Multiagent Systems: Spring 2006

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Basic Auction Theory

- As you know by now, negotiation is a central issue in MAS: agents need to reach agreements on just about anything ...
- Last week we have studied the case of bilateral negotiation, but these ideas are not easily (maybe not at all) generalisable to the case of negotiation between many agents.
- With the rise of the Internet, *auctions* have become popular in many *e*-commerce applications (e.g. *ebay*).
- In the context of MAS, auctions provide simple and implementable protocols for one-to-many negotiation.

Plan for Today

Today's lecture will be an introduction to *Auction Theory*:

- We are going to concentrate on the problem of auctioning off a *single good* at a time (rather than a whole bundle of goods).
- We are going to define and compare (the) four basic auction protocols: *English*, *Dutch*, *first-price sealed-bid*, and *Vickrey*.
- We are also going to discuss issues related to *lying* and *cheating* in auctions.

Auctions

General setting for "simple" auctions:

- one seller (the *auctioneer*)
- many *buyers*
- one single item to be sold, e.g.
  - a house to live in (*private value auction*)
  - a house that you may sell on (*correlated value auction*)

There are many different *auction mechanisms* or *protocols*, even for simple auctions ...

English Auctions

- Protocol: auctioneer starts with the *reservation price*; in each round each agent can propose a higher bid; final bid wins
- Used to auction paintings, antiques, etc.
- Dominant strategy (for private value auctions): bid a little bit more in each round, until you win or reach your own valuation
- Counterspeculation (how do others value the good on auction?) is not necessary.
- *Winner's curse* (in correlated value auctions): if you win but have been uncertain about the true value of the good, should you actually be happy?

Dutch Auctions

- Protocol: the auctioneer starts at a very high price and lowers it a little bit in each round; the first bidder to accept wins
- Used at the flower wholesale markets in Amsterdam.
- Intuitive strategy: wait for a little bit after your true valuation has been called and hope no one else gets in there before you (no general dominant strategy)
- Also suffers from the winner's curse.

First-price Sealed-bid (FPSB) Auctions

- Protocol: one round; sealed bid; highest bid wins (for simplicity, we assume no two agents make the same bid)
- Used for public building contracts etc.
- Problem: the difference between the highest and second highest bid is "wasted money" (the winner could have offered less).
- Intuitive strategy: bid a little bit less than your true valuation (no general dominant strategy)
- Strategically equivalent to the Dutch auction protocol:
  - only the highest bid matters
  - no information gets revealed to other agents

Vickrey Auctions

- Proposed by William Vickrey in 1961 (Nobel Prize in Economic Sciences in 1996)
- Protocol: one round; sealed bid; highest bid wins, but the winner pays the price of the *second highest* bid
- Dominant strategy: bid your true valuation
  - if you bid more, you risk to pay too much
  - if you bid less, you lower your chances of winning while still having to pay the same price in case you do win
- Problem: counterintuitive (problematic for humans)
- Antisocial behaviour: bid more than your true valuation to make opponents suffer (not "rational")
- For private value auctions, strategically equivalent to the English auction mechanism

Parameters of Simple Auction Protocols

To summarise, we can distinguish different types of auctions according to the following parameters:

- either *open-cry* or *sealed-bid*
- either *ascending* or *descending* or *one-shot*
- either *first-price* or *second-price*

We have seen the following examples:

- *English auctions:* first-price, open-cry, ascending
- *Dutch auctions:* first-price, open-cry, descending
- *First-price sealed-bid auctions:* first-price, sealed-bid, one-shot
- *Vickrey auctions:* second-price, sealed-bid, one-shot

In particular the sealed-bid protocols are also applicable to the case of *reverse auctions* (one buyer, many sellers).

Pareto Efficiency

All four auction protocols guarantee a *Pareto optimal* outcome:

They result in an agreement x (the winner obtaining the good for the specified price from the auctioneer) such that there is no other agreement y that would be better for at least one of the agents without being worse for any of the others:

- paying a higher price would be worse for the winner
- paying a lower price would be worse for the auctioneer
- giving the good to a different buyer would be worse for the winner (who would have paid a price less or at most equal to their private valuation, given agreement x)

Revenue for the Auctioneer

- Which protocol is best for the auctioneer?
- Revenue-equivalence Theorem (Vickrey, 1961):

  All four protocols give the same expected revenue for private value auctions amongst risk-neutral bidders with valuations independently drawn from a uniform distribution.

- Intuition: revenue $\approx$ second highest valuation:
  - Vickrey: clear ✓
  - English: bidding stops just after second highest valuation ✓
  - Dutch/FPSB: because of the uniform value distribution, top bid $\approx$ second highest valuation ✓

Exceptions to the Revenue-equivalence Theorem

Note that the Revenue-equivalence Theorem applies only to an artificial and rather idealised situation. There are many exceptions:

- For valuations that are *not independent and uniformly distributed:*
  - If one bidder has a very high valuation, then Dutch and FPSB auctions are likely to be better for the auctioneer.
- *Correlated value* auctions:
  - English auctions are good for the auctioneer, because observing other bidders may cause you to raise your own valuation.
- *Risk-averse* bidders:
  - Dutch and FPSB auctions increase expected revenue, because bidders can increase the probability of winning (at reduced expected profit) by bidding closer to their true valuation.

Lying and Cheating

We have seen that truth-telling is a dominant strategy for Vickrey auctions ... at least in the case of *private value* auctions, and as far as the *individual bidders* are concerned.

- *Winner's curse:* in correlated value auctions, winning means over-bidding, so truth-telling is not the best strategy.
- *Lying auctioneer:* problematic for Vickrey auctions, but not for any open-cry protocol or for first-price sealed-bid auctions.
- *Shills:* bidders placed by the auctioneer to artificially increase bids (English auction)
- *Collusion* (groups of bidders cooperate in order to cheat): none of the four auction protocols is collusion-proof.

More on Bidder Collusion

All four auction protocols are vulnerable to collusion amongst bidders. Particularly problematic for English and Vickrey auctions:

- *English* auction: If several bidders collude to keep bids low so that the agent with the highest valuation can get the item at an artificially low price, no agent has an incentive to break the collusion agreement, as the agent with the highest valuation could always still obtain the item by bidding its true valuation.
- *Vickrey* auction: The agent with the highest valuation from a group of colluding agents can safely bid their true valuation: if no agent breaks the collusion agreement to bid artificially low, it will obtain the good at a better price, but certainly at a price not exceeding its true valuation.

In the *Dutch* and the *FPSB* auction protocols, collusion is less likely, because the agent supposed to buy the good cheaply cannot control that other won't break the collusion agreement and may therefore decide not to collude in the first place.

Auctioning Multiple Items

Recall the following example from the introductory lecture:

Suppose the auctioneer is first selling a TV and then a DVD player. How should our agents bid?

- Ann wants to watch the news and is not interested in DVDs.
- Bob already owns a TV and is only interested in the DVD player.
- Chloë has an enormous collection of classic movies on DVD, a pretty low opinion of today's television programming, and no DVD player or TV.

A simple auction mechanism that allocates one item at a time is problematic, even if we make the (inappropriate) assumption that agents will bid truthfully ($\rightsquigarrow$ *combinatorial auctions*).

Summary

- Four basic auction protocols: *English*, *Dutch*, *FPSB*, and *Vickrey*
- Outcomes are guaranteed to be *Pareto efficient*.
- *Revenue-equivalence Theorem:* under suitable conditions, all four protocols give the same expected revenue for the auctioneer (and we have seen several examples where these conditions do *not* hold)
- While the Vickrey auction, in particular, promotes truth-telling, we have seen that all four protocols are vulnerable to *manipulation* by insincere agents.
- If there are *several goods* to be allocated and agents have utilities that are not just additive, then our basic auction protocols are problematic even amongst sincere agents.

References

- W. Vickrey. Counterspeculation, Auctions, and Competitive Sealed Tenders. *Journal of Finance*, 16(1):8–37, 1961.
- R.P. McAfee and J. McMillan. Auctions and Bidding. *Journal of Economic Literature*, 25:699–738, 1987.
- T.W. Sandholm. Distributed Rational Decision Making. Chapter 5 in G. Weiss (ed.), *Multiagent Systems: A Modern Approach to Distributed AI*, MIT Press, 1999. Section on Auctions.

What next?

The next couple of lecture will be devoted to richer models of auctions. We are going to discuss *complexity*, *algorithmic*, and *strategic* issues:

- *Combinatorial Auctions:* selling several goods together
- *Mechanism Design:* generalising the Vickrey auction