Game Theoretical Methodology and Technique for Internet Protocols

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Course Information

Objectives

To introduce

- Game theoretical methodology
- Incentive analysis in Internet protocols
- Examples and solutions

Contact Information

- Classroom: Chen Rui Qiu Building, 309.
- Time: Mondays and Wednesdays 0800-0940am
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- TA: Keyu Zhu and Other students

Assessment Information

- 50% coursework plus 50% final examination
- Coursework:
  - Self study maximum 10%
  - 4 Assignments, 5% each, maximum 20%
  - 1 Middle term test, maximum 10%
  - One project or case study or research paper 10%. (Here report writing is important for your mark).
- Final Examination: Problems given out 24 hours before examination and each redoes it in class. Two parts separately marked and both counted in final examination evalution.

Reference Books

- Text Book and Lecture Notes
- N. Nisan, T. Roughgarden, E. Tardos, and V. V. Vazirani (Editors), Algorithmic Game Theory. Cambridge University Press (most recent edition).
- C.H. Papadimitriou, K. Steiglitz. Combinatorial Optimization: Algorithms and Complexity. Dover Publicaion (most recent edition)
- M. J. Osborne, An Introduction to Game Theory. Oxford University Press (most recent edition).

Online Resources

- Alvin E. Roth Market Design http://kuznets.fas.harvard.edu/~aroth/alroth.html
- Yiling Chen, Fall 2008 Topic: Social Computing: http://www.eecs.harvard.edu/cs286r/
- Computational Mechanism Design. Prof. David C. Parkes: http://www.eecs.harvard.edu/ parkes/cs700/
- Noam Nisan's Course on CS, Game Theory, and Economics. http://www.cs.huji.ac.il/ noam/econcs/index.html
- Christos Papadimitriou: Algorithmic Aspects of Game Theory. http://www.cs.berkeley.edu/ christos/games/cs294.html
- Joan Feigenbaum's Course on Economics and Computation. http://zoo.cs.yale.edu/classes/cs455/
- Jeff MacKie-Mason's Course on Information Economics. http://www.jeff-mason.com/courses/econ755/econ755-syll.html
- Kate Larson's Electronic Market Design Course. http://www.cs.uwaterloo.ca/ klarson/teaching/F04-886/index.html
- Computational Game Theory. Yishay Mansour, Tel Aviv University.

  http://www.math.tau.ac.il/ mansour/course_games/course_games_03_04.htm

Course Intended Learning Outcomes

1% for attending the first class or the last class. 33% for development of skills in the following topics and techniques:

1. Mathematical techniques: mathematical programming, Matching, Fixed point.
2. Game theory methodology in Internet protocols: Nash equilibrium, Truthful mechanism, Cooperative games.
3. Incentive design and analysis in Internet protocols.

Syllabus

- Algorithms: Bipartite matching, linear programming (Farkas' Lemma and duality), Sperner's Lemma and PPAD
- Game Theory: Nash equilibrium, truthful mechanism, cooperative games.
- Algorithmic Game Theory: computational bounded rationality, incentive ratio, price of anarchy.
- Selected applications: matching market, digital goods Market, CPU time pricing, peer to peer networks, crowdsourcing, cryptographic money design.

History of Markets

Exchange of Goods

- Bartering (6000 B.C.) e.g., in Mesopotamia: Cows for hens.
  - Double Coincidence of wants
    - Tom has twenty cows and Igor has eighty hens
    - If Tom wants hens and Igor wants cows, then the trade could take place.
    - if they agree that one cow is worth four hens, Tom gets eighty hens and Igor gets twenty cows.
- Silver rings or bars as money (Ancient Iraq before 2000 B.C.)
  - Something everyone wants
- Reversal on the Internet: http://socialmode.com/2009/02/21/coincidence-of-wants-problem-destroyed-by-interne/

Driving Force in Economics

- Self-interest acts as a guiding force toward the work society desires
  - "It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their self-interest.
- While one would naturally assume that everyone following only his or her self-interest would not create a very good society,
  - "It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their self-interest.
- That regulator is competition.

Adam Smiths Economics

- A man who permits his self-interest to run away with him will find that competitors have slipped in to take his trade away;
  - if he charges too much for his wares or if he refuses to pay as much as everybody else for his workers,
  - he will find himself without buyers in the one case and without employees in the other.

Market Role: Allocation and Pricing

- Workers go to the competitor who is willing to pay more customers will go to the competitor who charges less.
- The wonderful paradox of the market, through the interaction of supply and demand and competition,
  - creates a price that properly allocates industry so as to produce the proper quantities of goods and services.
- No intervention, planning, or forethought is needed to create exactly what society desires, in the exact amount it desires.
- As long as society can promote competition and innovation, standards of living will continue to grow and wealth will increase.

Auction History

Auction Market

- Auction is an important and ancient way of allocating resources and pricing them.
- Key players:
    - Consignor: owner of item to be sold
    - Organizer: regulator/financial backer
    - Promoter: advertiser/auctioneer
    - Buyer(s): bidders

Auction Market Has a Long History

- Auction is an important and ancient way of allocating resources and pricing them.
- Key players:
  - Auctus: "to increase" in Latin
  - Annual Babylonian wedding auctions
    - Herodotus, in Histories (440 BC)
  - Rome auction of spoils of war
    - Made by "a crier sub hasta" Latin for under the spear.
  - King Henry VII of England (15th century) instituted early laws of auction, including auction licenses
  - Sotheby established in 1744, Christie 1766
  - China auction market.
    - Moore & Co. L. by Luis Moore 1891.
  - Japanese wholesale market:
    - (The Central Wholesale Market Law in 1923)

Internet Auction

- Early stage
  - Appear as early as 1988 (see historical record in google groups)
  - via e-mail and newsgroup
- Text-based auction
  - Before 1993, sellers post the product via static information (i.e. text and images)
  - Still collect bids via e-mail
- WWW auctions
  - Automatically collect and process bids
  - The first WWW-based auction: Onsale opened in May 1995
  - Ebay: opened in September,1995
  - Within a year many competitors araise: uBid, Z-auctions

Internet Auction Systems

- Internet auction platforms in research laboratories:
  - Michigan Internet AuctionBot
  - FishMarket system
  - GEM
- Auction software
  - OpenSite, FreeMarkets(1995), Moai(1996), Trading Dynamics(1998), Siebel Systems, Ariba
- More recently
  - Combinatorial auctions: place offer on sets of items
  - Multi-attribute auctions: object has several negotiable params.

Internet Auction Sites

- eBay
- http://www.auction.com/
- http://www.ebay.com/
- http://www.taobao.com/
- http://www.paipai.com/
- http://auctions.yahoo.com/
- http://www.auctusdev.com/
- http://www.internetauction.net/

Auction Protocols

Basic Model

- n buyers
- 1 item for sale
- each buyer i has a private value v_i for the item.
- the seller does not know the private values and need to set a price for the item and determine who get it.

Different Auction Methods

- English Auctions
- Dutch Auctions
- Vickrey Auctions

English Auction

- Ascending auction of one item
  - Proceed openly with higher and higher bids.
  - Auction terminates when no one would bid higher, and the last remaining bidder wins the item at his/her bidding price.
  - Such as the case when Julianus bade 25,000 sesterces to win the crown of Rome in December 31, 192.
- commonly used for selling goods, most prominently antiques and artworks.

Dutch Auction

- Descending-bid auction of one item
  - Auctioneer opens a high quotation that no one would accept
  - The quotation goes down successively until someone bid to accept it
  - The first person bids to accept wins and pay that price
    - Use in dutch flower auction
- commonly used for selling goods, most prominently antiques and artworks.

Vickrey Auction

- One item to sell
- n bidders simultaneously submit bids
- The highest bidder wins and pays the second highest bid.

Dominating strategy and truthful protocol

- No single bidder can lie to gain more in Vickrey auction.
- Dominating strategy: The best strategy for a player no matter what strategies other players choose.
- Truthful Protocol: For any agent, it is a dominating strategy, under this protocol, to speak the truth.
- Vickrey auction is truthful.

Nash equilibrium

- A profile of agents' strategies such that no one can benefit by changing its strategy.
- relationship with a truthful protocol:
  - A truthful protocol has an equilibrium: each speaks the truth.
  - A protocol with a Nash equilibrium may not be truthful.
    - Example: Submit your scores, and one whose value is the average of all will be paid by CNY100.
  - What should be your optimal bid?

Role of Game Theory on the Internet

Alternative Payment Models

- Pricing Models for Information Goods
  - Single price
  - Differentiate pricing
    - This has been widely used now
    - Price differently for different countries
    - Pricing according to user profiles
  - Group price
  - Versioning
    - Human learning curve
- More: http://www.caycon.com/blog/2011/02/ten-top-product-pricing-models-for-startups/

Network Traffic and Equilibrium

- Braess′ Paradox: Individuals pursuing their best routes may reduce the network efficiency
  - Indiviaul Rationality: everyone finds the best route for herself/himself
  - Nash Equilibrium: a state where no one can change to a better strategy than its current own.
  - Price of Anarchy: Ratio of social welfare under Nash equilibrium over the social optimum.

Jurong Paradox

References: Auction

- Auction off a Kingdom
  http://en.wikipedia.org/wiki/Didius_Julianus.
- http://en.wikipedia.org/wiki/FloraHolland
- Vickrey, William. 1961. "Counterspeculation and Competitive Sealed Tenders." Journal of Finance. 16:1, pp. 8-37.
- . . jds.cass.cn/UploadFiles/zyqk/2010/12/jdszl81.pdf, pp.46 and Economic Behavior 65 (2009)

References: Braess Paradox

- D. Braess, ber ein Paradoxon aus der Verkehrsplanung. Unternehmensforschung 12, 258268 (1969)
- T. Roughgarden, Designing network for selfish users is hard. FOCS 2001, 472-481.
- A. Rapoport, T. Kugler, S. Dugar, and E. J. Gisches, Choice of routes in congested trafc networks: Experimental tests of the Braess Paradox. Games and Economic Behavior 65 (2009)

The first exercise: Solve two problems

1. Given $n+1$ numbers $x_0 < x_1 < \cdots < x_n$, label them by 0 or 1. Let x_0 be labelled as 0 and x_n be labelled as 1. Consider the number of $< x_i, x_{i+1} >$ are labelled as $< 0, 1 >$ and the number of those labelled as $< 1, 0 >$, what is the relationship of the two ?
2. Given a weighted complete graph $G = (V, E; w)$ where V is the vertex set and E are the edge set, $w : V \cup E \to R_+$ is a non-negative function on the vertices of V and the edges of E. For a partition of V into two subsets of vertices V_1 and V_2, we set the weight of (V_1, V_2) as the total weight of edges between V_1 and V_2. What is the relationship of $w(V_1)$ and $w(V_2)$ for the maximum weighted partition of G ?
3. Prove $Ax \leq b, x \geq 0$ cannot hold simultaneously with $y^T A \geq 0, y^T b < 0, y \geq 0$.

Truthful Auctions

Second Price Auction

1. Professor is auctioning off a CNY100 bill.
2. The highest bidder of the class bids CNY1,000,000, the second highest bids CNY102. Professor wins CNY2.

Self Study Problems

- Design a quiz question for the next year's students.
- Design a real monetary auction experiment for the next year's students.

The VCG Protocol on Matching Markets

- $G = (U, V; E, w)$. U agents, V items for sale, $w(i, j)$ values of item j to agent i.
- VCG allocation: optimal social welfare. The maximum weighted matching.
- VCG payment: winner's marginal contribution to the society.

  $$p_{i,i*} = OPT(G - u_i) - [OPT(G) - b_{i,i^*}(OPT(G))]$$

  where i^* is the item assigned to agent i in $OPT(G)$.
- Claim: VCG is truthful.

Notation for Deviating Agent

- VCG payment for truthful agent i is
  $$p_{i,i^*} = OPT(G - u_i) - [OPT(G) - v_{i,i^*}(OPT(G))]$$
  where i^* is the item assigned to agent i in $OPT(G)$.
- Payment when agent i bids differently is
  $$p'_{i,i'} = OPT(G' - u_i) - [OPT(G') - b_{i,i'}(OPT(G'))],$$
  where i' is the item assigned to agent i in $OPT(G')$.

Proof of Truthfulness

- Its corresponding utilities are

$$ut_i = v_{i,i^*} - p_{i,i^*} = OPT(G) - OPT(G - \{u_i\})$$

$$ut'_i = v_{i,i'} - p'_{i,i'} = OPT(G') - OPT(G' - \{u_i\}) + v_{i,i'} - b_{i,i'}$$

$$ut_i - ut'_i = [OPT(G) - v_{i,i'}] - [OPT(G') - b_{i,i'}]$$

- Let M' be the optimal matching in $OPT(G')$. Then

$$OPT(G) \geq w(M'), OPT(G') = w'(M')$$

- Claim follows since $w(M') - v_{i,i'} = w(M' - \{e(i,i')\})$, and $w'(M') - b_{i,i'} = w'(M' - \{e(i,i')\}) = w(M' - \{e(i,i')\})$,