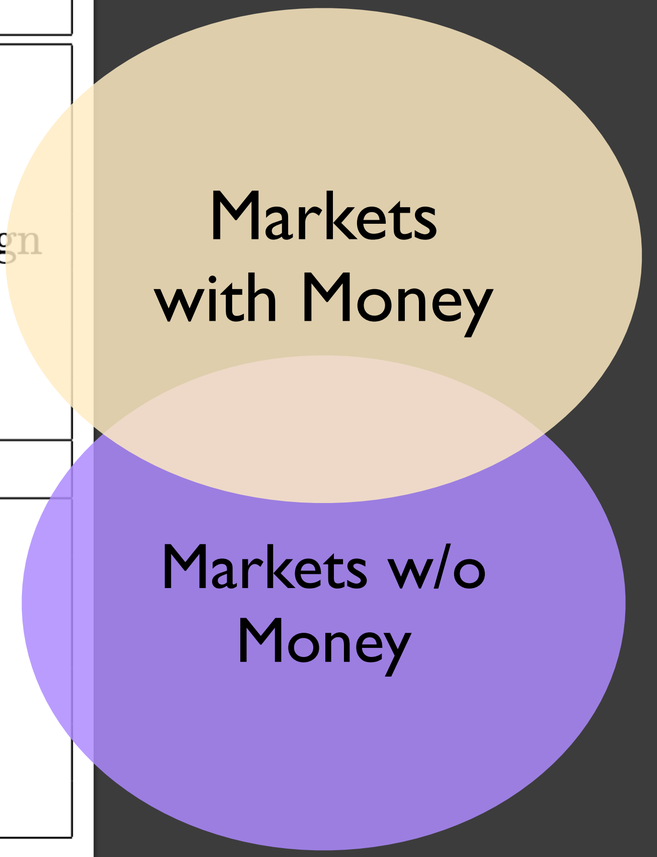

Readings Textbook(s)

- No single textbook; we will refer to several
  - **Twenty Lectures in Algorithmic Game Theory** by Roughgarden
  - **Algorithmic Economics: A Design Approach** by Parkes and Sueken (Unpublished, shared with us by author's permission)
  - **Networks, Crowds and Markets** by Easley and Kleinberg (available online)
  - **Mechanism Design and Approximation** by Hartline (available online.)
- Relevant chapters will be linked on GLOW (do not share)
- Will read research papers on relevant topics along the way
- Please skim readings before class and re-read after!

What to Expect

- Theoretical content: **formalize** and **analyze** properties of the mechanisms
  - Expect to write proofs
- Learn about **economics**
- Technical prerequisites:
  - Probability and multi-variable calculus
  - Python for simulations
  - Always reach out if you need more resources/help on prerequisites
- Learn about cool real-life algorithms and their consequences
- **Have fun!**

Course Support

- We have a TA ! (Rather half a TA, but still yay!)
  - Tai Henrichs (took AGT in Fall 2021)
  - Will hold ~2.5 hours of TA hours per week
- My office hours:
  - Tues & Wed 2-4.30 pm, Thurs 4-5 pm
- Treat office hours like lab time
  - Come and work on the problem set
  - Great place to collaborate with peers!

Assignment 0 Activities

- Posted on GLOW
- Join Slack:
  - Post an introduction with photo in #general
  - Get to know your classmates!
- Fill out short course survey
  - Let me know if you have any questions or concerns
- Sign up for a short Zoom chat with me
- Sign up for Gradescope

Honor Code Policies

- Collaboration is encouraged
  - Can discuss questions at a high-level
  - No sep-by-step problem solving or joint writing
  - Cannot share source code or write ups!
- Never turn in a solution you do not understand
- Always **cite collaborators** and **resources** in Acknowledgment section
- You are **not allowed to research homework questions on the internet**
  - This would be violation of the honor code

Coming Up

- Our first synchronous lecture (**Lecture 1 Part B**) will be held on **Wed Feb 2** from **3.10-3.50 pm**
    - Formalizing a game and Nash equilibrium
- **Assignment 1** will be released Thursday Feb 3, due Thursday Feb 10th
- **Lecture 2** will be held synchronously on Zoom on Monday Feb 7 at 2.35 pm
- Looking forward to meeting all of you!