Algorithmic Game Theory

COMP6207

Lecture 1: Introduction

Dr Bahar Rastegari
b.rastegari@soton.ac.uk
Electronics and Computer Science
University of Southampton

Advanced Intelligent Agents

- What is this module about?
  - It used to be Advanced Intelligent Agents
    - A successor of COMP6203: Intelligent Agents
  - Algorithm + Game Theory + **Mechanism Design**

- What is this module NOT about?
  - Not a programming course

Module Structure

- 3 hours of in-person lectures per week
  - 1 hour on Mondays 13:00-14:00 in 27/2003 (L/R 2)
  - 1 hour on Thursdays 9:00-10:00 in 07/3027 (L/R F1)
  - 1 hour on Fridays 11:00-12:00 in 13/3021
- Lectures will often include interactive activities such as playing games, solving assignments and short (ungraded) quizzes
- MS Teams group for Q&A on lectures and coursework
- Course Team:
  - Dr Bahar Rastegari (b.Rastegari@soton.ac.uk)
  - Dr Pavel Naumov (P.Naumov@soton.ac.uk)

Where to find what

- **Module's page**: general information about the module, schedule, slides and other materials

- **MS Teams**: Q&A and discussions

Assessment

- 75% Exam

- 25% Coursework
  - 2 worksheets each worth 8%
  - 1 group presentation project worth 9%

Guess the value of the laptop

- Two of you each lost a laptop (identical) and claimed for compensation towards the insurance company.

- Insurance company does not know the actual value of the laptop, only you two know.

- To find out a reasonable compensation amount, the IC separates you two and asks you its value $\in$[£2, £100].
  - If you declare the same number x, each of you will be given £x
  - If you declare different numbers x and y ($x < y$), then you will be given x+2 and x-2 respectively

Guess 2/3 of the average

- Each of you write down a number between 0 and 100.
- Whoever is closest to 2/3 of the average wins.

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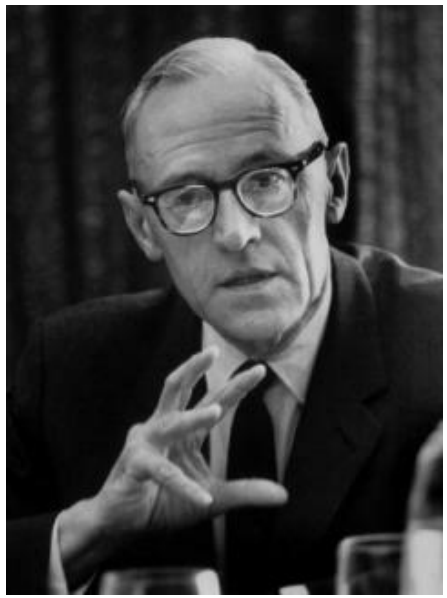
- 21.6 was the winning value in a large internet-based competition organized by the Danish newspaper Politiken. This included 19,196 people and with a prize of 5,000 DKK.

Keywords

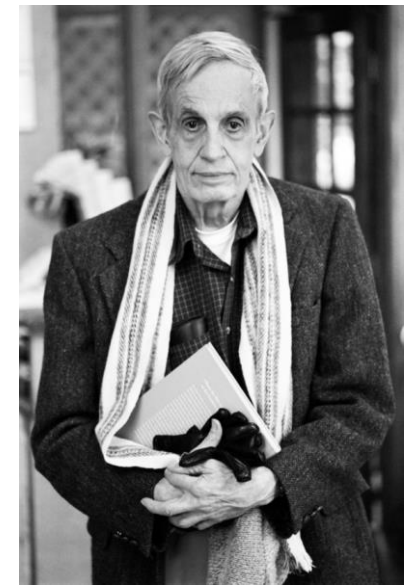

Game
Dominated
theory
strategy
Incomplete
information
Incentive
Outcome
Iteratively
elimination
Rationality
Payoff

Game Theory: Pioneer



Oskar Morgenstern

John von Neumann
Minimax theorem, 1928
Linear programming duality



John Nash
Nash equilibrium
Bargaining game

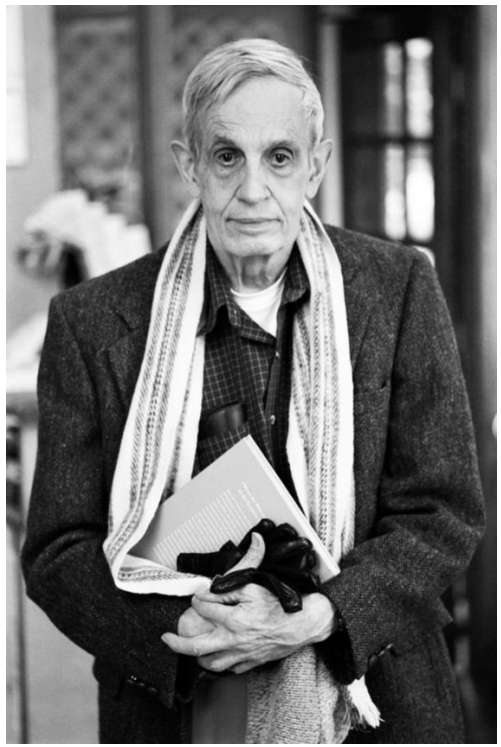
Theory of Games and Economic Behavior, 1944, 1947, 2004

- Objective/Subjective probabilities
- vNM Utility Theorem

} Expected Utility Theory

Recognition of Excellence

1994 Nobel Prize

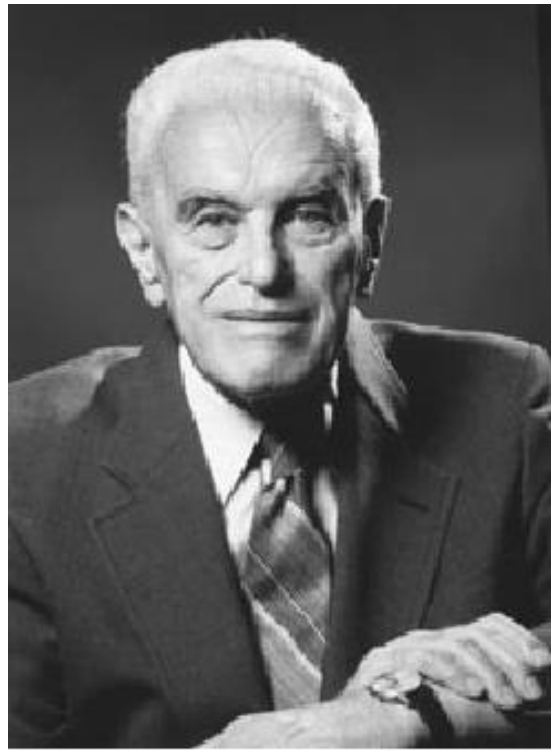


John Nash

Nash equilibrium

Bargaining game

Abel Prize



John Harsanyi

Bayesian games

Equilibrium selection

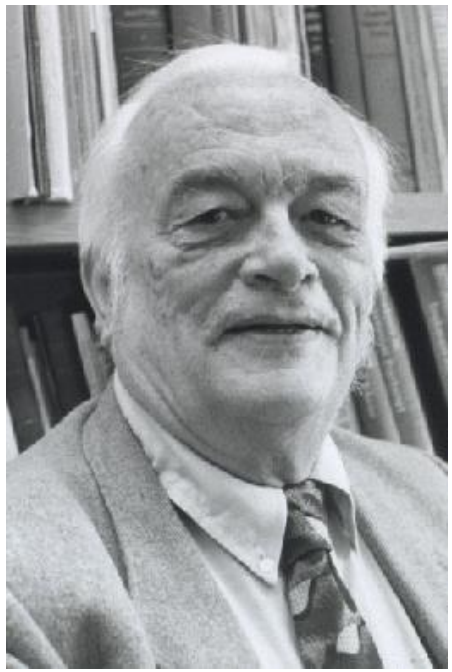
Application in political and moral philosophy

Reinhard Selten

Bounded rationality

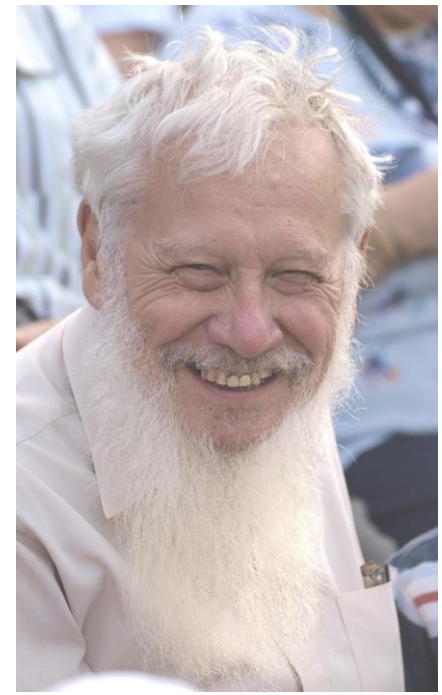
Subgame perfect equilibrium

1996 Nobel Prize



William Vickrey

James Mirrlees



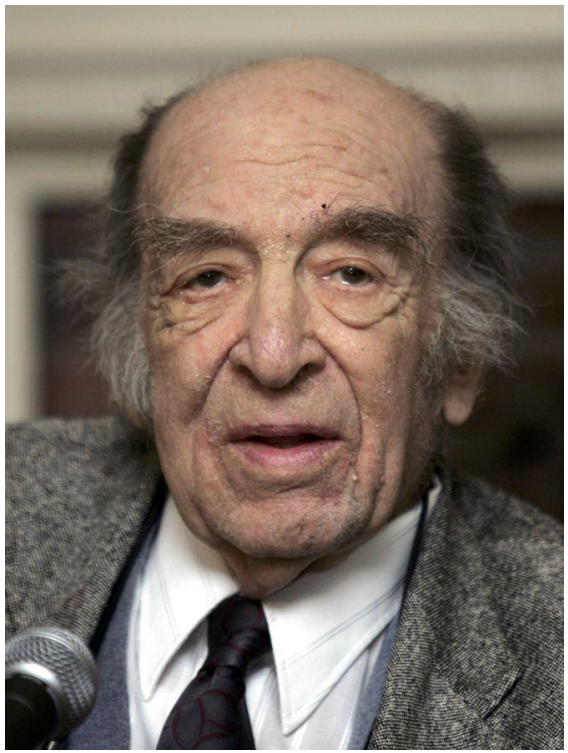
Robert Aumann

Incentives under asymmetric information

Repeated Games
Correlated Equilibrium

Mechanism Design

2007 Nobel Prize



Leonid Hurwics

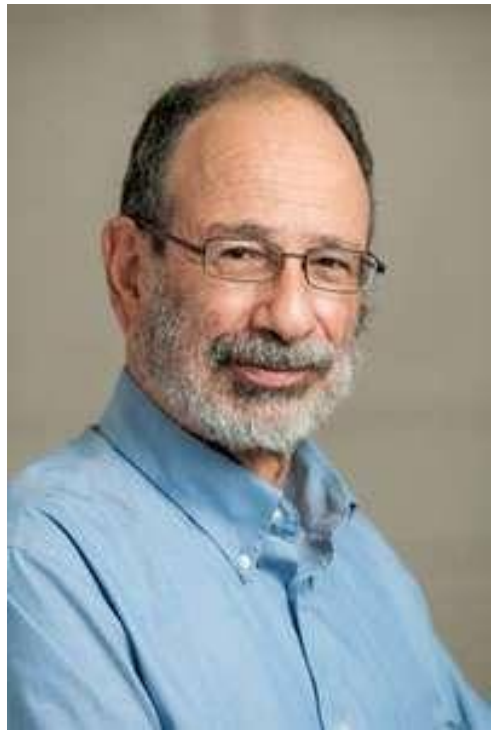
Eric Maskin

Roger Myerson

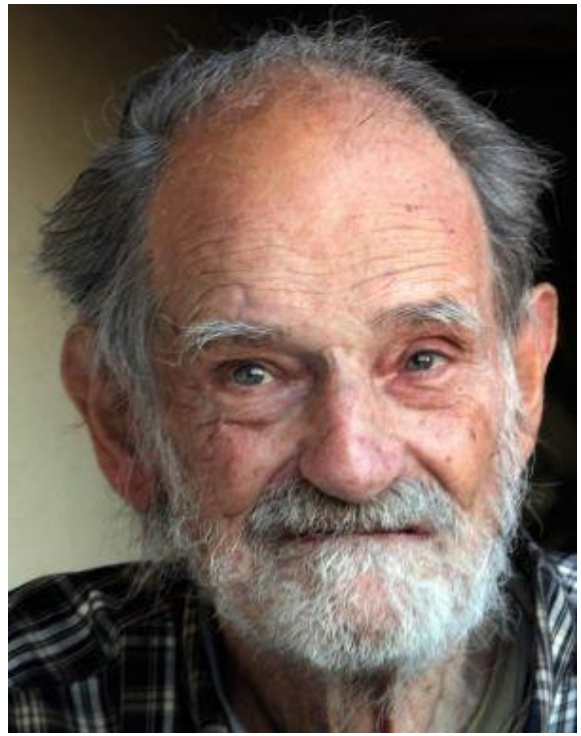
``for having laid the foundations of mechanism design theory"

Market Design

2012 Nobel Prize



Alvin Roth



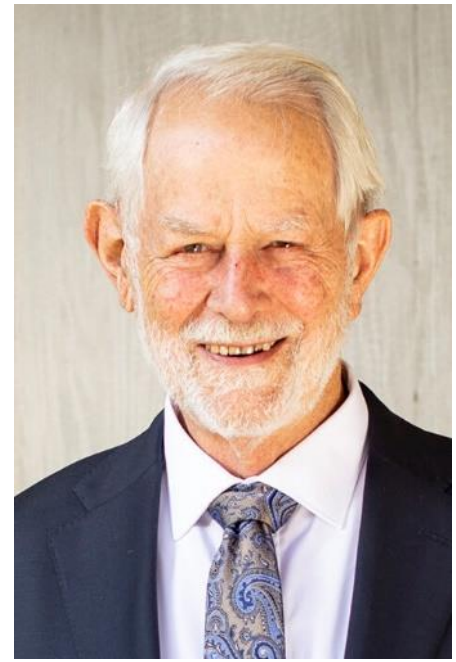
Loyd S. Shapley

``for the theory of stable allocations and the practice of market design''

Auction Theory

2020 Nobel Prize

Paul R. Milgrom



Robert B. Wilson

``for improvements to auction theory and inventions of new auction formats"

Artificial Intelligence and Game Theory

- AI: to design ***intelligent*** robots/agents to perform human tasks.
  - cognition, psychology 
  - learning, optimisation 

- ***Game theory*** is the study of mathematical models of conflict and cooperation between intelligent rational decision-makers.

- *Rationality*: maximizing expected utility.
  - Perfect vs. Bounded.

- GT offers: principles of rationality + theoretical foundation.

Why study Game Theory

- Method of studying strategic situations, i.e., where the outcomes that affect you depend on actions of others.
- Used in business, cybersecurity, economics, politics, etc.
- Beautiful theoretical results.
- Get better at rock-paper-scissors.

Mechanism Design

- A.k.a. Reverse Game Theory
  - Algorithm design, protocol design
- Impossibilities
  - Mutually exclusive desired properties
- Approximability
  - Approximation rations
  - Worst-case, smoothed analysis, average-case

Content

- Mechanism design with money
  - Vickrey–Clarke–Groves mechanism (VCG)
- Mechanism design without money
  - Matching theory (One-sided, two-sided, roommate, stability)
- Auctions & Computational advertising
- Computational Social Choice
  - Voting and fair division

Learning Outcomes

By the end of this module, you should be able to

- **Describe** various game-theoretic concepts and governing principles
- **Solve** problems arising in settings with self-interested participants, and **predict** possible behaviour and outcomes
- **Describe** the principles of mechanism design and explain its use to shape incentives and designing markets/mechanisms
- **Apply** game theory and mechanism design on practical problems, **develop** efficient algorithms, and **evaluate** the solutions.

Reference books (partial list)

- David F. Manlove, ***Algorithmics of Matching under Preferences***. World Scientific Publishing Company, 2013, ISBN 10: 9814425249/ISBN 13: 9789814425247.
- Martin J. Osborne, ***An Introduction to Game Theory***. Oxford University Press, 2003, ISBN 10: 0195128958/ISBN 13: 9780195128956.
- Alvin E. Roth, Marilda A. Oliviera Sotomayor, ***Two-Sided Matching: A Study in Game-Theoretic Modelling and Analysis***. Cambridge University Press, 1990, ISBN 10:0521437881/ISBN 13:9780521437882.
- Yoav Shoham, Kevin Leyton-Brown**,** ***Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations***. Cambridge University Press, 2009, ISBN: 9780521899437.
- Vijay Vazirani, Noam Nisan, Tim Roughgarden, Éva Tardos, ***Algorithmic Game Theory***. Cambridge University Press, 2007, ISBN: 9780521872829.
- Michael Wooldridge, ***An Introduction to Multi-Agent Systems***. John Wiley & Sons, 2nd Edition, 2009. ISBN 10: 0470519460/ISBN 13: 9780470519462

Reference courses (partial list)

- Yiling Chen http://www.eecs.harvard.edu/cs286r/
- Constantinos Daskalakis
  https://stellar.mit.edu/S/course/6/sp17/6.853/index.html
- Matthew O. Jackson, Kevin Leyton-Brown, Yoav Shoham
  https://www.coursera.org/learn/game-theory-1
  https://www.coursera.org/learn/game-theory-2

- Jonathan Levin http://web.stanford.edu/~jdlevin/teaching.html
- Christos H. Papadimitrio
  http://www.cs.berkeley.edu/~christos/games/cs294.html
- David C. Parkes http://beta.blogs.harvard.edu/k108875/lectures
- Alvin E. Roth https://stanford.edu/~alroth/alroth.html
- Tim Roughgarden http://theory.stanford.edu/~tim/f13/f13.html
- Eva Tardos http://www.cs.cornell.edu/courses/cs6840/2012sp/

Suggested reading for next lecture

- Read Huffington Post's article on ``*Badminton and the science of rule making*'', by Jason Hartline and Robert Kleinberg.

- Watch Tim Roughgarden's introductory lecture on algorithmic game theory.

- Next lecture: Q&A on Strategic Form Games a.k.a. Normal form games