CS 886
Electronic Market Design

Kate Larson
School of Computer Science
University of Waterloo

What is electronic market design?

- Building the next eBay?
  - Possibly
- Designing software agents for the stock market?
  - Possibly

Study the economic foundations of market design (game theory and mechanism design)

Study computational issues that arise in market design

Study the interaction between GT/MD and computation

Why now?

- Fast computers and high bandwidth have changed the cost of dynamic market mechanisms
  - Automated winner determination
  - Automated bidding using software agents
  - Distributed bidders
- Standardized ontologies (ie. XML)
  - Ability to exchange structured information

Able to construct new markets

Historical Perspective*

- Nash (1950): General definition of equilibrium for large class of games, proof of existence. [Nobel prize 1994]
  - "the analytic structure for studying all situations of conflict and cooperation"(Myerson'99)
- Vickrey (1961): Birth of auction theory [Nobel prize 1996]
- FCC Spectrum auction ($100B by 2001)
  - Many other countries followed
- More and more practical applications
  - MarketDesign, CombineNet, FreeMarkets, Frictionless
  - Used within CS to design and study networked systems
  - ….

*Shamelessly borrowed from D. Parkes

Two communities

- **Economics**
  - Traditional emphasis on game theoretic rationality
  - Describing how agents should behave
  - Multiple self-interested agents
- **Computer Science**
  - Traditional emphasis on computational and informational constraints
  - Building agents
  - Individual or cooperative agents

Resolve conflicts between game-theoretic and computational constraints, develop theories and methodologies

Lots of excitement!

- Fifth ACM Electronic Commerce Conference, May 2004
  - Market clearing algorithms, mechanism design, preference elicitation, reputation, economic models for getting rid of spam…
- Workshop on Agent Mediated Electronic Commerce, July 2004
- Radcliffe Institute Workshop on Preferences and Computation, May 2004
- FCC Combinatorial Bidding Conference, Nov 2003
- Dagstuhl Workshop on Electronic Market Design, 2002 (another one soon)
- Many papers appearing in AAAI, AAMAS, STOC, FOCS, SODA,…

This Course

- Introduced to the state-of-art in electronic market design
  - Game theoretic issues
  - Computational issues
  - The intersection
- Course structure
  - Introductory lectures [until September 29]
  - Current research papers
    - Combinatorial auctions (WDP, approximation issues, false-name bids, bidding languages, iterative auctions)
    - Preference elicitation and communication complexity
    - Reputation mechanisms
    - Bidding agents
    - Selling digital goods
    - Applications

Prerequisites

- Students must be comfortable with mathematical proofs
- Background in algorithms and complexity (for example, CS 466)
- Ideally an AI course (for example CS 486) – must be comfortable with agent rationality concepts
- I will cover all game theory and mechanism design required

Grading

- 2-3 assignments on game theory and mechanism design 10%
- In class presentation(s) 20%
  - Peer-reviewed
- Class participation 20%
- Research project 50%

Presentations

- Each student is responsible for presenting a research paper in class
  - Short survey + a critique
  - Everyone in class will provide feedback on the presentation
  - Marks will be given on coverage of the material + organization + presentation

Class Participation

- Students should participate!
  - Before each class (midnight the day before) student must email me a list of comments on the paper to be presented
    - What is the main contribution?
    - Is it important? Why?
    - What assumptions are made?
    - What applications might arise from the results?
    - How can it be extended?
    - What was unclear?
    - …

Projects

- Goal of the project is to develop a deep understanding of a topic related to electronic market design
- Topic is open
  - Theoretical, experimental, in depth literature review,…
  - Can be related to your own research
  - If you have troubles coming up with a topic, come talk to me
  - Proposals due October 20th
  - Final project due December 6th
  - Students will present projects in class

Other Important Information

- Office Hours:
  - Wednesday 2:30-3:30
- Course webpage
  - http://www.cs.uwaterloo.ca/~klarson/teaching/F04-886
  - Readings and schedule will soon be finalized

An Example

London Bus System

(as of April 2004)

- 5 million passengers each day
- 7500 buses
- 700 routes

- The system has been privatized since 1997 by using competitive tendering
- Idea: Run an auction to allocate routes to companies

The Generalized Vickrey Auction

(VCG mechanism)

- Let G be set of all routes, I be set of bidders
- Agent i submits bids $v_i^*(S)$ for all bundles $S \subseteq G$
- Compute allocation S* to maximize sum of reported bids

$$V^*(I)=\max_{(S1,\ldots,SI)}\Sigma_i v_i^*(S_i)$$

- Compute best allocation without each agent i:

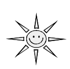
$$V^*(I\backslash i)=\max_{(S1,\ldots,SI)}\Sigma_{j\neq i} v_i^*(S_i)$$

- Allocate each agent Si*, each agent pays

$$P(i)=v_i^*(S_i^*)-[V^*(I)-V^*(I\backslash i)]$$

Example cont.

- Mechanism: Generalized Vickrey auction (GVA)
  - Specifies the rules
  - Describes how outcome will be determined
- Strategies:
  - Policies which specify what actions an agent should take
  - Agents are free to take any allowable action (ie. Specify any amount for each bid)
  - Assume self-interested rational agents (ie select strategies which maximize their own utility)



GVA is efficient and strategy-proof!

But….

- There are some computational issues
- Winner determination problem: selecting bids to maximize reported value is NP-hard
  - Equivalent to maximum weighted set packing
  - Solve this problem $I+1$ times (for payments)
- Agent valuation problem:
  - For each combination of routes, an agent has to compute its value for getting them (exponential number)
- Communication complexity:
  - Each agent has to communicate 2^{700} bids to the auctioneer

It might be too difficult to find and execute the optimal strategy (chess)

Tractable Winner Determination

- Restricted bidding languages [Rothfkopf et al 98, Vohra & de Vries 00]
  - Limited bid prices
  - Limited bundle types
- Implement approximate solutions to the WDP
  - Care must be taken – approximations can change the incentive properties of the mechanism
- Change the mechanism [Lehmann et al 02]
- Distribute computation to agents

Agent Valuation Problem

- Explicitly include the valuation problem into the model
- Use dynamic methods
  - Ask for some information and perform intermediate computation, ask for more information if required

Preference Elicitation and Communication Complexity

- Sometimes complete information is not necessary!

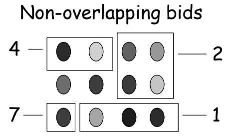
Single item:

v1=4, v2=8, v3=12

Only need to know v2=8, v1<8 and v3>8

Combinatorial auction:

Non-overlapping bids



We can compute and check the efficient outcome in both cases

Overview of Initial Lectures

1. Introduction (today)
2. Introduction to Game Theory
   - normal and extensive form games, dominant strategy, Nash equil, Bayesian-Nash equil
3. Introduction to Social Choice Theory
   - Voting protocols, voting paradoxes, Arrow's thm
4. Mechanism Design (I)
   - Implementation, Revelation principle, Gibbard-Satterthwaite Thm, VCG mechanism
5. Mechanism Design (II)
6. Auctions
   - Auctioning a single item, private and common values, Revenue equivalence thm

Other topics

- Combinatorial auctions
  - Winner determination problem
  - Approximations
  - Bidding Languages
  - Iterative Auctions

Other Topics

- Preference elicitation
- False name bidding
  - New form of cheating in Internet auctions
- Selling digital goods
- Agents
  - Trading agents (TAC)
  - Computationally limited agents

Other topics

- Reputation mechanisms
  - eBay and others
- Automated mechanism design
- Applications
  - Scheduling
  - Avoiding spam
  - P2P