Computational Game Theory

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TCP Backoff Game

- Internet traffic is governed by the TCP protocol.
- When the protocol is correctly implemented, it includes a backoff mechanism:
  - if the rates at which a sender sends information packets into the network causes congestion, the sender reduces this rate for a while until the congestion subsides.
- A defective implementation of TCP does not back off when congestion occurs.

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

TCP Backoff Game

- Consider this situation as a two-player game:
  - both use a correct implementation: both get 1 ms delay
  - one correct, one defective: 4 ms delay for correct, 0 ms for defective
  - both defective: both get a 3 ms delay.
- Play this game with someone near you. Then find a new partner and play again. Play five times in total.
- Questions:
  - What action should a player of the game take?
  - Would all users behave the same in this scenario?
  - What global patterns of behaviour should the system designer expect?
  - Under what changes to the delay 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?

Section 1

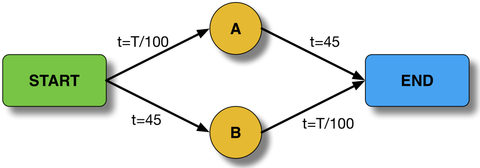
What is Game Theory?

Non-Cooperative Game Theory

- What is it?
  - mathematical study of interaction between rational, self-interested agents
- What does it mean to say that an agent is rational?
  - take actions to maximize its expected gain/utility
- What does it mean to say that an agent is self-interested?
  - not that they want to harm other agents
  - not that they only care about things that benefit them
  - that the agent has its own description of states of the world that it likes, and that its actions are motivated by this description
- Why is it called non-cooperative?
  - while it's most interested in situations where agents' interests conflict, it's not restricted to these settings
  - the key is that the individual is the basic modeling unit, and that individuals pursue their own interests
    - cooperative/coalitional game theory has teams as the central unit, rather than agents

Braess's Paradox

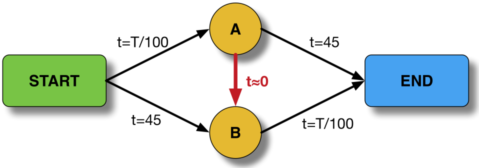
Consider a road network on which 4000 drivers wish to go from *Start* to *End*.



- The travel time in minutes on the Start-A road is the number of travellers (T) divided by 100, and on Start-B is a constant 45 minutes (likewise with the roads across from them).
- The time needed to drive the Start-A-End route with A drivers would be $\frac{A}{100} + 45$.
- The time needed to drive the Start-B-End route with B drivers would be $\frac{B}{100} + 45$.
- What happens if the 4000 drivers are rational and self-interested?
  - $A = B = 2000$ when the system is at equilibrium.
  - Therefore, each route takes $\frac{2000}{100} + 45 =$ 65 minutes.

Braess's Paradox

- Suppose we add the road $A - B$ with an extremely short travel time of approximately 0 minutes.



- What happens now?
  - One driver tries Start-A-B-End and finds out that the time is $\frac{2000}{100} + \frac{2001}{100} = 40.01$ minutes, a saving of 25 minutes.
  - Then, more drivers try the new route, and the time taken keeps climbing.
  - When the number of drivers trying the new route reaches 2500, with 1500 still in the Start-B-End route, their time will be $\frac{2500}{100} + \frac{4000}{100} = 65$ minutes, which is no improvement over the original time.
  - Meanwhile, those 1500 drivers still in the Start-B-End have been slowed to $45 + \frac{4000}{100} = 85$ minutes, a 20-minute increase.
  - So, they are compelled to switch to the new route via A too, so it now takes $\frac{4000}{100} + \frac{4000}{100} = 80$ minutes.
  - Nobody has any incentive to travel A-End or Start-B because any driver trying them will take 85 minutes.
- The new route increased everyone's cost from 65 to 80!

Section 2

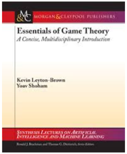
What will we study in this course?

Computational Game Theory

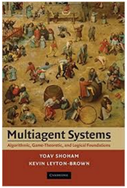
- Game Theory
  - Normal Form Games
  - Extensive Form Games of Perfect Information
  - Extensive Form Games of Imperfect Information
  - Repeated Games
  - Stochastic Games
  - Bayesian Games
  - Coalitional Games
- Mechanism Design
  - Social Choice
  - Mechanism Design for Strategic Players
  - Resource Allocation

Bibliography

- Yoav Shoham and Kevin Leyton-Brown , Essentials of Game Theory: A Concise Multidisciplinary Introduction, Synthesis Lectures on Artificial Intelligence and Machine Learning, Morgan & Claypool Publishers, 2008.



- Yoav Shoham and Kevin Leyton-Brown, Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations, Cambridge University Press, 2009.



Available at `http://www.masfoundations.org/mas.pdf`

Assessement

- Theoretical Component (70%)
  - Two Tests or One Exam (min 9.5)
- Practical Component (30%)
  - Project (min 9.5 to obtain “frequency”)
    - Implementations (in JAVA)
    - Practical Evaluation (tournaments)
    - Report

Course Plan (tentative)

Week	Wednesday	Thursday
06-Mar	Lecture	Lecture
13-Mar	Lecture	Problem Set
20-Mar	Lecture	Lab
27-Mar	Lecture	Lab
03-Apr	Lecture	Lab
10-Apr	Problem Set	Tournament1
17-Apr	Lecture	
30-Apr	Test1	
01-May		Lab
08-May	Lecture	Lab
15-May	Lecture	Problem Set
22-May	Lecture	Lab
29-May	Lecture	Problem Set
31-May	Tournament2	
05-Jun	Test2	