

Algorithmic Game Theory

Professor Amy Greenwald

CSCI 1440/2440

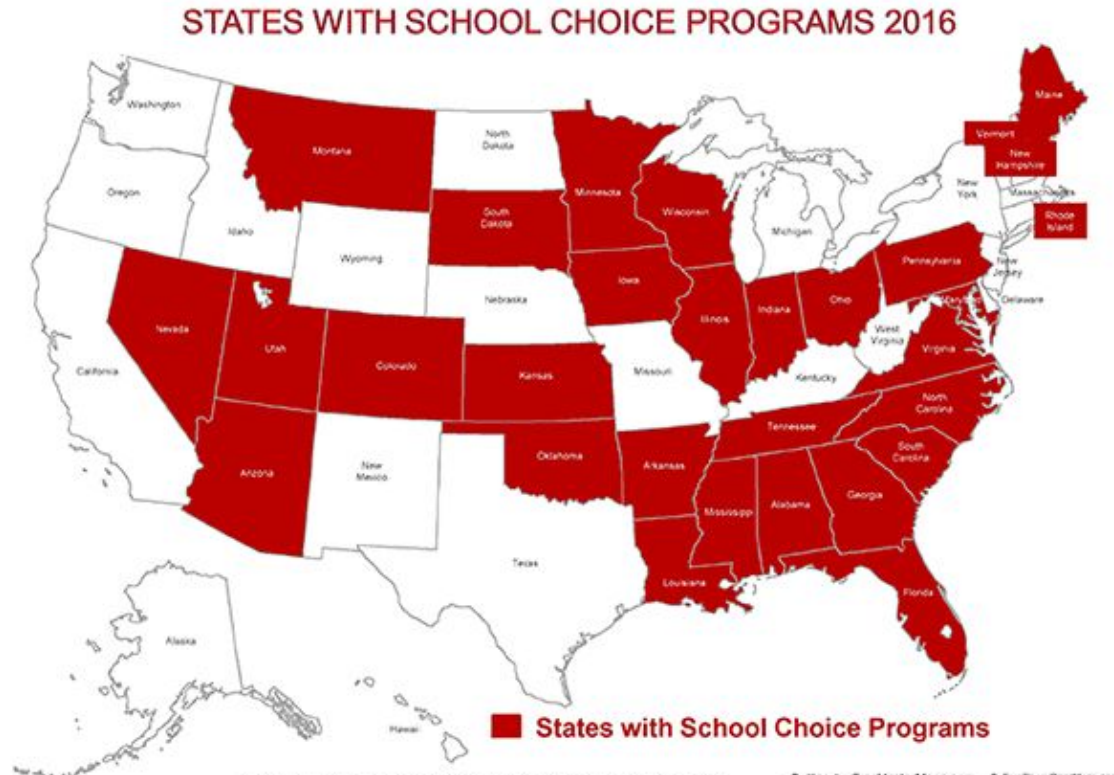
Algorithmic Game Theory

- Game theory is used to model multiagent interactions (multiagent systems)
 - Participants (agents, players, etc.) have partially competing & partially cooperative interests
 - Economics: agents are people, nations, etc.
 - AI: softbots, robots, LLMs, etc.
- **Q:** How do agents play games?
- If we assume agents behave rationally, then **A:** equilibrium (stable outcome)
 - Computational game theory: algorithms that solve for equilibrium in games
 - Game-theoretic machine learning: learning algorithms that converge to equilibrium in games
- **Heuristic:** Agents play their part of an equilibrium strategy
 - Successful examples in complete- and incomplete-information zero-sum games: AlphaGo, poker agents, etc.

Mechanism Design (Inverse Game Theory)

- Given assumptions about how agents play games (e.g., rationality), the goal is to design games that achieve a desired objective:
i.e., whose equilibria satisfy certain properties
- Typical approach: design games that are straightforward to play:
e.g., games with unique equilibria
- In practice: this goal is difficult to achieve
- Why? Because the agents' preferences are unknown, and must be elicited

School Choice



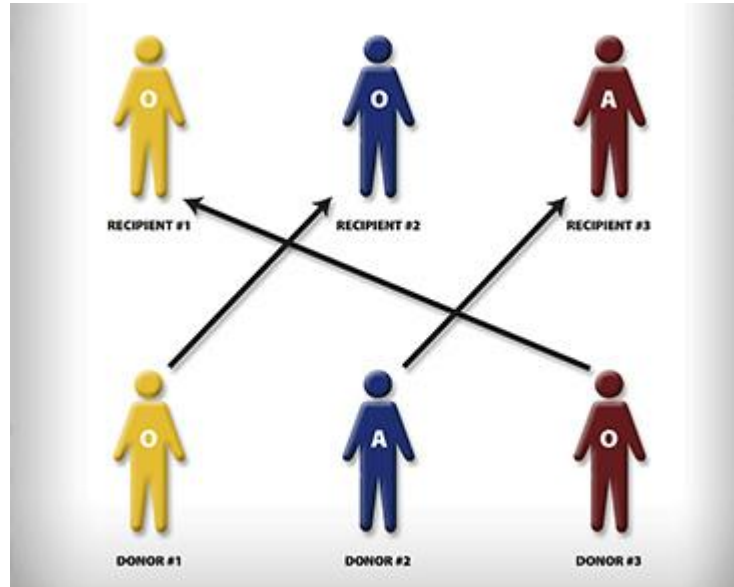
Source: www.edchoice.org/school-choice/school-choice-in-america

Outline by FreeVectorMaps.com © FreePowerPointMaps.com

School Choice

- Milton Friedman (Nobel laureate)
- Students: rank (a subset of) schools
- Schools: “rank” students (neighborhood, siblings, etc.)
- Objective: make students happy, make schools diverse, etc.
- Matching algorithm
 - Stable marriage
 - Gale & Shapley 1962
- Are these mechanisms truthful?

Kidney Exchanges



Kidney Exchanges

- Al Roth (Nobel laureate)
- An exchange announces a matching algorithm to find compatible kidneys for people whose donor's kidney is incompatible with theirs
- Hospitals report incompatible donor-recipient pairs (e.g., blood type mismatch)
- Objective: to facilitate as many trades as possible
- Matching algorithm
 - Stable marriage
 - Gale & Shapley
- Are these mechanisms truthful?

Auctions

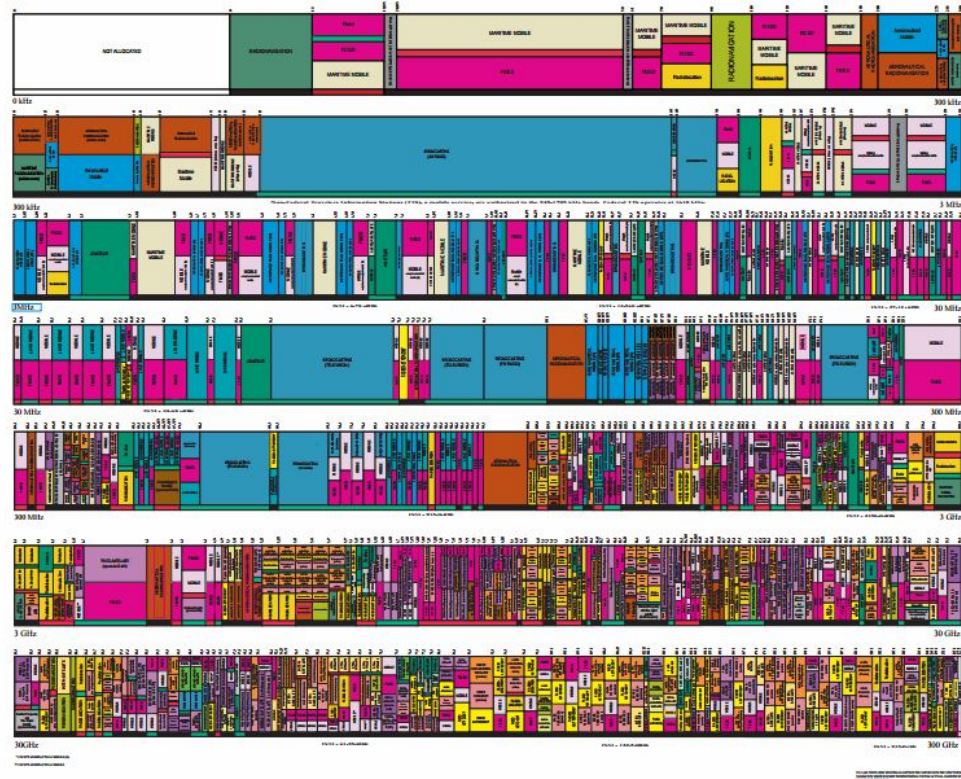


Auctions

- William Vickrey (Nobel laureate)
- An auction for some goods is announced
- Bidders report their willingness to pay for the goods
- Bidders' values for the goods are their private information
- Utilities are the difference between the value to bidders of what is allocated to them and what they pay
- An “optimal” auction is one that extracts maximal total payments (i.e., revenue) from the participants
- Another common objective (especially in government auctions) is to maximize welfare

from Theory to Practice

UNITED
STATES
FREQUENCY
ALLOCATIONS
THE RADIO SPECTRUM



Spectrum Auctions

- All wireless communication signals travel over the air via radio frequency: a.k.a. spectrum
- No two radio or TV stations transmit data over the same spectrum at the same time in the same area, because doing so would cause interference!
 - Ditto for wireless communication: wireless operators also cannot transmit wireless signals over the same frequency at the same time in the same area
- Combinatorial resource allocation problem, because providers have preferences over sets of goods (e.g., MA, RI, and CT; or CT, NY, and NJ)
- Combinatorial auctions
 - 1990 New Zealand: simultaneous second-price auctions
 - 1999 Germany: simultaneous first-price auctions

Computational Advertising: Sponsored Search Auctions

+You Search Images Maps Play YouTube News Gmail Documents Calendar More ▾

Google

Search About 3,500,000 results (0.21 seconds)

Everything
Images
Maps
Videos
News
Shopping
More

Colorado Springs, CO
Change location

All results
Related searches
More search tools

Ads related to web design colorado springs Why these ads?

Colorado Web Design Pro | madwirewebdesign.com
www.madwirewebdesign.com/
Web design That will Increase Sales Design, Hosting & Marketing package

Colo Springs Web Design | infront.com
www.infront.com/
Custom Design & Development - Take a Look at Our Portfolio
↳ Services - Portfolio - Marketing - Our Team

Website Design & SEO Mktg | icontrolwebstudio.com
www.icontrolwebstudio.com/
We design & build, you update 24/7 Serving Colorado Springs for 14yrs

Colorado Springs Web Design, Development, and SEO | Infront ...
www.infront.com/
Infront Webworks is a full service online agency offering Web Design, Web Development, Internet Marketing, Search Engine Marketing, Email Campaigns.
↳ Contact - Help - Portfolio - Company

Colorado Springs Web Design ...
www.blueskydesign.com
Web design company that builds sites for small to medium sized businesses that they can update themselves. Includes service description and portfolio.

Ads - Why these ads?

CTU Colorado Springs
www.ctudegreenow.com/
Offering Online Enrollment Now!
Colorado Springs Classes Start 5/20
4435 N. Chestnut Street, Colorado Springs

Hire Web Experts
www.elajute.com
Instant Access to Great Designers.
Get a Free Web design quote.

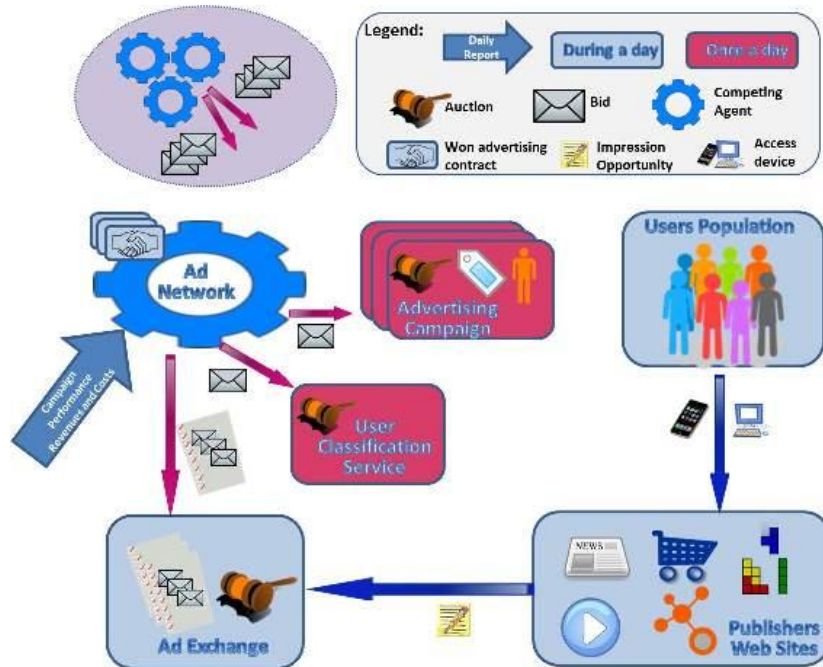
Build Your Own Website
www.buildyoursite.com/
4000 Templates - Easy-to-Use Tools.
Free Domain Name - From \$9.95/mo.

Creative Digital Design
www.blur-designs.com/
Great artwork for your projects!
Cost-effective and high-quality

Website Design From \$635
www.webcreationus.com/
Award Winning Custom Built Sites,
Instant Online Quote, Stunning Work

Computational Advertising: Ad Exchanges

Trading Agent Competition



Automated Agents Negotiation Competition

- Automated Negotiation League
- Supply Chain Management League
- Human-Agent Negotiation Pilot

My thesis, 1999

Environment

- Shopbots and pricebots were causing a paradigm shift in Ecommerce
- But their widespread deployment posed technical and societal challenges

Key Observation

- Shopbots and pricebots are economic agents, and can thus be modeled as boundedly rational decision makers in an online economy

Key Questions

- Can we use machine learning to build better shopbots and pricebots?
- Can we use game theory to explain dynamic interactions among bots?

My hypothesis, 2023

Environment

- Foundation models (like LLMs) are causing a major paradigm shift in AI
- But their widespread deployment pose technical and societal challenges

Analogous Observation

- Foundation models are loss minimizers, and can thus be modeled as boundedly rational decision makers in an online ecosystem

Key Questions

- We are already using machine learning to build foundation models
- Can we use game theory to build *strategic* foundation models?
- Can we use game theory to explain dynamic interactions among SFMs?

Game plan

1. Build strategic foundation models by incorporating GT modeling and tools

Examples:

- GANs (generative adversarial networks) as zero-sum games
 - RLHF as a general-sum Stackelberg game
2. Advance game theory and algorithmic game theory using strategic FMs
 3. Assess the societal impact of strategic FMs using game theory