Auctions

(Based on Shoham and Leyton-Brown (2008). *Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations*, Cambridge.)

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Purpose

- We will assume **unknown individual preferences**, and ask whether we can design a game such that, **no matter what the secret preferences** of the agents actually are, **the equilibrium of the game is guaranteed to have a certain desired property or set of properties**
  - Engineering emergent behavior, or
  - Incentive engineering
- **The most famous application of mechanism design is *auction theory* (Chapter 11)**

Introduction

- Auctions are widely used in real life, in consumer, corporate, as well as government settings
  - Millions of people use auctions daily on Internet consumer Web sites to trade goods
  - More complex types of auctions have been used by governments around the world to sell important public resources such as access to electromagnetic spectrum
  - All financial markets constitute a type of auction
  - Auctions are also often used in computational settings, to efficiently allocate bandwidth and processing power to applications and users

Have you participated in auctions before?

Introduction 2

- **Auctions provide a general theoretical framework for understanding resource allocation problems among self-interested agents**
- Formally speaking, an auction is any protocol
  - That **allows agents to indicate their interest in one or more resources,** and
  - That **uses these indications of interest to determine both an allocation of resources and a set of payments by the agents**

Is auction a type of negotiation? 1-to-n negotiations? N-to-n negotiations

Single-Good Auctions

Double-sided auctions?
Multi-good auctions?

- There is **one good for sale**, **one seller**, and **multiple potential buyers**.
- Each buyer has his or her own valuation for the good, and each wishes to purchase it at the lowest possible price.
- These auctions are called ***single-sided***, because there are multiple agents on ***only*** one side of the market.
- Our task is to design a protocol for this auction that satisfies certain ***desirable global criteria***
  - E.g., one that **maximizes the expected revenue of the seller**
  - E.g., one that is **economically efficient**; that is, one that guarantees that **the potential buyer with the highest valuation ends up with the good**.

Mechanism Efficiency

- **Definition 10.3.6 Efficiency.** *A quasilinear mechanism is* **strictly Pareto efficient,** *or just* **efficient**, *if in equilibrium it selects a choice x such that* $\forall v \forall x', \sum_i v_i(x) \geq \sum_i v_i(x')$.
  - An agent's *valuation* for choice $\in X$, written $v_i(x)$ should be thought of as the ***maximum amount of money*** that i would be willing to pay to get the mechanism designer to implement choice x

Auction Protocols

- **Open-outcry auctions**
  - All the bidding is done by calling out the bids in ***public***
  - English auctions, Japanese auctions, Dutch (descending) auctions
- **Seal-bid auctions**
  - First-price seal-bid auctions, Second-price seal-bid auctions (aka Vickrey)

- **Christie's Auctions?**
- **Government open or closed contract bids?**
- **NSF call for proposals?**
- **A student posting a flyer selling an item with "best offer" tear-away phone number?**

English Auctions

- Perhaps the **best-known** family of auctions (auction houses, most of the online consumer auction sites)
- The auctioneer sets a **starting price** for the good
- Agents then have the option to **announce successive bids**, each of which **must be higher** than the previous bid
  - usually by some minimum increment set by the auctioneer
- The rules for when the auction closes vary
  - Ends at a fixed time
  - Ends after a fixed period during which no new bids are made
  - Etc.
- The final bidder, who by definition is the **agent with the highest bid**, must purchase the good for the amount of his or her final bid

Japanese Auctions

- Similar to the English auction in that it is an **ascending bid auction** but is different otherwise
- The auctioneer sets a **starting** price for the good
- **Each agent must choose whether or not to be "in,"** that is, whether he or she is willing to purchase the good at that price. (**Open-Exit**)
- The auctioneer then **calls out successively increasing prices** in a regular fashion and after each call **each agent must announce whether he or she is still in**
- When he or she drops out it is **irrevocable**
  - he or she ***cannot*** reenter the auction
- The auction ends when there is ***exactly*** one agent left in
  - the agent must then purchase the good for the current price

Dutch Auctions (aka Descending Dutch)

- The auctioneer begins by announcing a **high** price and then proceeds to announce **successively lower prices** in a regular fashion
  - In practice, the descending prices are indicated by a clock that all of the agents can see.
- The auction ends when the **first agent signals the auctioneer by pressing a buzzer and stopping the clock**
  - The signaling agent must then purchase the good for the displayed price.
- This auction gets its name from the fact that it is used in the Amsterdam flower market; in practice, **it is most often used in settings where goods must be sold *quickly***

Seal-Bid Auctions

When are seal-bid auctions desirable?
When are Vickrey auctions desirable?

- Each agent submits to the auctioneer a **secret, "sealed" bid** for the good that is ***not*** accessible to any of the other agents
- The agent with **the highest bid must purchase the good**, but the price at which he or she pays depends on the type of sealed-bid auction
- ***First-price sealed-bid*** auction (aka the *first-price* auction)
  - the winning agent pays an amount equal to his or her own bid
- ***Second-price sealed-bid*** auction (aka the ***Vickrey*** auction)
  - The winning agent pays an amount equal to the next highest bid (i.e., the highest rejected bid)
- In general, in a kth-price auction, the winning agent purchases the good for a price equal to the kth highest bid

Auctions as Structured Negotiations

- **Elimination Auction**
  - Consists of **a sequence of sealed bids**
  - In the first round **the lowest bidder drops out**
  - His/her bid is announced and becomes the **minimum** bid in the next round for the remaining bidders
  - This process continues until **only one bidder remains**
  - This bidder **wins** and **pays the minimum bid in the final round**

These auctions (multi-round, or two-phase) are not uncommon in industry. Why?

Auctions as Structured Negotiations 2

- **Procurement Reverse Auction**
  - An initial sealed-bid auction is conducted among the interested suppliers
  - Then a reverse English auction is conducted among the three cheapest suppliers (the “finalists”) to determine the ultimate supplier.
  - A ***reverse auction*** is a type of auction in which the roles of buyers and sellers are reversed

These auctions (multi-round, or two-phase) are not uncommon in industry. Why?

Auctions as Structured Negotiations 3

- At heart an auction is simply a **structured framework for negotiation**
- Each such negotiation has certain rules, which can be broken down into three categories
  - **Bidding rules**: How are offers made (by whom, when, what can their content be)?
  - **Clearing rules**: When do trades occur, or what are those trades (who gets which goods, and what money changes hands) as a function of the bidding?
  - **Information rules**: Who knows what when about the state of negotiation?

Take Information Rules and Vickrey auction: The second highest bid is also revealed. Is that good or bad?

Contract Net Protocol

- Based on Smith, R. (1980). The Contract Net Protocol: High-Level Communication and Control in a Distributed Problem Solver, *IEEE Transactions on Computers*, **C-29**(12):1104-1113.
- It was developed to specify problem-solving communication and control for **nodes** in a distributed problem solver
- Task distribution is affected by a **negotiation** process, a discussion carried on between nodes with tasks to be executed and nodes that may be able to execute those tasks

Nodes are akin to agents. At that time, the notion of agents was not well known

Contract Net Protocol 2

- **Task Announcement**: A node that generates a task normally **initiates** contract negotiation by advertising existence of that task to the other nodes with a **task announcement** message: **task abstraction**, **bid specification**, **expiration time**. It then acts as the **manager** of the task.
- **Task Announcement Processing**: For each type of task, a node maintains a **rank-ordered list of announcements** that have been received and have not yet expired. Each node checks the **eligibility specifications** of all task announcements that it receives to see whether they can be met. If it is qualified, then the node ranks that task relative to others under consideration.
- **Bidding**: A node checks its list of task announcements and **selects a task (or tasks) on which to submit a bid**.

Contract Net Protocol 3

- **Bid Processing**: When a bid is received, the manager **ranks** the bid relative to others under consideration. If any of the bids are determined to be **satisfactory**, then the **contract is awarded immediately to the associated bidder**. Otherwise, the manager waits for further bids. Successful bidders are informed that they are now contractors for a task through an **announced award** message.
- **Contract Processing, Reporting Results, and Termination**: The **report** is used by a contractor to inform the manager (and other report recipients, if any) that a task has been partially executed (an **interim report)** or completed (a **final report).**
- (Optional) **Negotiation Tradeoffs**: Because bids are binding and if a node is allowed to have ***more*** than one bid outstanding at a time, a node may receive multiple awards. A node can **negotiate** with the manager to decide which award to accept if there are multiple awards.

Connection to MAS?

Auctions are prevalent. Agent practitioners build agents to bid following specific auction protocols

The Contract Net Protocol and its variants are very popular in task or resource allocation in MAS
The fundamental idea is that each bidding agent is **self-interested** and is motivated to submit the **most "appropriate" bids** in order to win
Thus, if every agent is rational, then a desired **economically efficient** outcome can emerge: meaning that a resource is allocated or a task is assigned to the most needed or capable agent
This means that the overall system thus **optimizes** its allocation, e.g., best uses its resources

Silly Question: Suppose that it was required that the list of companies to which you submit your applications is made available to all companies at real time. How would you plan and decide how to proceed with your job application process?