

Introduction

1 Why study CS 6001?

Games \Rightarrow Strategic Interactions between Rational Agents

- *Game Theory*: Analysis of Games
- *Mechanism Design*: Designing Games with Desirable Outcomes

Traditionally studied in economics and politics...

Computer science meets game theory:

- Proliferation of computing technologies (e.g. Internet) into economic settings (e.g. e-markets)
- Many problems in distributed computing involves strategic agents making selfish decisions.

This led to two new disciplines in computer science:

- Theoretical computer science focused on studying the algorithmic aspects (e.g. computational complexity, inefficiency) of finding equilibria in different game theoretic settings.

- Designing strategic mechanisms for computing applications which produce desired outcomes.

However, there is a third area hidden within the game-theoretic literature which involves learning utilities of agents from data...

This course covers the three broad areas...

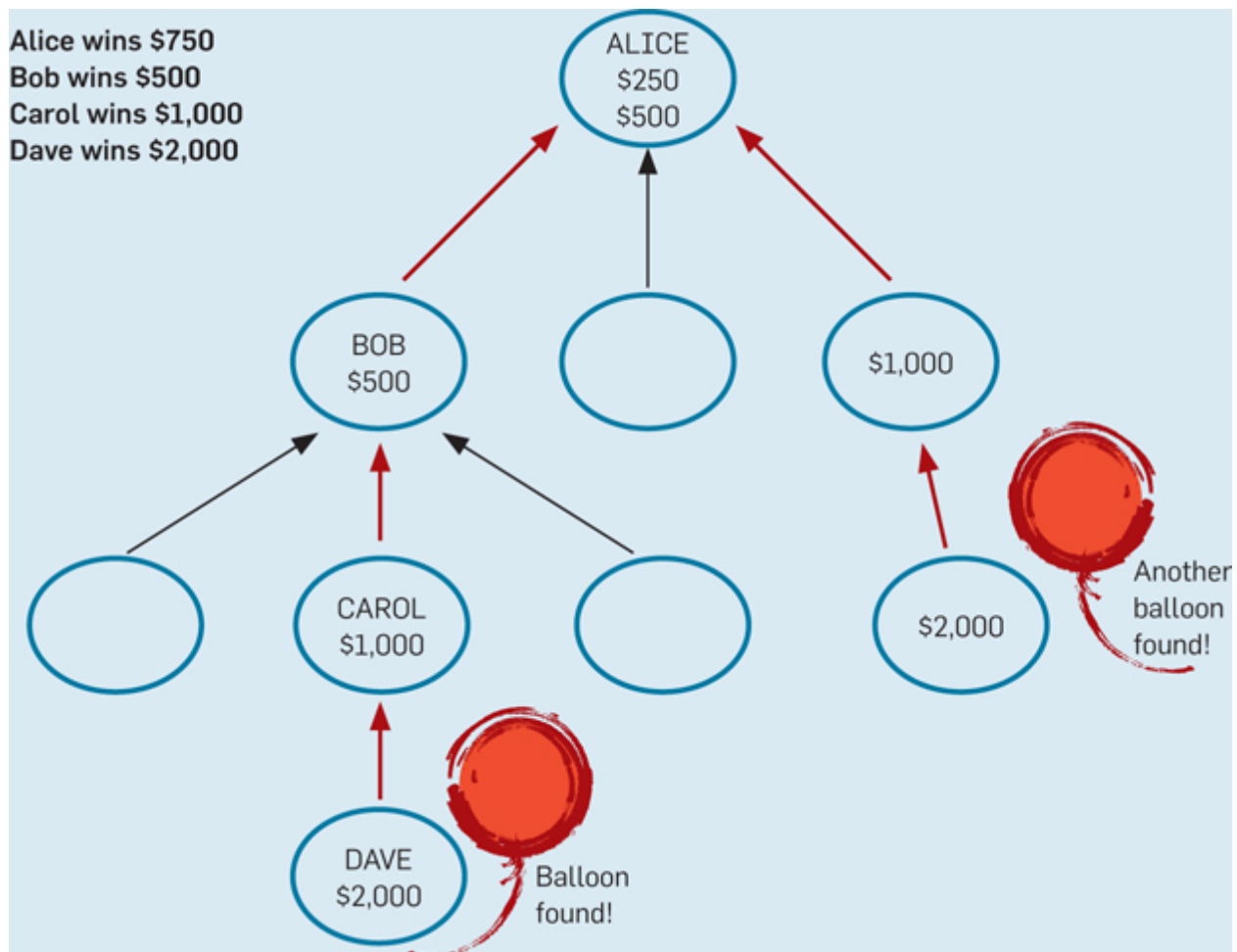
2 Algorithmic Game Theory: Its Impact

2.0.1 DARPA's Red Balloon Challenge



- Occassion: 40th anniversary of Internet

- 10 red balloons randomly deployed in US in unknown locations.
- Contestants should leverage **social networks** to locate all the ten balloons within a week.
- Prize: \$40,000
- MIT Red Balloon Challenge Team: 8 hrs, 52 mins, 41 secs.
- Strategy: Multi-level incentives in crowdsourcing



2.1 Keyword Auctions

The screenshot shows a Google search for "adwords". The search bar at the top contains the word "adwords". Below the search bar, there are tabs for "All", "News", "Videos", "Books", "Images", "More", "Settings", and "Tools". The search results show "About 55,100,000 results (0.74 seconds)".

The first search result is from ads.google.com/ and is titled "Google Ads - Official Site | AdWords is now Google Ads." The description says: "Thousands of people search for businesses like yours. Advertise on Google today. Advertise On Mobile. Pick Your Budget. Show Up Online. No Budget Minimums. Customized Reporting. Styles: Search Ads, Banner Ads, Video Ads, Mobile Ads, App Ads." Below the description are four links: "Get Started", "See How Google Ads Works", "What Does It Cost?", and "Why Choose Google Ads?".

The second search result is from business.linkedin.com/sponsored-ads and is titled "LinkedIn Sponsored Ads | #1 Platform for B2B Lead Gen". The description says: "Reach Your Ideal Customers On The World's Largest Professional Network. Generate Leads, Drive Website Traffic, and Build Brand Awareness with LinkedIn Ads. Types: Website Conversions, Lead Generation, Brand Awareness, Website Visits, Video Views, Engagement." Below the description are several links: "Lead Generation", "LinkedIn Ad Pricing", "Ad Targeting", "Brand Awareness", and "Create an Ad".

The third search result is from ads.google.com/ and is titled "Get More Customers With Easy Online Advertising - Google Ads". The description says: "Get more customers on the phone, on your site, and in the door. Online ads on Google can help you reach the right customers and grow your business." Below the description are two links: "Pricing" and "How it works".

On the right side of the search results, there is a knowledge panel for "Google Ads". It includes a description: "Google Ads is an online advertising platform developed by Google, where advertisers pay to display brief advertisements, service offerings, product listings, video content, and generate mobile application installs within the Google ad network to web users." It also mentions "Developed by: Google" and "Initial release date: October 23, 2000". Below the description, there is a section "People also search for" with icons for Google AdSense, Google Tag Manager, Google Drive, WordPress, and Google My Business.

At the bottom of the search results, there is a section "People also ask" with the question "What is AdWords and how it works?" and a dropdown arrow.

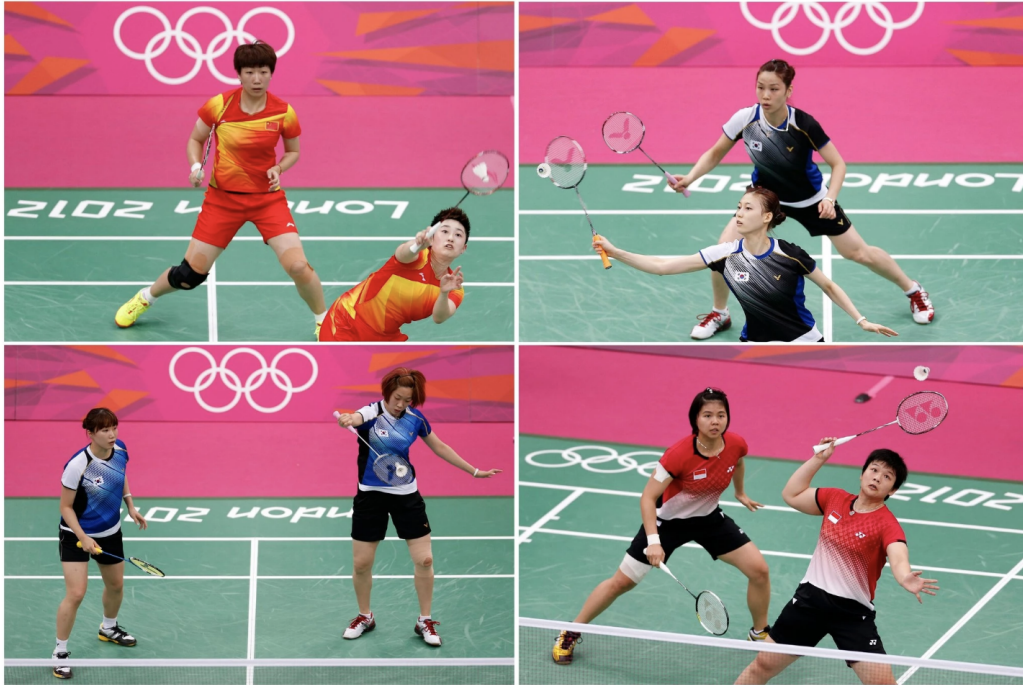
- Prior to 1994: Price charged per click... (less competition)
- 1994: Overture (GoTo.com in 1998) replaced pay-per-click system with a first-price auction.
- Late 1990s: Yahoo and MSN adopt first price auctions.

- 2002: Google Adwords adopted a second-price auction for one advertisement per page.
- Shortly, adopted a generalized second-price auction to accommodate multiple advertisements per page.
- GSP auctions are not truthful => huge burden on servers
- Later, most search engines adopted VCG auctions.

2.2 2012 London Olympics – Women’s Badminton

- Teams segregated into four groups (A, B, C, D) before Quarterfinals...
- Quarterfinal 1: A1 vs. C2
- Quarterfinal 2: B1 vs D2
- Quarterfinal 3: A2 vs. C1
- Quarterfinal 4: B2 vs. D1
- Group D: Danish team Pedersen and Juhl (PJ) beats Chinese team Tian and Zhao (TZ)

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

By Ken Belson

Aug. 1, 2012



- TZ is the favorite...
- Last day of Round-robin competition:
 - Group A: Chinese team Wang and Yu (WY) and South Korean team Jung and Kim (JK)

have equal points in the round-robin competition.

- Knockout tie-breaker \Rightarrow Both did not want to win this game..
- <https://www.youtube.com/watch?v=7mq1ioqiWEo>

- This was just the start...
- A classic example of bad tournament design.

3 How is this different from CS 5001?

In this course, we will follow a rigorous approach and will adopt theorem-proof style. The vision behind designing this course is to help **advanced graduate students** become independent research scholars in the area of algorithmic game theory. Therefore, the course shall have the following objectives:

- Develop mathematical rigor in modeling individual rationality using revealed preferences.
- Become proficient in analyzing the complexity of computing Nash equilibria.
- Develop deeper insights about the design of strategic mechanisms and their limitations.

- Gain mastery with designing various types of markets.

4 Prerequisites

Students are expected to have a strong foundation in the following (non-exhaustive) list of topics:

- Algorithms (‘C’ or better grade in CS 5200),
- Artificial Intelligence (‘C’ or better grade in CS 5400, or CS 5401)
- Game theory (‘C’ or better grade in CS 5001).

5 Textbook

There is **no textbook** for this course. However, students are encouraged to refer to one or more recommended books¹ from the following (non-exhaustive) list:

- **Noam Nisan *et al.* (Editors), “Algorithmic Game Theory,” Cambridge University Press, 2007.**
- Tamer Başar and Geert Jan Olsder, “Dynamic Non-cooperative Game Theory,” SIAM, 2nd Ed., 1999.

¹Links to free electronic copies of the books will be provided in the website, if available.

- John von Neumann and Oskar Morgenstern, “Theory of Games and Economic Behavior,” 60th Anniversary Commemorative Edition, Princeton University Press, 2007.
- Yoav Shoham, Kevin Leyton-Brown, “Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations,” Cambridge University Press, 2008.
- Y. Narahari, “Game Theory and Mechanism Design,” IISc Press and the World Scientific Publishing Company, March 2014.
- T. Roughgarden, “Twenty Lectures on Algorithmic Game Theory,” Cambridge University Press, 2016.

6 Prospective List of Topics

In this course, we will tentatively cover six topics, each with mathematical rigor in a lecture format, followed by a case study on some practical state-of-the-art paper(s) presented by students. The order in which these topics shall be covered are highlighted in red.

- *Mechanism Design*
 - Revelation Principle
 - Impossibility Theorems

- Quasi-Linear Environments
- ***Markets***
 - Auctions
 - Stable Matching
 - Dynamic Pricing and Bandits
- ***Learning in Games***
 - Fictitious play
 - Regret Minimization
- ***Inefficiency***
 - Price of Anarchy
 - Selfish Routing
 - Braess Paradox
- ***Games and Complexity***
 - PPAD Class
 - Non-Linear Complementarity
 - Lemke-Howson Algorithm

7 Grading Information

All the grades will be posted and maintained on Canvas.

| | |
|---------------------|--------------------|
| Assignments: | 50% of total grade |
| Case Study: | 20% of total grade |
| Project: | 30% of total grade |

Final Grade:

A: $[85 - 100]$, B: $[75 - 85)$, C: $[60 - 75)$, F: < 60 .