CS243: Introduction to Algorithmic Game Theory

Week 1.1, Introduction (Dengji ZHAO)

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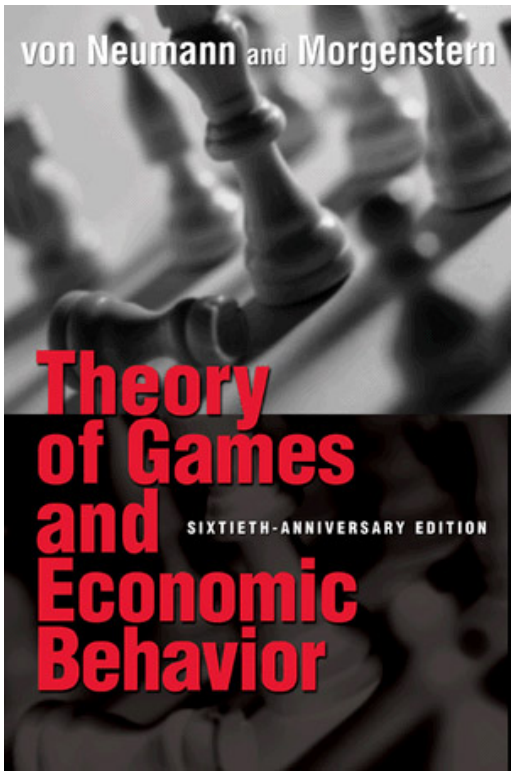
What is Game Theory

- **Game theory** is the study of mathematical models of conflict and cooperation between intelligent rational decision-makers [von Neumann and Morgenstern 1944].



- Extensive form: Go, poker
- Normal form: rock-paper-scissors
- Cooperative game: coordination games

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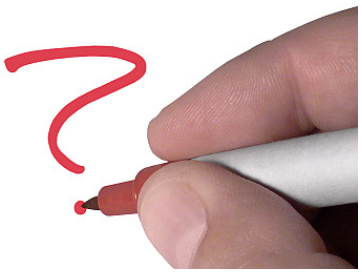
	Participants	Game	Outcome
Game Theory			
Mechanism Design			

Mechanism Design (Reverse Game Theory)

Mechanism Design is to answer...

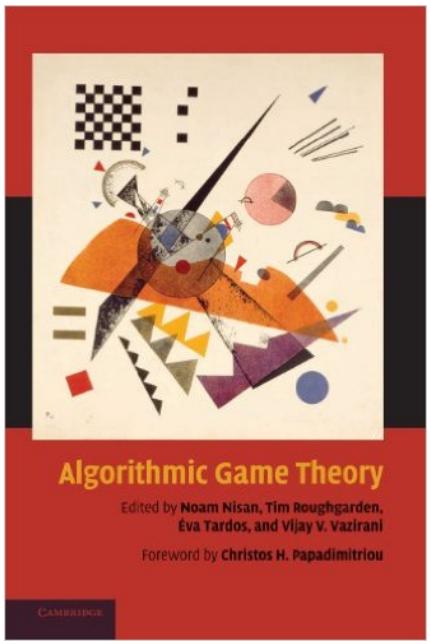
Question

How to design a mechanism/game, toward desired objectives, in strategic settings?

- **Roger B. Myerson** (born March 29, 1951, University of Chicago, US)
  - Nobel Prize for economics (2007), for "having laid the foundations of mechanism design theory."
  - *Eleven game-theorists have won the economics Nobel Prize.*

When Game Theory Meets CS?

- **Algorithmic Game Theory** is an area in the intersection of game theory and algorithm design, whose objective is to design algorithms in strategic environments [Nisan et al. 2007].



- *Computing in Games*: algorithms for computing equilibria
- *Algorithmic Mechanism Design*: design games that have both good game-theoretical and algorithmic properties
- ...

When Game Theory Meets CS?

- **Algorithmic Game Theory** is an area in the intersection of game theory and algorithm design, whose objective is to design algorithms in strategic environments [Nisan et al. 2007].

It is multidisciplinary:

- Artificial Intelligence $\rightarrow$ Multi-agent Systems $\rightarrow$ Algorithmic Game Theory
- Economics
- Theoretical Computer Science

Algorithmic Game Theory in Artificial Intelligence

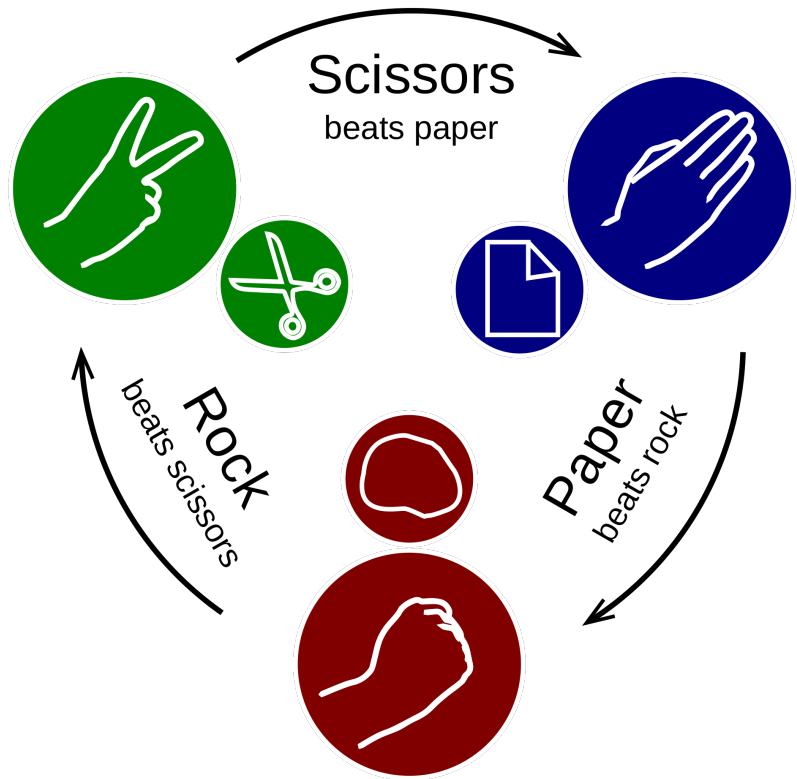
- Algorithmic Game Theory research in AI (multi-agent systems):
  - Game Playing: computation challenge, AlphaGo, poker
  - Social Choice: preferences aggregation, voting, prediction
  - Mechanism Design: the allocation of scarce resources (security games), Ad auctions, online auctions, false-name-proof mechanisms (**Makoto Yokoo**)
- IJCAI Computers and Thought Award: 5 out of the 12 winners (1999-2017) had worked on AGT, **Nick Jennings** (1999), Tuomas Sandholm (2003), Peter Stone (2007), Vice Conitzer (2011), Ariel Procaccia (2015).

Outline

Game Play

Let's playing games...

Rock Paper Scissors



Prisoners' Dilemma

- Two players: P1 and P2
- Strategies: Confess, Silent
- Outcomes: number of years in prison

P1 \ P2	Confess	Silent
Confess	4, 4	5, 1
Silent	1, 5	2, 2

Battle of the Sexes

- Two players: Girl, Boy
- Strategies: Baseball (B), Softball (S)
- Outcomes: payoffs/benefits/utilities

Girl \ Boy	B	S
B	6, 5	1, 1
S	2, 2	5, 6

Chicken Game

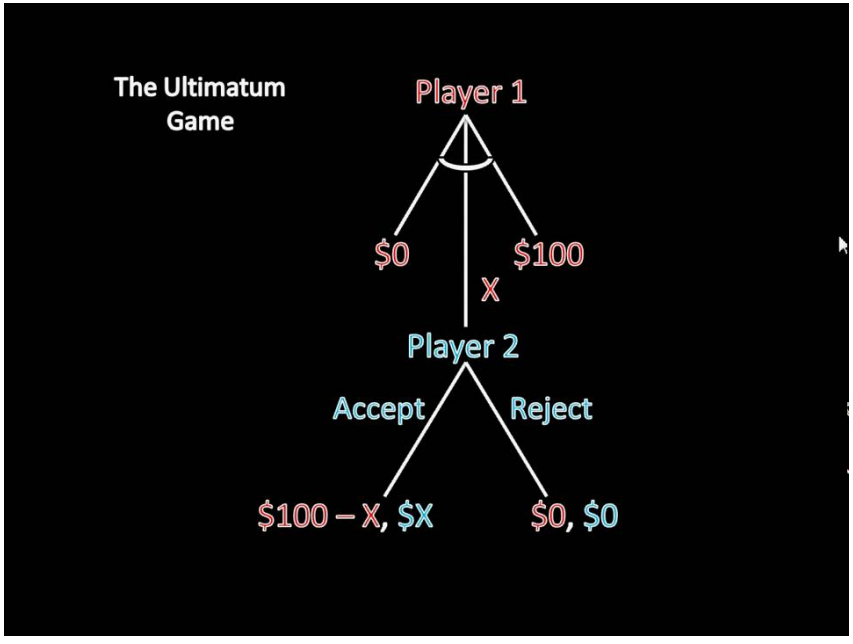
- Two players: P1, P2
- Strategies: Swerve, Straight
- Outcomes: utilities

	Swerve	Straight
Swerve	Tie, Tie	Lose, Win
Straight	Win, Lose	Crash, Crash

	Swerve	Straight
Swerve	0, 0	-1, +1
Straight	+1, -1	-1000, -1000

Ultimatum Game

- Two players: P1, P2
- Strategies:
  - P1: propose to divide $100 between P1 and P2
  - P2: accept or reject
- Outcomes: utilities



College/Master/PhD Entrance Exam

The setting:

- The are two colleges: $\mathcal{C}_1, \mathcal{C}_2$ and three students $\mathcal{S}_1, \mathcal{S}_2, \mathcal{S}_3$.
- The colleges' preferences are:
  - $\mathcal{C}_1$: $\mathcal{S}_1 \succ \mathcal{S}_2 \succ \mathcal{S}_3$
  - $\mathcal{C}_2$: $\mathcal{S}_1 \succ \mathcal{S}_2 \succ \mathcal{S}_3$
- The students' preferences are:
  - $\mathcal{S}_1$: $\mathcal{C}_1 \succ \mathcal{C}_2$
  - $\mathcal{S}_2$: $\mathcal{C}_1 \succ \mathcal{C}_2$
  - $\mathcal{S}_3$: $\mathcal{C}_2 \succ \mathcal{C}_1$

The process (each college can only accept one student):

1. Stage 1: each student chooses one college to apply and each college chooses her most preferred student to accept.
2. Stage 2: unaccepted students from Stage 1 can choose their second college to apply and the colleges who have quota left choose their most preferred student to accept.

Outline

A Game Design Example

Let's design a game...

Design Goal

How can a house-seller sell her house with the "highest" profit?

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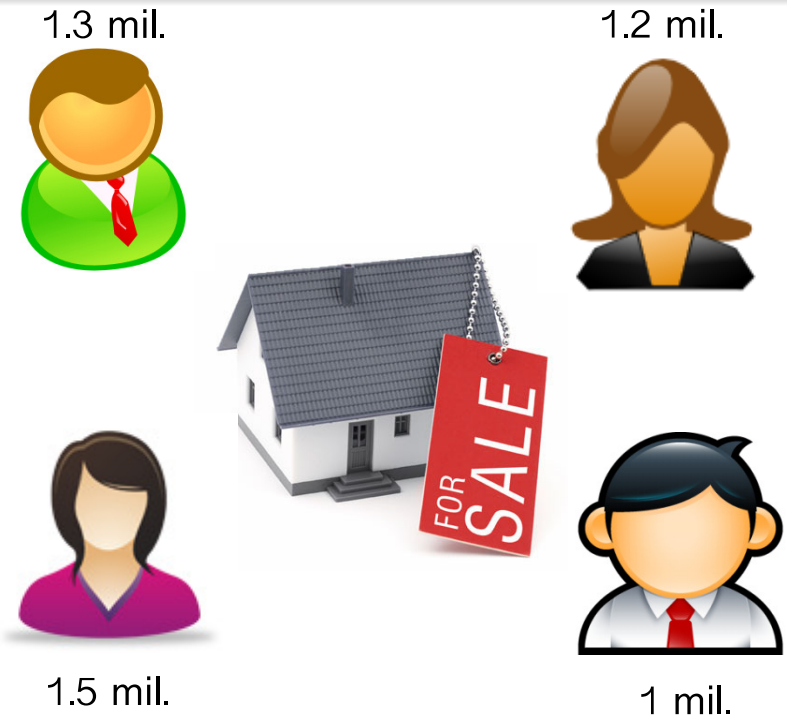
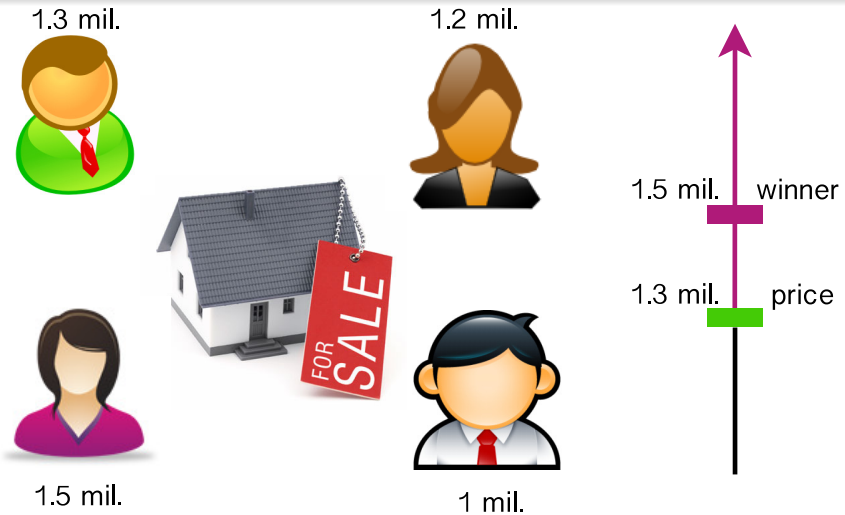


- **Challenge**: the seller doesn't know how much the buyers are willing to pay (their valuations).

A Game Design Example

Design Goal

How can a house-seller sell her house with the "highest" profit?



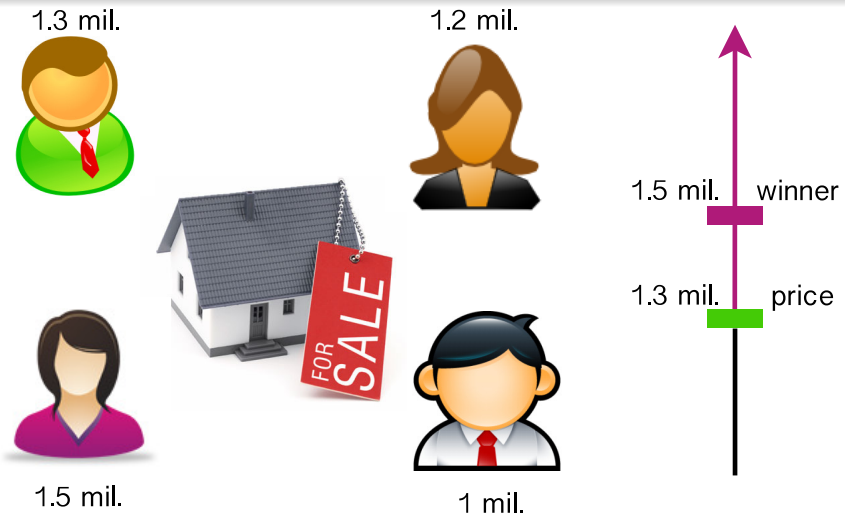
Solution: Second Price Auction (Vickrey Auction/VCG)

- Input: each buyer reports a price/bid to the seller
- Output: the seller decides
  - *allocation*: the agent with the highest report price wins.
  - *payment*: the winner pays the second highest price reported.

A Game Design Example

Design Goal

How can a house-seller sell her house with the "highest" profit?



Solution: Second Price Auction (Vickrey Auction/VCG)

Properties:

- Efficient: maximising social welfare
- Truthful: buyers will report their highest willing payments

Generalized Second Price (GSP) Auction

Generalized Second Price (GSP) Auction

Advertiser	Bid	Price	Order	CTR
A_1	6	4	1st	1
A_2	4	2	2nd	0.9
A_3	2	1	3rd	0.5
A_4	1			

Car Plates Allocation

Outline

The Objectives of CS243

- Introduction of the basic concepts of AGT such as Nash equilibria, dominant strategies, and their computations
- Study of its key applications such as auctions, matching, voting, predictions
- Be ready for the advanced topics of AGT such as mechanism design, repeated games

Schedule

- 12 weeks lectures (Mon and Tue 3:00PM-4:40PM)
- One project (from Week 4)
- One exam (after Week 12)

Course Plan

- Introduction
  - Game Play: Nash equilibrium, dominant/mix strategies, etc.
  - Game Design: auctions, voting, crowdsourcing, etc.
- Auctions
  - Second Price Auction (English auction)
  - Internet Advertising (Google, Baidu)
  - Combinatorial Auction (spectrum auction)
- Social Choice
  - President Election (winner determination)
  - Ranking (preference aggregation)
- Matching Markets
- Human Computation
- Exchange Markets
- Advanced Topics (Blockchains)

Course Plan

- Introduction
- Auctions
- Social Choice
- Matching Markets
  - Student-School Matching (college entrance examination)
  - Kidney Exchange (kidney donations)
- Human Computation
  - Crowdsourcing (image labeling)
  - Peer Prediction (who is going to win the next world cup?)
- Exchange Markets
  - Double Auction (stock exchanges)
  - Online Auction
  - Sharing Economy Markets (car/house-sharing)
- Advanced Topics (Blockchains)

Project Plan

Plan A Choose one top quality conference/journal paper related to game theory and apply the results in a new setting. Write a report.

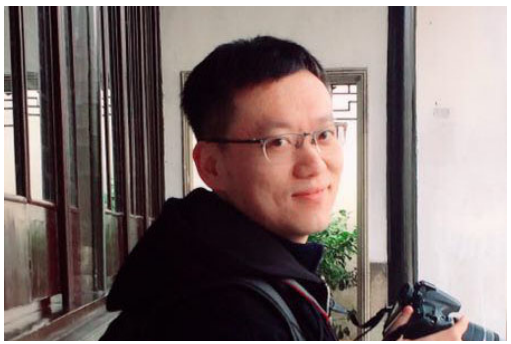
Plan B Implement a game theory related game and test it with enough players. Write a report.

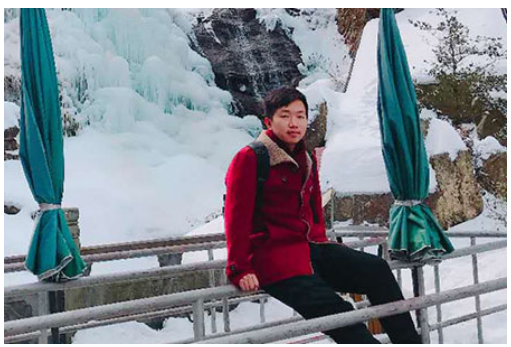
Evaluation

- Classroom Quizzes (10%)
- Homework (25%)
- Project (25%)
- Exam (40%)

Questions and Interactions

- Teaching Assistants: Zhang Tianyi (PhD Y4), Yang Tianyi (RA), Zhang Yao (Ms. Y2), Lian Xinyuan (Ms. Y2), Ge Xu (Ms. Y1).




- Online Interactions:
  - Piazza (slides and QnA)

Reading Material

- **Algorithmic Game Theory**, edited by N. Nisan, T. Roughgarden, E. Tardos, and V. Vazirani, Cambridge University Press, 2007.