CSCE 475/875 Multiagent Systems
Handout 19: Auctions
March 30, 2020
(Based on Shoham and Leyton-Brown 2011)

Background

The auction setting is important for two reasons.

- First, 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. Indeed, 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.
- The second—and more fundamental—reason to care about auctions is that they 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. Thus, auctions are important for a wide range of computational settings (e.g., the sharing of computational power in a grid computer on a network) that would not normally be thought of as auctions and that might not even use money as the basis of payments.

Single-good auctions

In the most familiar types of 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*. For example, we might want an auction protocol that maximizes the expected revenue of the seller.
- Or, we might want an auction that is *economically efficient*; that is, one that guarantees that the potential buyer with the highest valuation ends up with the good.

1. English auctions

The *English auction* is perhaps the best-known family of auctions, since in one form or another such auctions are used in the venerable, old-guard auction houses, as well as most of the online consumer auction sites.

- The auctioneer sets a starting price for the good, and
- 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; in some instances the auction ends at a fixed time, in others it ends after a fixed period during which no new bids are made, in others at the latest of the two, and in still other instances at the earliest of the two.

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.

2. Japanese auctions

The *Japanese auction* is similar to the English auction in that it is an ascending bid auction but is different otherwise.

- Here the auctioneer sets a starting price for the good, and 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-outcry)
- 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, and 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.

3. Dutch auctions

In a *Dutch auction* 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.

4. Sealed-bid auctions

All the auctions discussed so far are considered *open-outcry* auctions, in that all the bidding is done by calling out the bids in public. The family of *sealed-bid auctions*, probably the best known after English auctions, is different.

- In this case, 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 does so depends on the type of sealed-bid auction.
  - In a *first-price sealed-bid* auction (or simply *first-price auction*) the winning agent pays an amount equal to his or her own bid.
  - In a *second-price auction* he or she pays an amount equal to the next highest bid (i.e., the highest rejected bid). **The second-price auction is also called the *Vickrey auction*.**
  - In general, in a *kth-price auction* the winning agent purchases the good for a price equal to the *k*th highest bid.

5. Auctions as structured negotiations

Consider the following auction, consisting 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. This auction, called the *elimination auction*, is different from the auctions described earlier, and yet makes perfect sense.

Or consider a procurement reverse auction, in which an initial sealed-bid auction is conducted among the interested suppliers, and then a reverse English auction is conducted among the three cheapest suppliers (the "finalists") to determine the ultimate supplier. This two-phase auction is not uncommon in industry. (***Note***: A *reverse auction* is a type of auction in which the roles of buyers and sellers are reversed.)

> **What is an auction? At heart it is simply a structured framework for negotiation. Each such negotiation has certain rules, which can be broken down into three categories.**

1. **Bidding rules**: How are offers made (by whom, when, what can their content be)?
2. **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?
3. **Information rules**: Who knows what when about the state of negotiation?

6. 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.)

The contract net protocol has been 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.

1. **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.
2. **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.
3. **Bidding**: A node checks its list of task announcements and selects a task on which to submit a bid.
4. **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.
5. **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).**
6. (Optional) **Negotiation Tradeoffs**: Because bids are binding and 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.