Teoria dos Jogos em Computação

Pedro O.S. Vaz de Melo

1/2025

Agenda

- What is game theory?

- Computer Science applications

- Course program

- Grading

- References

- Goals

Agenda

- ***What is game theory?***
- Computer Science applications
- Course program
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- Goals

Before we start...

- This course is not about...

Before we start...
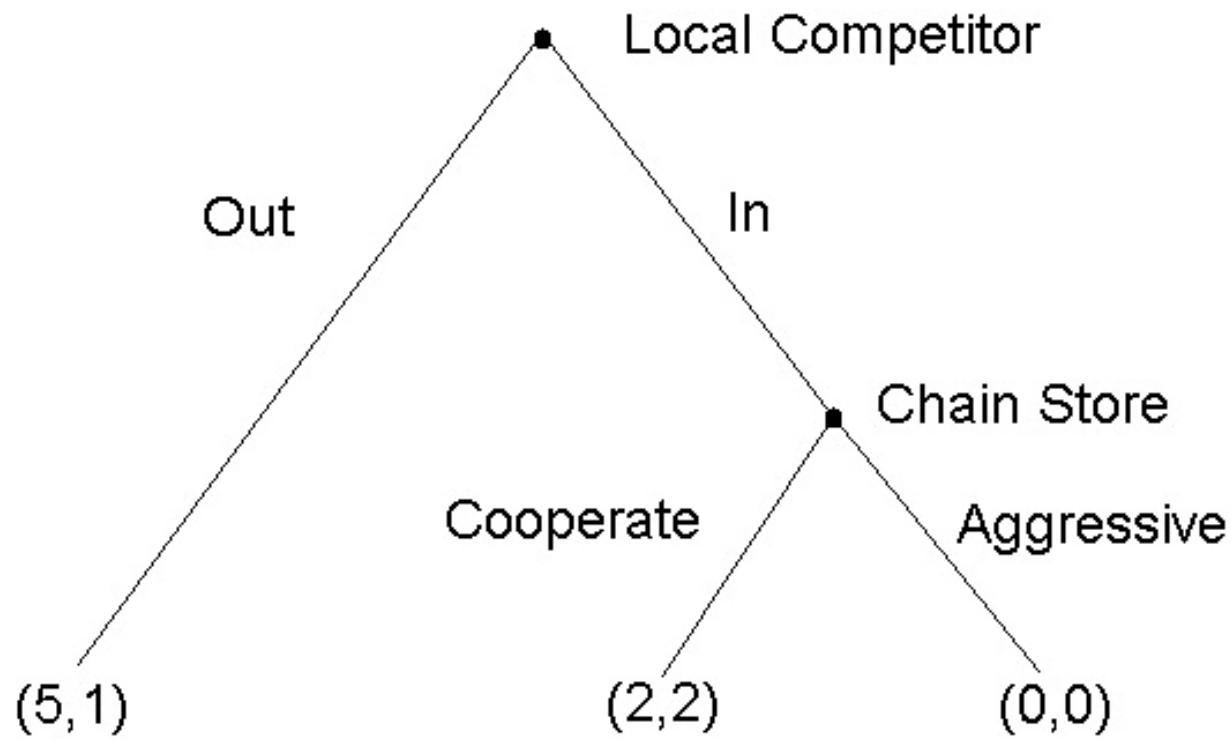
- This course is about modeling

Before we start...

- This course is about modeling
  - Should a local competitor open a store next to a chain store?

Before we start...

- This course is about modeling

What is game theory?

- Game theory studies settings where multiple players (agents) each have
  - different preferences (utility functions)
  - different actions that they can take

What is game theory?

- Let's play a game…

  - Each student should write a number between 0 and 100 on a paper

  - The student who gets closer to the average wins

What is game theory?

- Let's play another game…
    - Each student should write a number between 0 and 100 on a paper
    - The student who gets closer to **_half_** the average wins
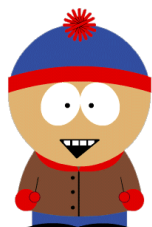
What is game theory?

- Let's play another game…

  - Each student should write a number between 0 and 100 on a paper.

  - The student who gets closer to **_half_** the average wins

- What is the solution of this game?

What is game theory?

- Let's play a final game…

  - Each student should write a number between 0 and 100 on a paper

  - Two winners

    - The student who gets closer to **_half_** the average

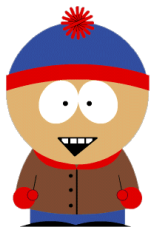   - The student who gets closer to the amplitude (biggest difference)

What is game theory?
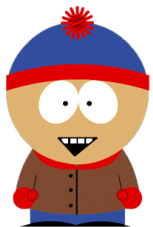
- Three kids must choose a cell phone

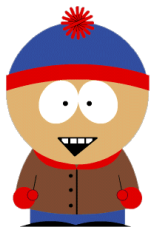# What is game theory?

- Who are the players?

What is game theory?

- What are their strategies?
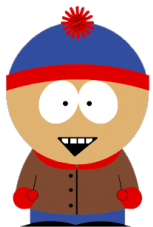
What is game theory?

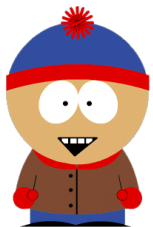- What are the possible outcomes?

What is game theory?

- The action of an agent can influence the strategy of another?

What is game theory?

- What are the possible payoffs for each agent?

What is game theory?

- Each agent's utility (potentially) depends on all agents' actions

- What is optimal for one agent depends on what other agents do

What is game theory?

- Each agent's utility (potentially) depends on all agents' actions

- What is optimal for one agent depends on what other agents do

  - Very circular!

I will buy what Cartman buys!

I won't buy what Butters buys!

What is game theory?

- Game theory studies how agents can rationally form beliefs over what other agents will do, and (hence) how agents should act

What is game theory?

- Game theory studies how agents can rationally form beliefs over what other agents will do, and (hence) how agents should act
  - Useful for acting as well as predicting behavior of others

Butters don't have money
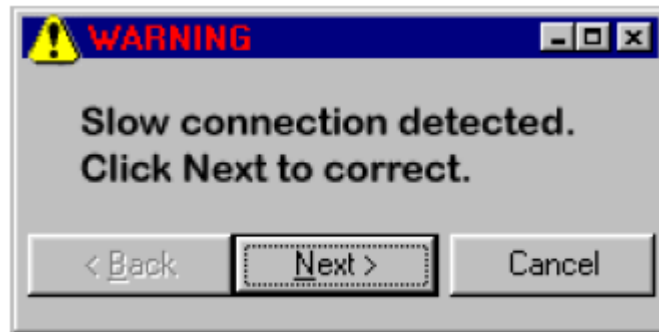to buy an iPhone!
That's the one I'll get it!

Cartman is a show-off!
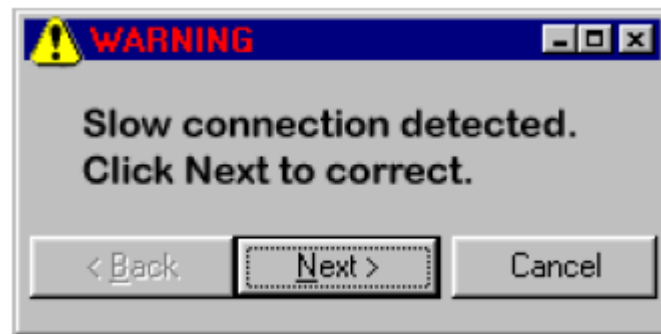If I use my college funds,
I can buy an iPhone!

What is game theory?

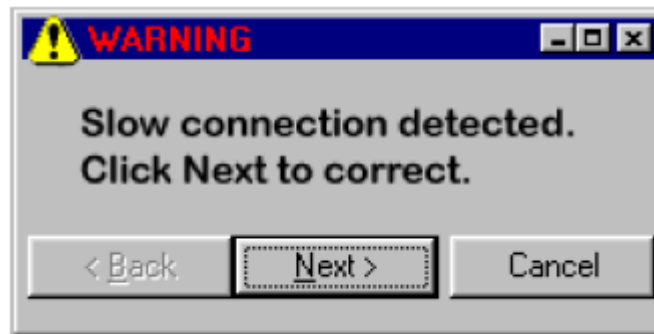- TCP Backoff game

What is game theory?

- TCP Backoff game

- Question: Should you send your packets using correctly-implemented TCP (which has a "backoff" mechanism) or using a defective implementation (which doesn't)?

What is game theory?

- TCP Backoff game

- This problem is an example of what we call a two-player game:
  - both use a correct implementation: both get 1 ms delay
  - one correct, one defective: 4 ms for correct, 0 ms for defective
  - both defective: both get a 3 ms delay.

What is game theory?

- TCP Backoff game

  - What action should a player of the game take?

  - Would all users behave the same in this scenario?

  - What global behavior patterns should a system designer expect?

  - For what changes to the numbers would behavior be the same?

  - What effect would communication have?

  - Repetitions? (finite? infinite?)

  - Does it matter if I believe that my opponent is rational?

On the media
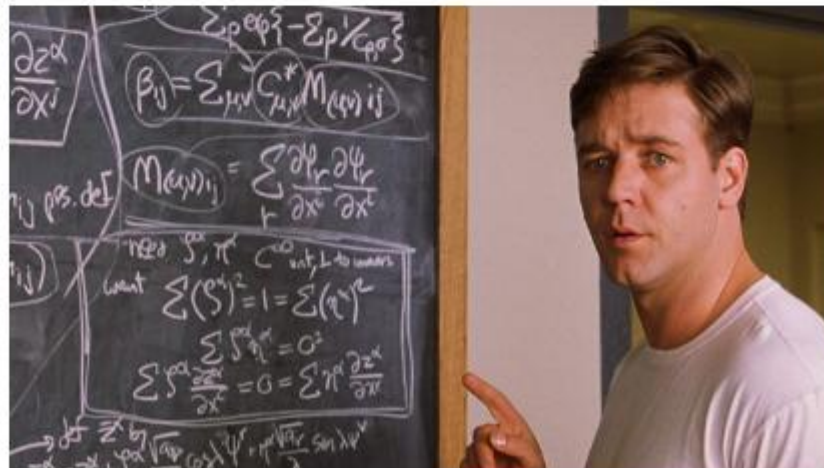
On the media

On the media

FOREIGN AFFAIRS

THE GAME THEORY OF TERRORISM
Jacob Olidort

PEDRO OLMO STANCIOL

A nam

SNAPSHOT   December 10, 2015

Terrorism & Counterterrorism

The Game Theory of Terrorism

How ISIS Radicalizes Others

By Jacob Olidort

On the media

- The evolution of trust
  - http://ncase.me/trust/

Now, let's play for real. You'll be playing against 5 different opponents, each with their own game "strategy". With each opponent, you'll play anywhere between 3 to 7 rounds. (You won't know in advance when the last round is) Can you trust them? Or rather... can they trust *you*?
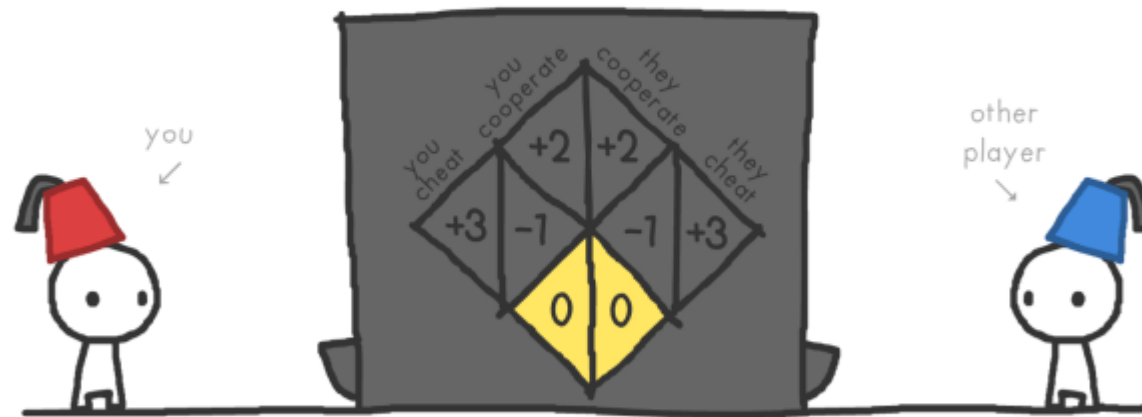
Pick your first, *real* move. Choose wisely.

On the media

THE
EVOLUTION
OF TRUST

playing time: 30 min • by nicky case, july 2017

This free, thoughtful browser game explains why people suck so much

2017-07-26 18:00:00 · Darren Nakamura **@Dexter345**

Using math   💬36

Nicky Case makes games that might just teach you something. There are topics ranging from voting to coming out to two-dimensional matrices.
This most recent game hits pretty hard right now, when the world seems bad and people in it seem bad.

On the media

Bloomberg View — Markets · Tech · Pursuits · Politics · **Opinion** · Businessweek

OPINION | OIL

OPEC's Game-Theory Dilemma

Cartel members are being pushed to seek ever-broader coalitions to secure an orderly influence on oil prices.

By Mohamed A. El-Erian
2 de agosto de 2017 02:30 BRT

On the media

On the media

` Ian Goodfellow, 31

Google Brain Team

Invented a way for neural networks to get better by working together.

A few years ago, after some heated debate in a Montreal pub, Ian
Goodfellow dreamed up one of the most intriguing ideas in artificial intelligence.
By applying game theory, he devised a way for a machine-learning system to
effectively teach itself about how the world works. This ability could help make
computers smarter by sidestepping the need to feed them painstakingly labeled
training data.

https://ai.facebook.com/blog/pluribus-first-ai-to-beat-pros-in-6-player-poker/?refid=52&__tn__=HH-R

On the media

MIT Technology Review

PIXABAY

Prisoner's dilemma shows exploitation is a basic property of human society

A new analysis of the famous game-theory puzzle finds that even when the players seem equal, one can learn to profit at the other's expense—and the victim will cooperate.

by Emerging Technology from the arXiv   May 30, 2019

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Where is game theory used?

- Economics (& business)
  - Auctions, exchanges, price/quantity setting by firms, bargaining, funding public goods, …

- Political science
  - Voting, candidate positioning, …

- Biology
  - Stable proportions of species, sexes, behaviors, …

- Philosophy
  - Conventions, ethics, …

And in Computer Science?

- Artificial Intelligence

  - Beat the Cheater: Computing Game-Theoretic Strategies for When to Kick a Gambler out of a Casino, AAAI'14

  - Towards a game theoretic approach for defending against crime diffusion, AAMAS'14

  - On influence, stable behavior, and the most influential individuals in networks: A game-theoretic approach, Elsevier Artificial Intelligence, 2014

And in Computer Science?

- Computer Networks

  - Game-Theoretic Topology Control for Opportunistic Localization in Sparse Underwater Sensor Networks, IEEE Trans. On Mobile Comp., 2014

  - Selfish behavior and stability of the internet:: a game-theoretic analysis of TCP, Sigcomm'02

  - Topology Design of Communication Networks: A Game-Theoretic Perspective, IEEE/ACM Trans. On Networking

And in Computer Science?

- Security
  - Game-Theoretic Analysis of DDoS Attacks Against Bitcoin Mining Pools, Financial Cryptography and Data Security, 2014

  - A Cryptographic Solution to a Game Theoretic Problem, Advances in Cryptology, 2014

  - RRE: A Game-Theoretic Intrusion Response and Recovery Engine, IEEE Transactions on Parallel and Distributed Systems, 2013

And in Computer Science?

- Complex networks and Web
  - Centrality and power in social networks: a game theoretic approach, Mathematical Social Sciences, 2003
  - Price Competition in Online Combinatorial Markets, WWW'14
  - Modeling collaboration in academia: a game theoretic approach, WWW'14 Companion

And in Computer Science?

- Data Mining and Big Data

  - Large human communication networks: patterns and a utility-driven generator, KDD'09

  - A Game Theoretic Framework for Analyzing Re-Identification Risk, Plos One, 2015

  - Game-Theoretic Strategy Analysis for Data Reliability Management in Cloud Storage Systems, Software Security and Reliability (SEME'14)

And in Computer Science?

- Robotics

  - Game theoretic controller synthesis for multi-robot motion planning Part I: Trajectory based algorithms, IEEE International Conference on Robotics and Automation (ICRA'14)

- Computer Vision

  - A Game-Theoretic Probabilistic Approach for Detecting Conversational Groups, ACCV'14

And in Computer Science?

- Information Retrieval
  - Towards a Game-Theoretic Framework for Information Retrieval, SIGIR'15

- Distributed Computing
  - Distributed computing meets game theory: robust mechanisms for rational secret sharing and multiparty computation, PODC '06

- Machine Learning
  - Goodfellow, Ian, et al. "Generative adversarial nets." Advances in neural information processing systems. 2014.
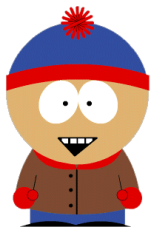
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Rationality

Decision and Utility Theory

Games

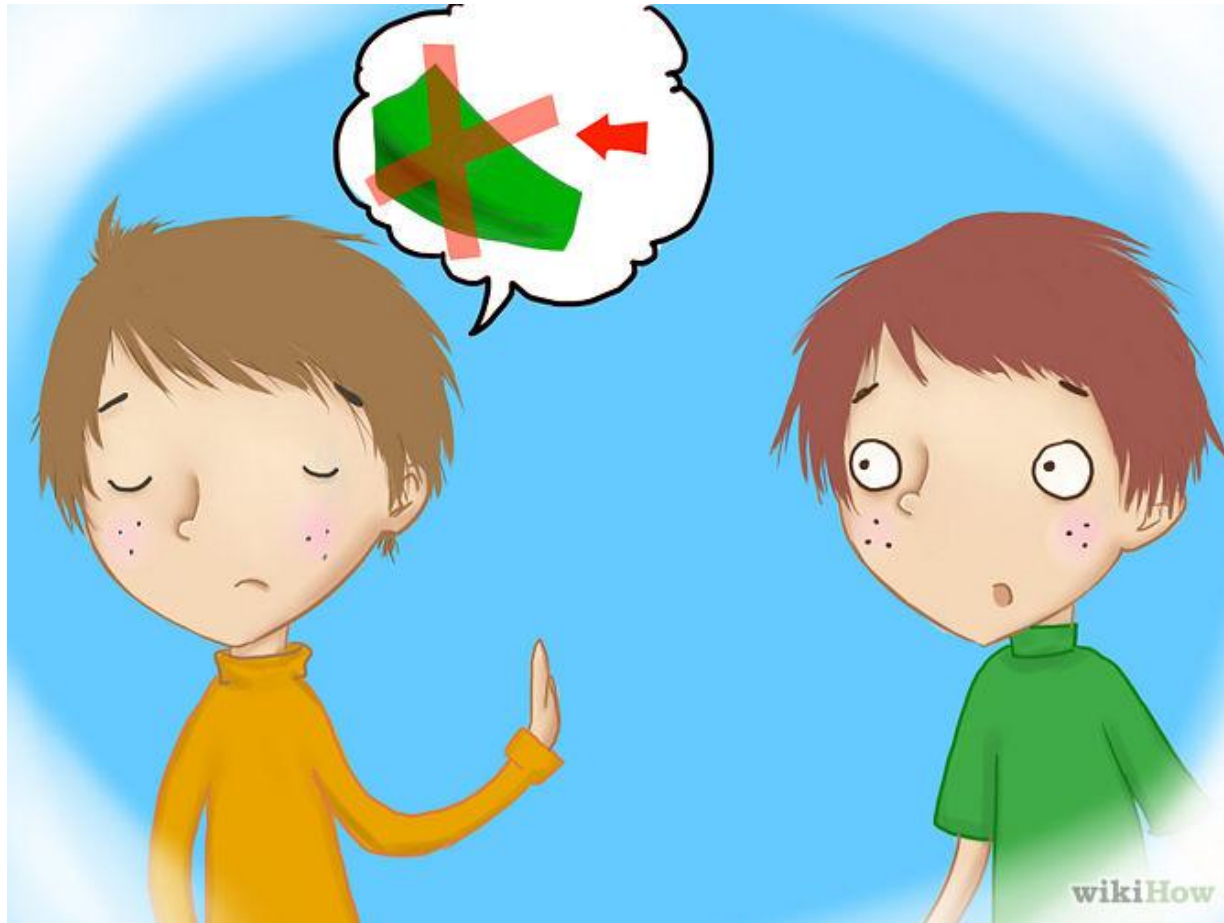# Types of games

Zero-sum games

coordination games

Game Solutions

- Should Grace celebrate her 91st birthday by jumping out of a plane strapped to this guy?

Repeated games

- Should Al lend some money to Bob?

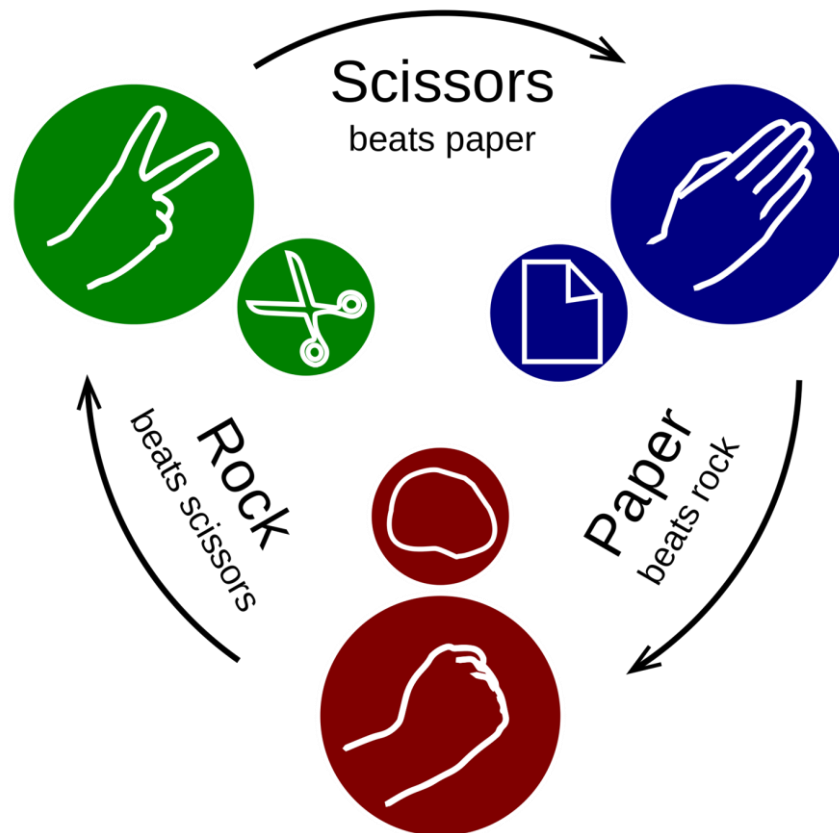# Bayesian and imperfect information games

Congestion games

Learning and Teaching in games

- Can I design an algorithm to perform better than random in PRS?

Coalitional games

Game Theory in Computer Science

- Seminars

Course program

- Prerequisites
  - English
  - Discrete math
  - Basic set theory
  - Basic probability theory
  - Notions of algorithms

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Grading

- **2 Exams**
- Class project
- 3 Exercise lists
- Participation
- Seminar
- PD competition

Exams

- Mostly modeling questions
  - Given a situation, how game theory can be used to model it?

- Simple and easy questions
  - Don't require advanced math (e.g. calculus) to solve

- May require knowledge about every topic given in class, which are covered by the books as well

Class project (20)

- An attempt to do some original work on topics related to the course

- Alone or with colleagues (depends on the number of enrolled in the course)

- Theoretical or experimental

- Creativity is encouraged

- The final product is a writeup (in the form of a research paper)

- Some projects may lead to publishable papers

Class project (20)

- Consider your own research and its relationship to the course

  – Do you work on techniques that can be applied to any of the course's problems?

  – Can techniques in the course help your work?

- Take some result in the course that you like, and change the setting

  – Do things become easier (harder) if we look at a more restricted (more general) version of the problem?

  – Do analogous results hold in similar settings?

Class project (20)

- On its simplest form:
  - Find a non trivial scenario
  - Describe this scenario informally: players, actions, conflicts, utilities, complications
  - Model one or more configurations for this scenario formally
    - game type
    - players
    - strategies
    - payoffs
    - solutions
  - Discussion and conclusions

Class project (20)

- Algorithmic game theory:
  - Pick a type of game
  - Implement one or more algorithms to find solutions in that type of game
  - Evaluate how these algorithms perform when the game grows
  - (optional) Change the algorithms for any given (positive) purpose
  - (optional) Evaluate such change

Seminar (20)

- Alternative class project
  - Find an interesting research paper that (uses / deals with) game theory
  - Look for papers published in top venus:
    - https://scholar.google.com.br/citations?view_op=top_venues&hl=en&vq=eng_gametheorydecisionscience
  - Alternatively, find a topic that was not cover in class
  - Make a didactic presentation, explaining the paper or the topic in details
  - Expected length of the presentation: 20 minutes

Participation (10)

- Points are given on my best judgement (sorry!)
- Lower bounded by:
  - I will ask for students to participate in several activities during classes
    - Games, quizzes, exercises
  - You will get points by your participation and performance in those activities

Grading

- **2 Exams (25 + 25)**

- 1 Seminar or Class Project (20)

- 3 exercise lists (20)

- Participation (10)

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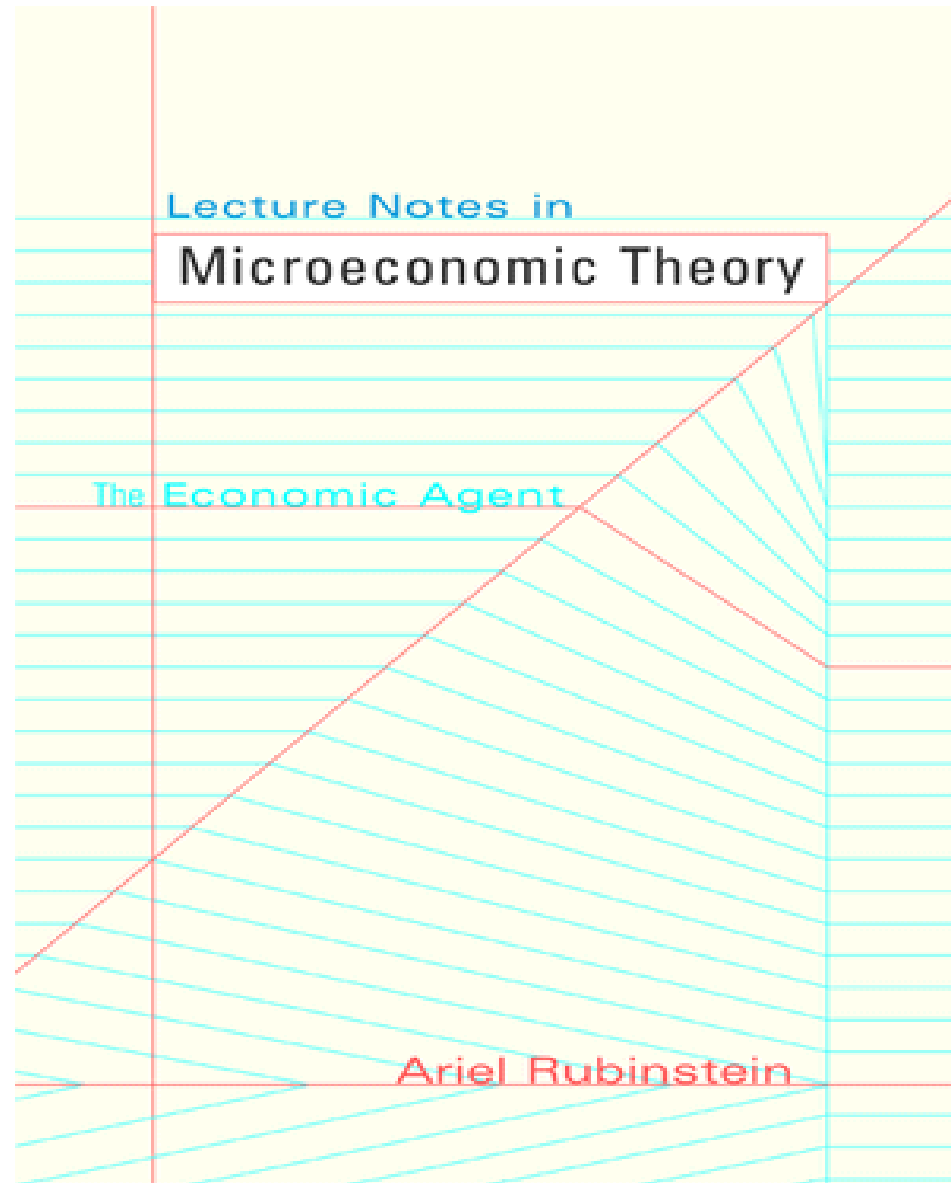- ***References***
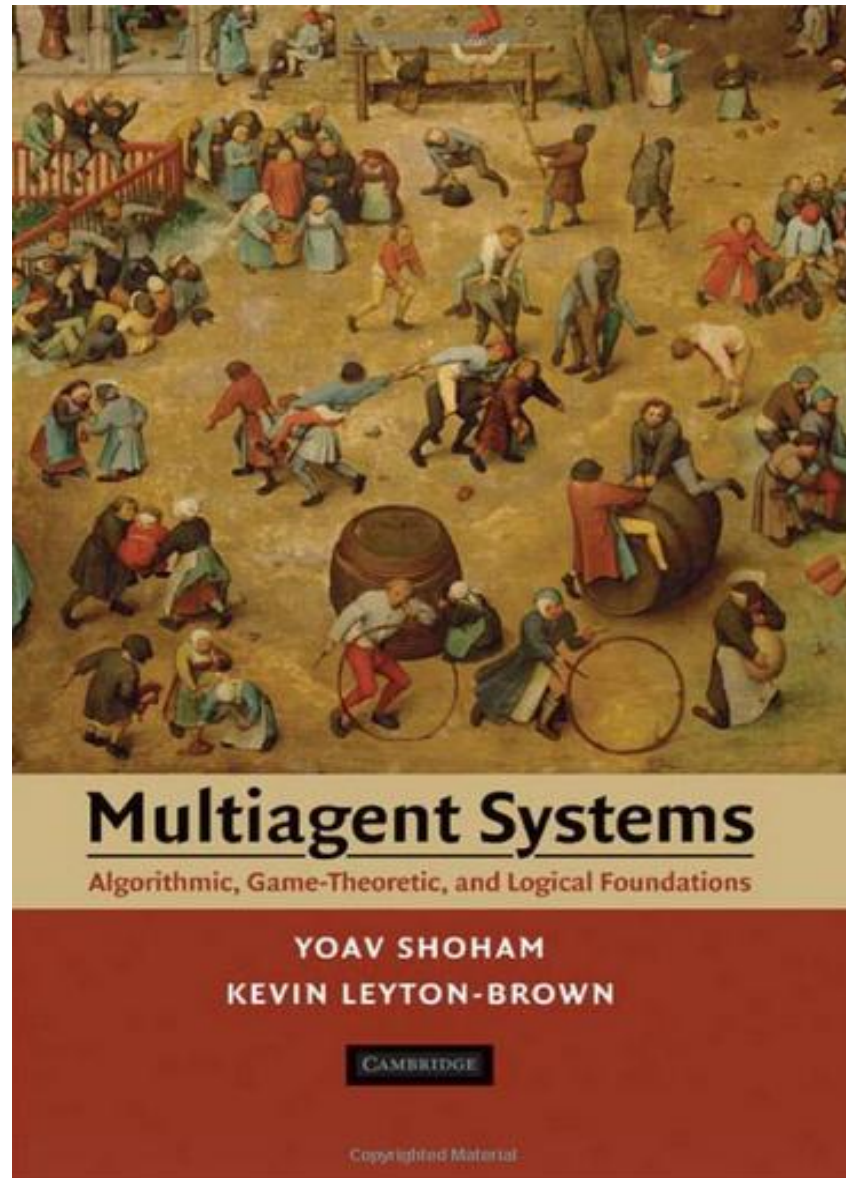
- Goals

References

- Slides
- Books
- Courses
- Papers

Slides

- I will post all the slides on Moodle

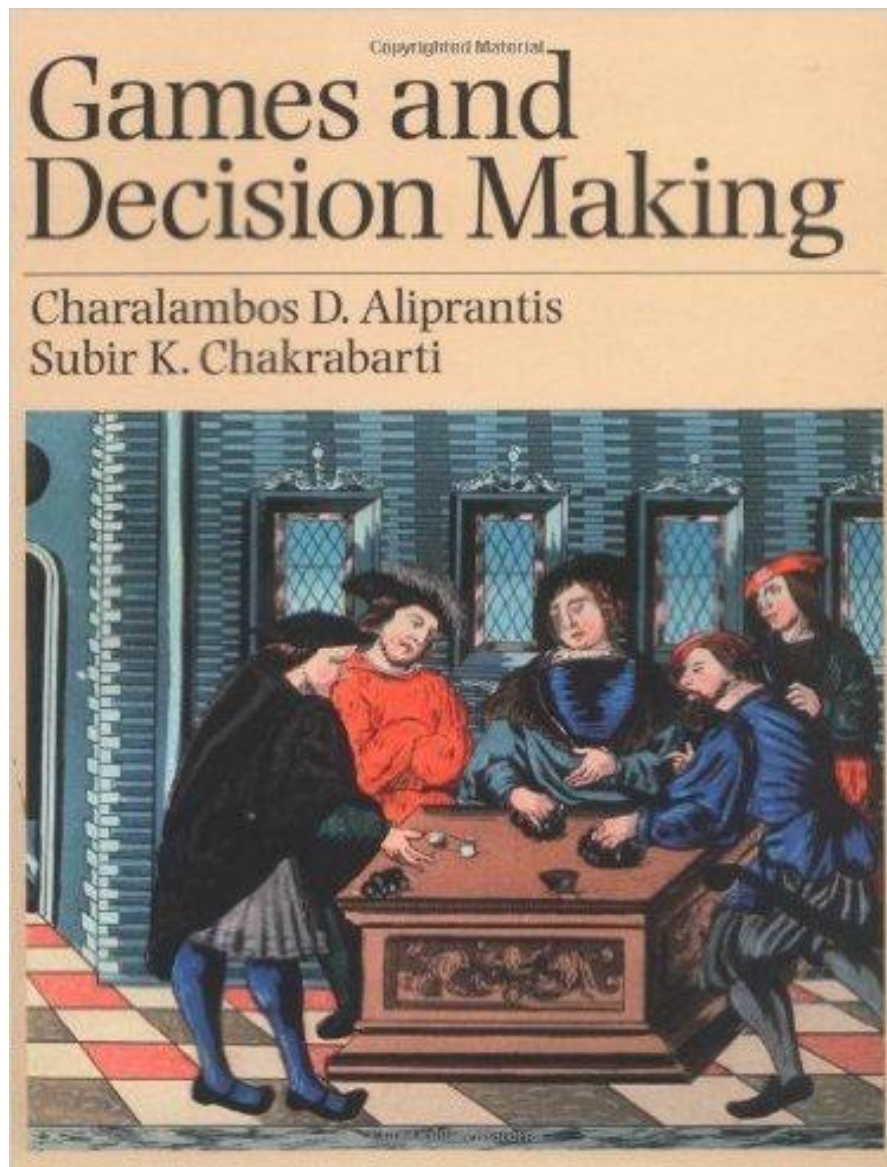- The slides may contain material different from the books

Books

Lecture Notes in
Microeconomic Theory

The Economic Agent

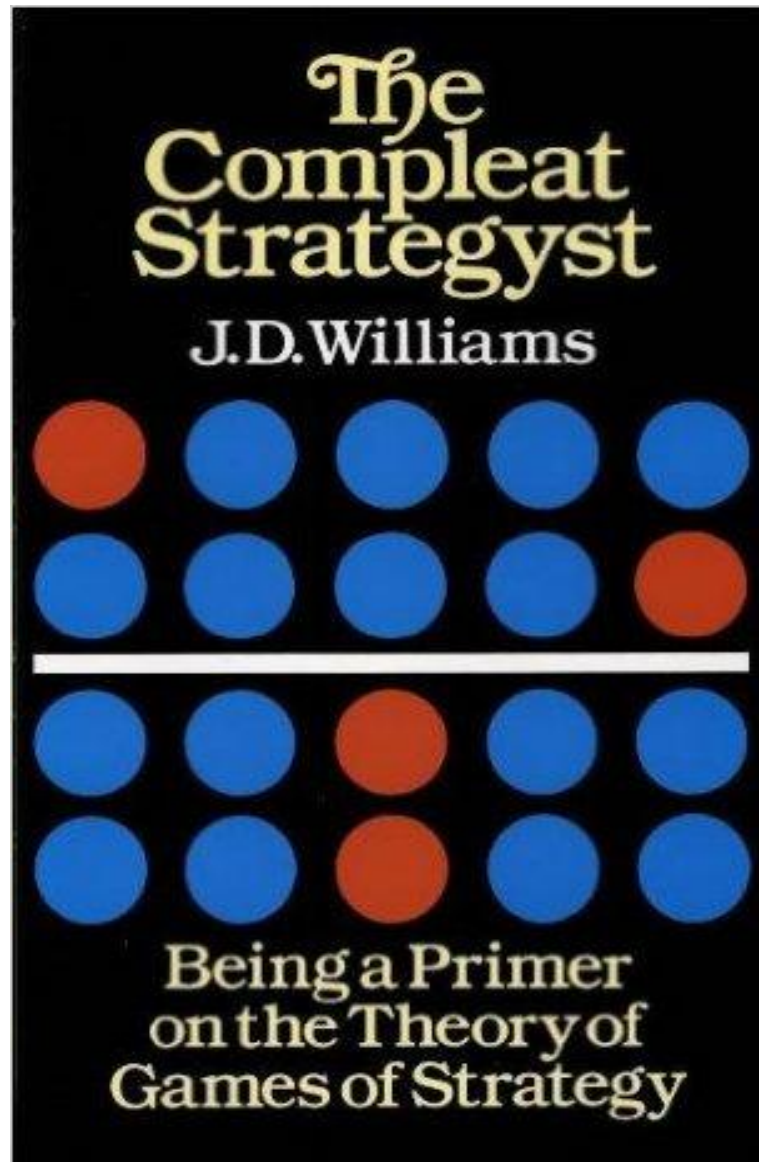Ariel Rubinstein

Books

Books

A COURSE IN GAME THEORY

MARTIN J. OSBORNE
ARIEL RUBINSTEIN

Books

Books
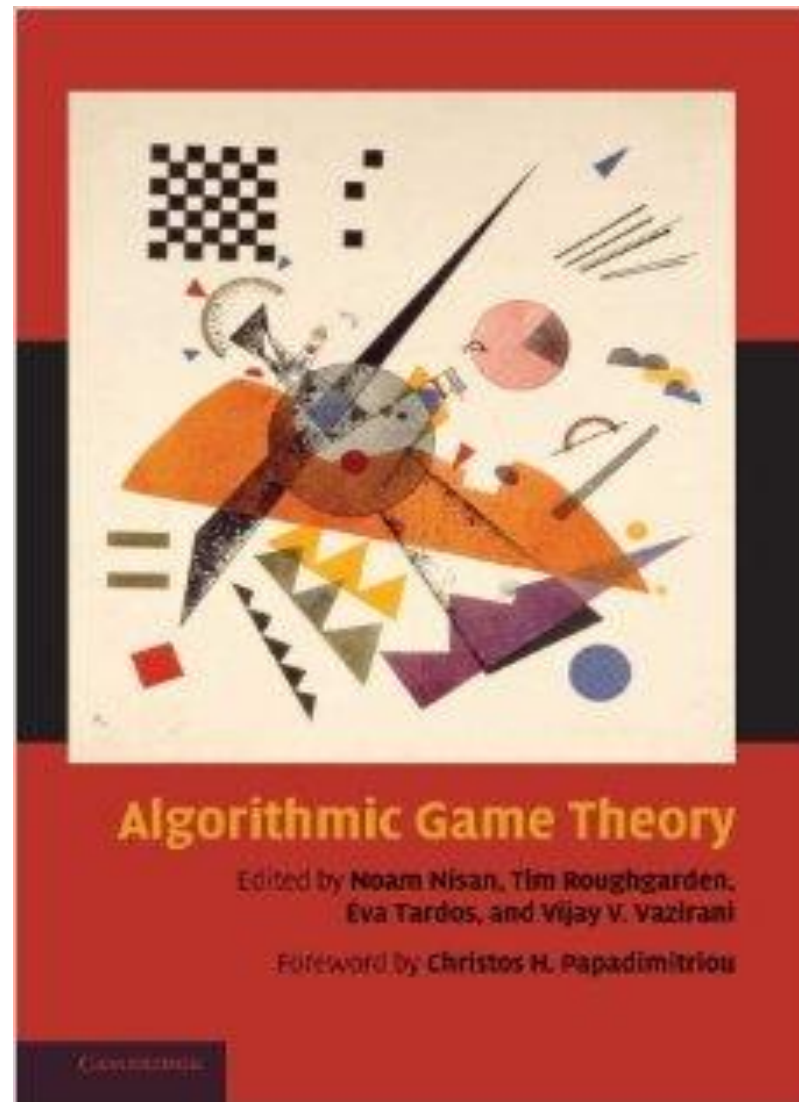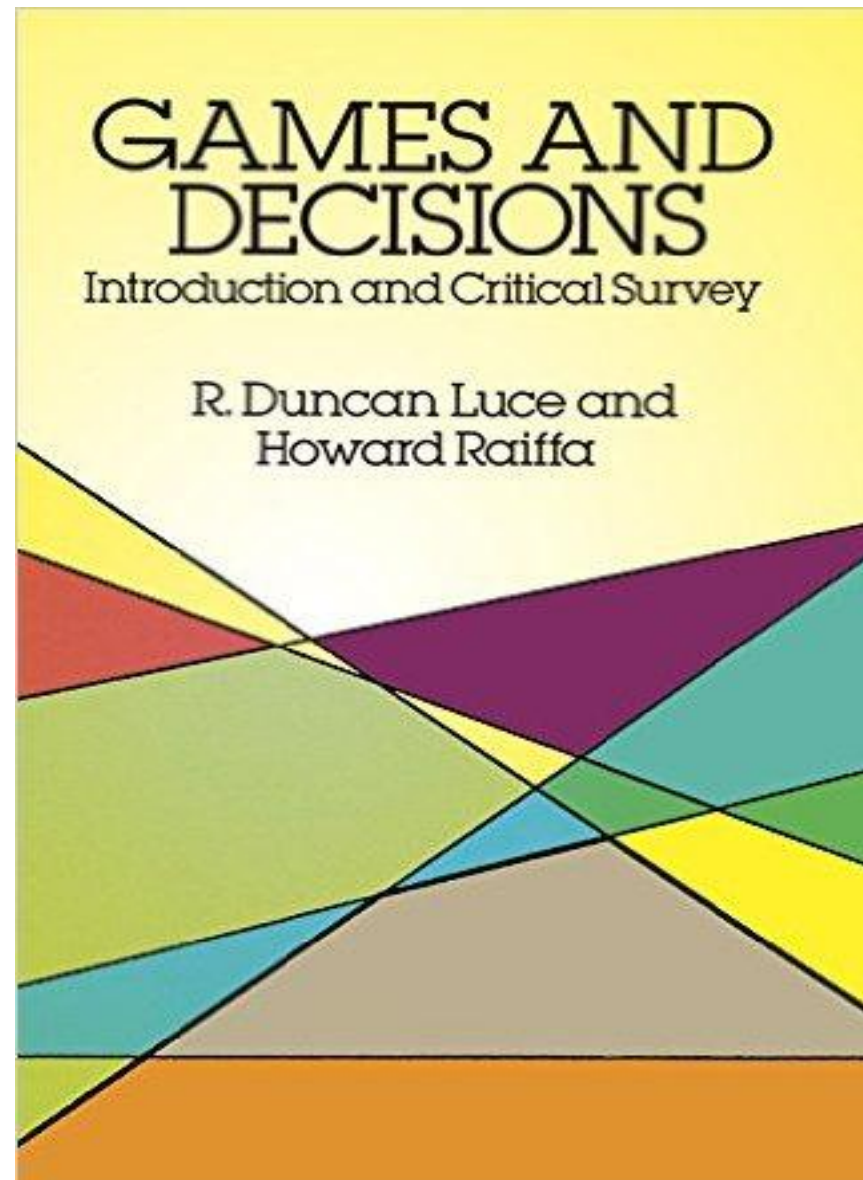
Books

Books

Algorithmic Game Theory

Edited by **Noam Nisan, Tim Roughgarden, Eva Tardos, and Vijay V. Vazirani**

Foreword by **Christos H. Papadimitriou**

Cambridge

Books

GAMES AND DECISIONS
Introduction and Critical Survey

R. Duncan Luce and
Howard Raiffa
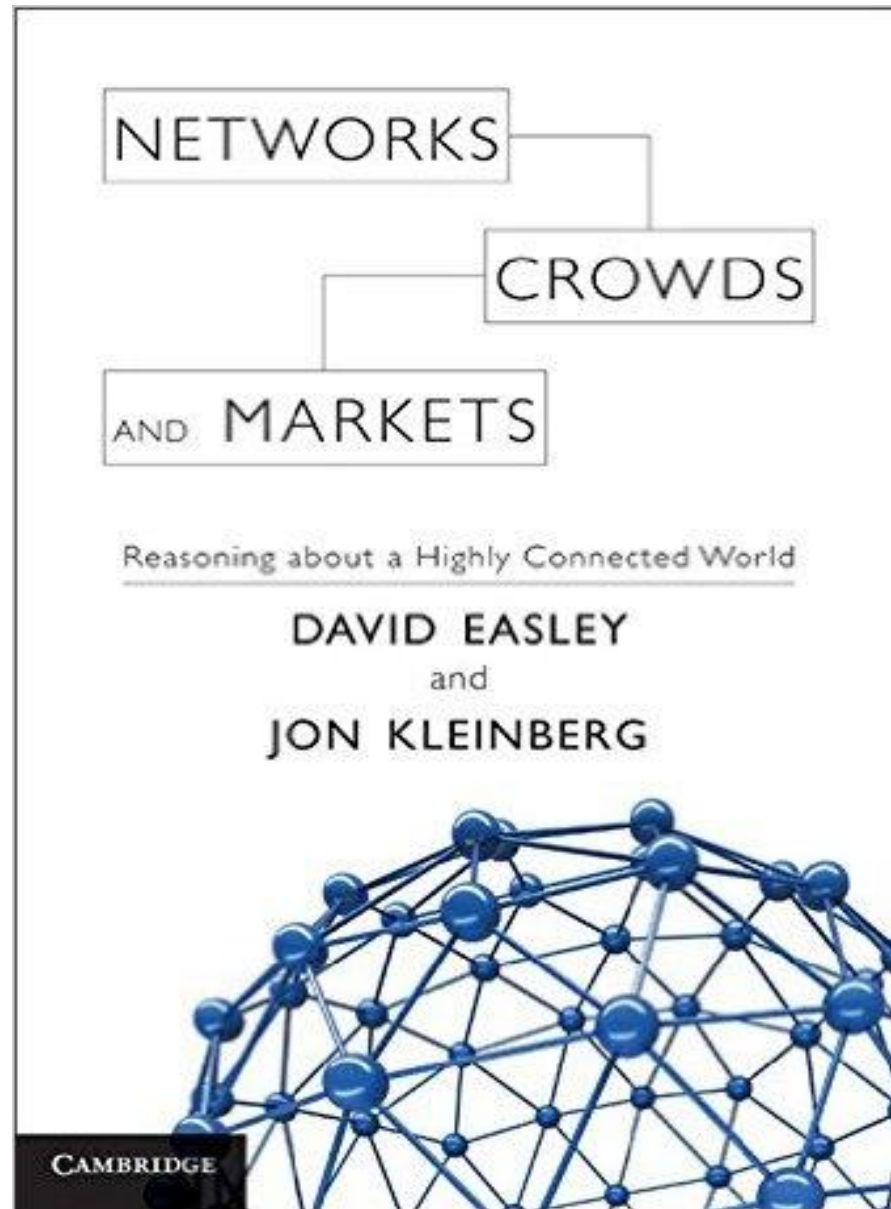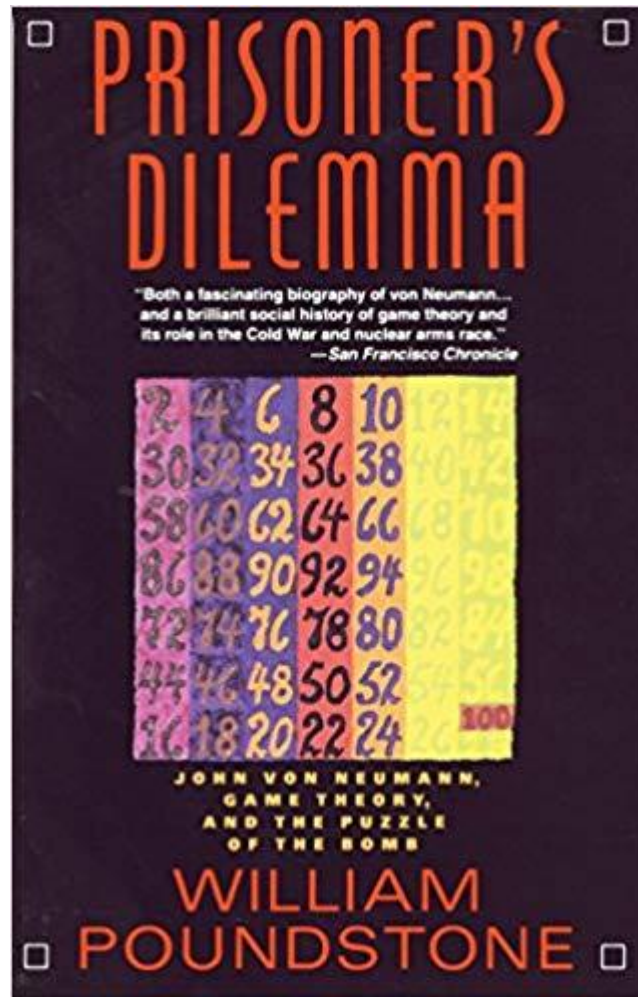
Books

Books

- Good news!
  - All books (except the last two) are publicly available online

Courses

- Coursera
  - Game Theory and Advanced Game Theory
  - M. Jackson, Y. Shoham, K. Leyton-Brown
  - Stanford University and UBC
- Computational Game Theory and Mechanism Design
  - Vincent Conitzer, Duke
  - http://www.cs.duke.edu/courses/fall06/cps296.2/
- Topics in Decision and Control: Static and Dynamic Game Theory
  - Bruce Hajek, University of Illinois
  - https://courses.engr.illinois.edu/ece586/sp2013/

Papers

- I will recommend papers to be read together with the classes

- I will also post a list of technical papers that link with computer science

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Goals

- Learn how to model conflict scenarios using game theory

- Be able to read and understand computer science papers that use game theory as a framework

- Be able to conduct your own research using game theory

Calendar

- Show calendar

Task due to Sunday!

- Details will arrive by e-mail
    - If you are enrolled to the course on Moodle