Escola Tècnica Superior d'Enginyeria
Universitat Rovira i Virgili

[DEIM]

Lecture 7: Cooperation in MAS (III) – Negotiation via auctions

Multi-Agent Systems

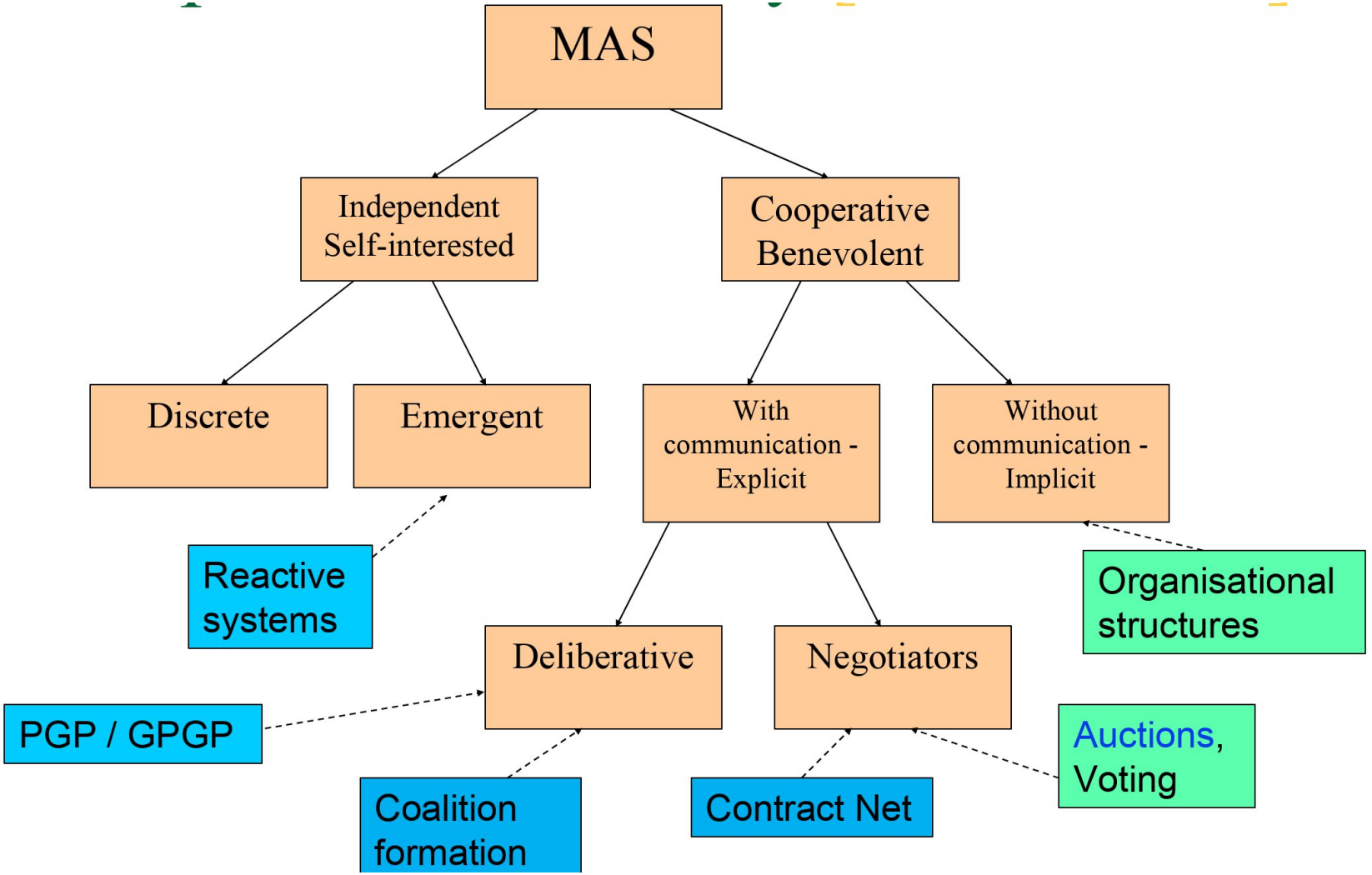
Universitat Rovira i Virgili

MESIIA – Master's Degree in Computer Security Engineering and Artificial Intelligence
MAI – Master's Degree in Artificial Intelligence

Outline

- Negotiation protocols
- Auctions
  - English/Dutch/FPSB/Vickrey
  - Multi-unit
  - Multi-attribute
  - Combinatorial

Cooperation hierarchy [last lectures]



Need of negotiation in MAS

- Agents may have incompatible goals, and the resources to achieve these goals may be limited; in such cases competition and conflicts may arise
- Agents must be able to reach compromises, resolve conflicts, allocate goods and resources by way of an agreement
- Agents' interactions are governed by a set of rules: an interaction protocol

Negotiation protocol elements

Private elements

- The strategies that the agents can use to participate in the negotiation process:
  - They are not dictated by the protocol itself
  - They may take into account the strategies of the other agents

Public elements

- A negotiation set which represents the space of possible offers/proposals that the agents can make
- The protocol rules which govern the agents' interactions

Protocol rules (I)

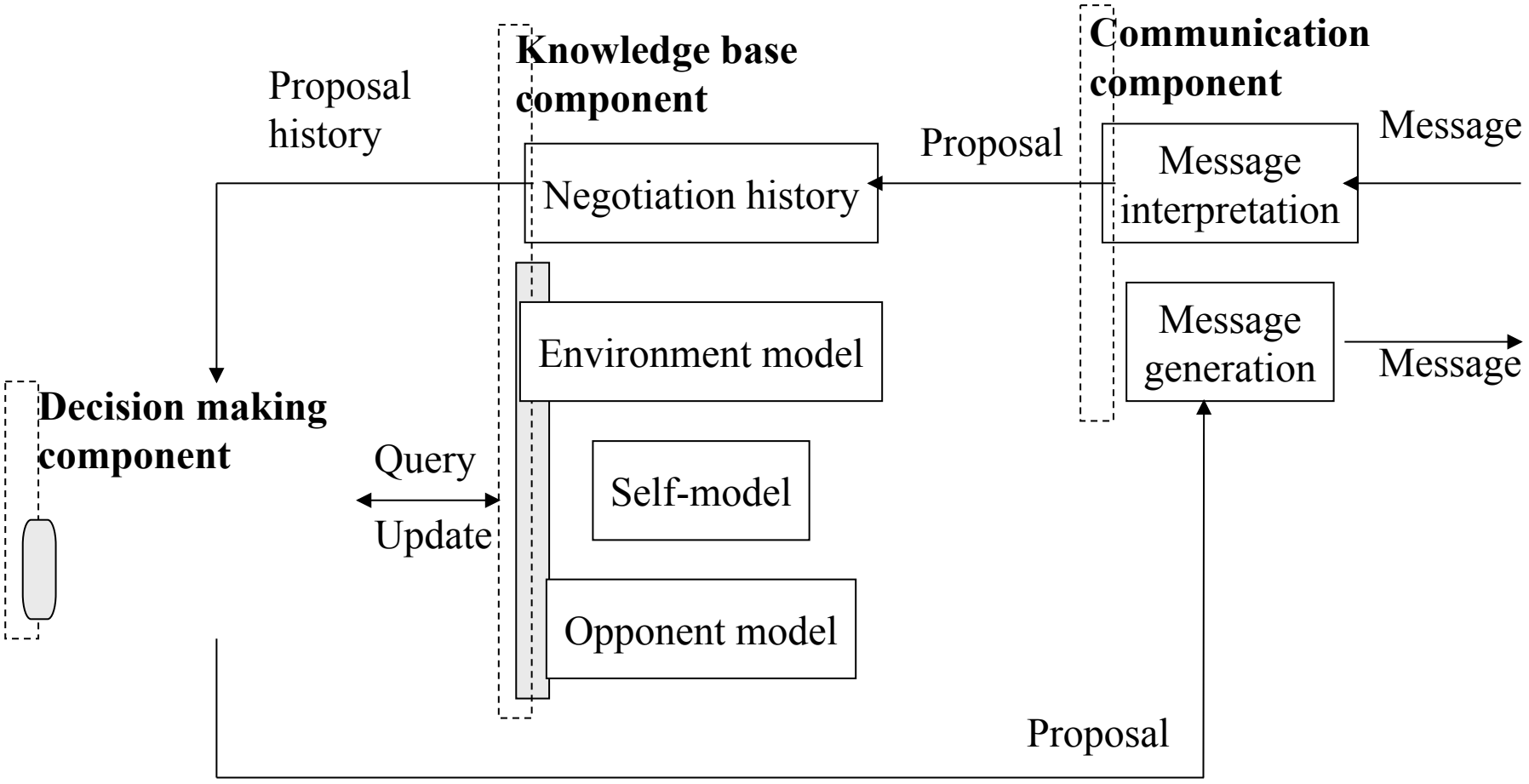
- Admission rules
  - When an agent can participate in a negotiation
- Interaction rules
  - Sequence of admissible/valid actions
- Validity rules
  - What constitutes a legal offer/proposal
- Outcome determination rules
  - When agreement is reached

Negotiation factors

- Number of attributes: one, many
  [Multi-attribute auctions]
- Number of agents:
  - One-to-one
  - One-to-many
  - Many-to-many
- Number of units: one, many
  [Multi-unit auction]
- Interrelated goods: one good or a number of goods that are substitutable or interdependent

  [Combinatorial auctions]

Architecture for negotiating agents



Auctions

- A class of negotiation protocols which provide us with methods for allocating goods/resources based upon competition among self-interested parties

Where are auctions used?

- Telecommunication and TV licenses, mining rights, airport gates and take-off/landing slots
- Google AdSense
- Extremely popular as a means for conducting consumer-to-consumer (C2C) negotiations online
- Collectibles (paintings, books, antiques)
- Agricultural products (flowers, fish, tobacco)

Advantages of Auctions

- Markets may not exist for what the seller wants to sell
- The seller does not know how much an item is worth
- Create competition
- Flexibility
- Less time-consuming and expensive than negotiating a price

Auction participants

The auctioneer

- A seller who wants to sell goods at the highest possible price
- Someone who wants to subcontract out contracts at the lowest possible price
- A buyer who wants to buy a good

The bidders

- Buyers who want to acquire goods at the lowest possible price
- Contractors who want to get a contract at the highest price
- Sellers who want to sell their goods

Basic concepts (I)

- Bids: offers by bidders to buy or sell the auctioned item
  - Buy bid: the price a bidder is willing to pay to own an item
  - Sell bid: the price a bidder is willing to accept to sell an item
- Reservation price: Maximum/minimum price that a buyer/seller is willing to pay/accept for an item – usually private information

Basic concepts (II)

- Process a bid: the auctioneer checks the validity of a bid according to the rules of the auction protocol and updates its database
- Clearance: matching between buyers and sellers and setting of the transaction price
- Clearing price: final transaction price that the winning bidder pays and the auctioneer receives

Typical auction process (I)

- Buyers and sellers register with the auction house
- The auction event is set up
- The auction is scheduled and advertised (local press, Internet, etc.)
- The actual bidding phase takes place according to the rules of the auction
  - Information may be revealed to participants to some extent during the bidding phase

Typical auction process (II)

- The bids are evaluated and the auction closes with a winner being determined if any of the bids is successful
- The transaction phase takes place: the buyer pays for the goods and the seller ships/delivers them

Classification of auctions (I)

(1) Bidding rules

- Single good or combinatorial
- Single attribute or multi-attribute
- Open (outcry) or sealed-bid
- Ascending or descending
- Single unit or multi-unit

Classification of auctions (II)

(2) Information revelation policy

- When to reveal information: on each bid, at predetermined points in time, on inactivity, etc.
- What information
  - **Bid**: the price a seller would have to offer in order to trade
  - **Ask**: the price a buyer would have to offer in order to trade
  - **Auction closure**: known, unknown, after a period of inactivity
- To whom: participants only, everyone

Classification of auctions (III)

- **(3) Clearing policy**

- When to clear: on each bid, on closure, periodically, after a period of inactivity
- Who gets what (allocation and winner determination problem)
- At what price: first, second price or other

Auction formats

- Basic
  - English
  - Dutch
  - FPSB-First price sealed bid
  - Vickrey
- Multi-unit
- Multi-attribute
- Combinatorial
- Others …

English auction (I)

- Open-outcry and ascending-price auction
- The auctioneer announces an opening price or the reserve price
- Bidders raise their bids and the auction proceeds to successively higher bids
- The winner of the auction is the bidder of the highest bid

English auction (II)

English auction (II)

- The best strategy is to bid a small amount above the previous bid until one reaches its private value and then stop
- The bidders gain information by *observing* the others' bids
  - Amount of bid increase, doubts, time taken to bid, …

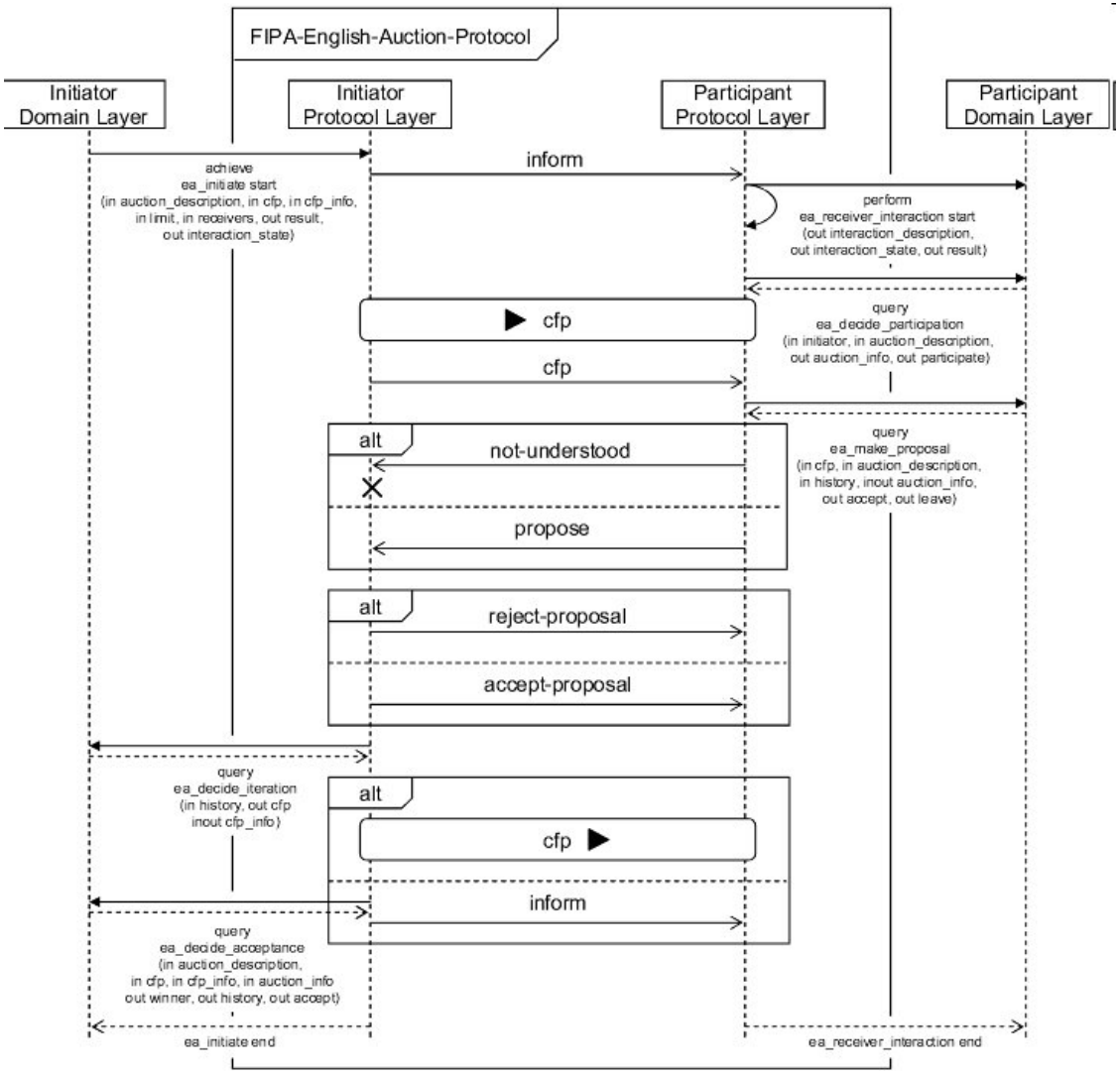
English auction: Disadvantages (I)

- The reserve price may not be met and the item may remain unsold
- The auctioneer may cheat by overstating a reserve price or present a reserve price that does not exist
- Susceptible to rings (collusions)
- Phantom bid
  - The auctioneer calls a bid that no one has made

English auction: Disadvantages (II)

- Bidders can become carried away and overbid
- Vulnerable to shills
  - Person associated to the seller that pretends to be an enthusiastic customer
- In real life it can become complicated (voices, signals)

English auction



Dutch auction (I)

- Open and descending-price auction
- The auctioneer announces a very high opening bid
- Then the auctioneer keeps lowering the price until a bidder accepts it – the winner pays the price of its bid

Dutch auction

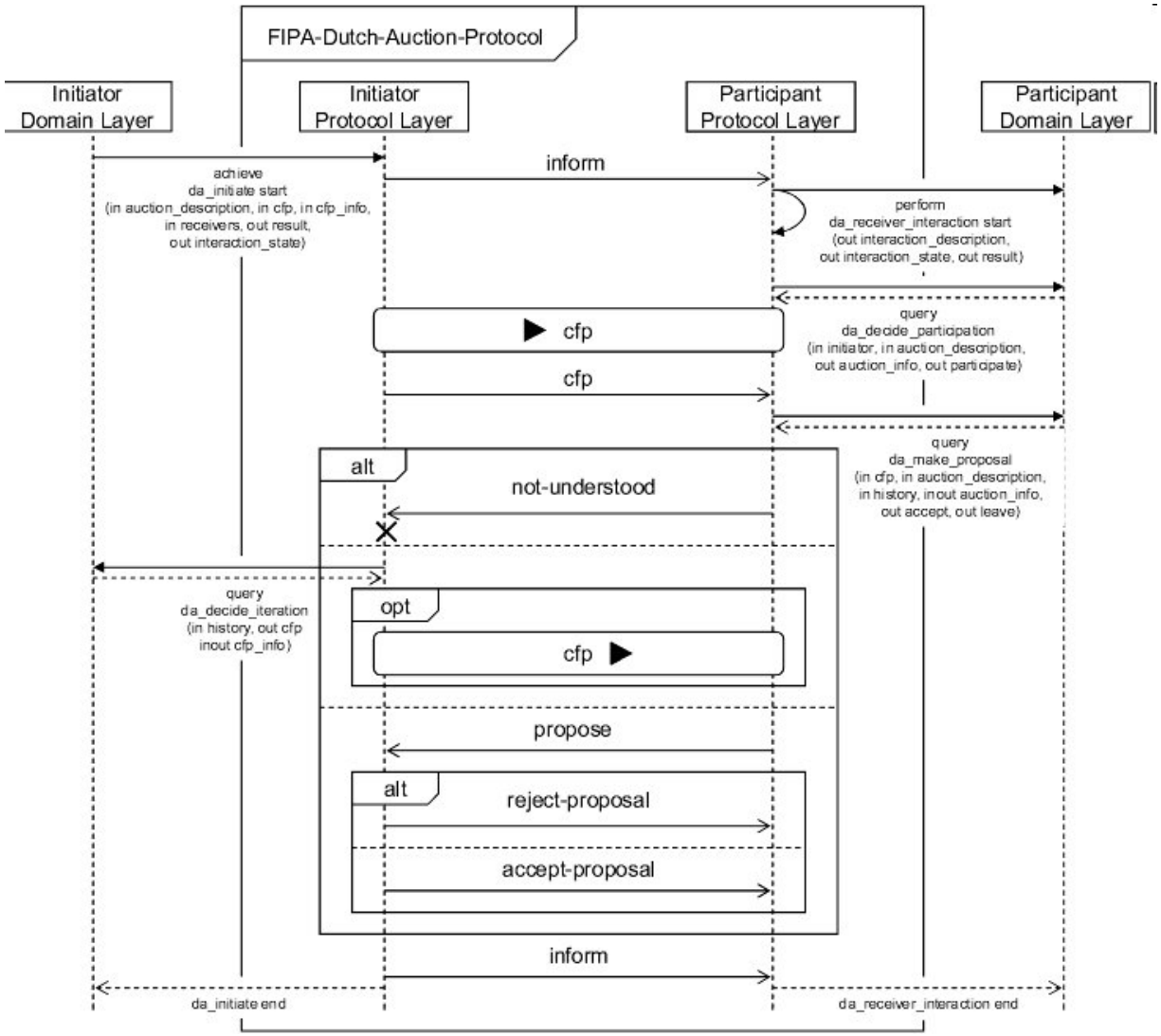
Dutch auction (II)

- Bidders need to decide in advance the maximum amount that they are willing to bid
- A bidder must decide when to stop the auction (bid) based upon its own valuation of the commodity and its prior beliefs about the valuations of the other bidders
- No relevant information on the valuation of the other bidders is disclosed during the process of the auction until it is too late

Dutch auction: Comments

- Very efficient in real time: used in The Netherlands for selling fresh flowers, Ontario tobacco auction, fresh produce auctions, fish markets
- The effect of competition on the buyers is stronger in the Dutch auction than in the English one

Dutch auction



First-price sealed-bid auction (I)

- Each bidder submits its own bid (usually in writing) without knowledge of the bids of others
- Two phases:

  (i) the bidding phase in which participants submit their bids

  (ii) the resolution phase in which the bids are opened and the winner is determined
- The highest bidder wins and pays the amount of its bid

First-price sealed-bid auction (II)

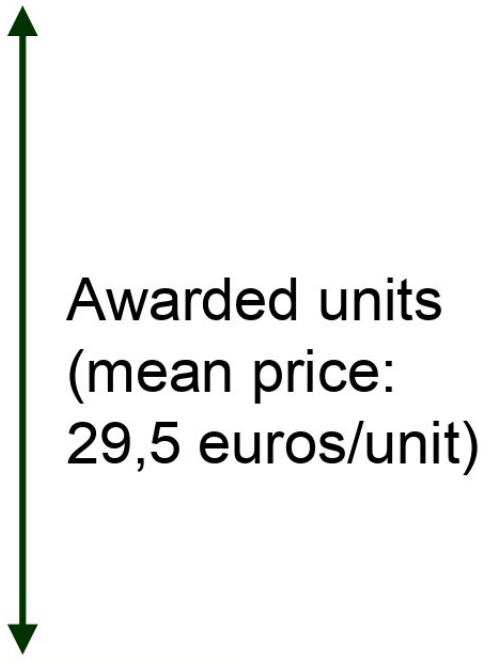
- An agent's strategy depends on its own valuation and prior beliefs about the other bidders' valuations
- A higher bid raises the probability of winning, but lowers the bidder's profit if it wins
- Bidders are better off not bidding their true valuations but a small amount below it
  - Trade-off between the profit they can get and the probability of losing the auction

First-price sealed-bid Multi-unit auction

- In many kinds of auctions there is a certain quantity of units of the same item, which may be distributed between different buyers
- In a multi-unit auction sealed bids are sorted from high to low, and the items are awarded at the highest bid price until the supply is exhausted

First-price sealed-bid Multi-unit auction: 1000 units

200 units at 35 euros
250 units at 30 euros
300 units at 28 euros
100 units at 27 euros
150 units at 26 euros
500 units at 25 euros



225 units at 20 euros

...

Vickrey auction

- A second-price sealed-bid auction, also known as *uniform second-price sealed-bid* or the *philatelist auction*
- Two distinct phases: the bidding phase and the resolution phase
- The highest bid wins but the bidder pays the amount of the second-highest bid

William Vickrey, Economics Nobel Prize 1996

Vickrey auction: Why do they work?

- Although it seems that the auctioneer would make more money out of a first-price sealed auction, this is *not* the case
- Bidders adjust their bids upwards since they are not deterred by fear that they will have to pay too much
- The price that the winning bidder pays depends on the others' bids alone and not on any action that the bidder undertakes

Vickrey auction: Comments

- The best strategy is for the agent to bid its true valuation
- The bidders do not waste time in *counter-speculating* what the other bidders will do

Vickrey auctions: Best bidding strategy (I)

- A bidder has a dominant strategy to bid an amount equal to their valuation, that is: $b_i = v_i$
- Consider bidding v - x if your true value is v
- Suppose the highest bid other than yours is w
  - Case 1: If v - x > w you win the auction and pay w, just as if you had bid v

Vickrey auctions: Best bidding strategy (I)

- Case 2: If w > v you lose the auction and get nothing, just as if you had bid v
- Case 3: If v > w > v - x bidding v - x causes you to lose the auction, whereas if you had bid v, you would have won the auction and paid w for a net surplus of v - w

- Hence you can only lose, and never gain, by bidding v - x

Multi-attribute auctions

- *Multi-attribute* or multi-dimensional auctions allow bidders to submit bids on more than one attribute or dimension of a good
- Very common in procurement situations
- The attributes under negotiation are usually defined in advance and bidders can compete in open-cry or sealed-bid auctions

Multi-attribute auctions: Procurement example

- Consider a manufacturer which uses raw materials from a number of suppliers to produce finished goods
- Assume the manufacturer requires 1000 units of A by March 31st
- The manufacturer sends a *Request For Quotes* (RFQ) to all potential suppliers of A

Multi-attribute auctions: Procurement example

- Suppliers reply with a bid b_i

  <quantity, delivery_date, price>
- The manufacturer's request could be covered by one or more bids in combination (sole or multiple sourcing)

Multi-attribute auctions: Winner determination

- A *multi-attribute offer* has the form
  $v_i=(v_{i1},\ldots,v_{ij})$ where v_{ij} is the level of attribute *j* offered by *i*
- Each bid is evaluated through a scoring function $S(v_i)$ which is a weighted average function – often scaled from 0 to 1

$$s_i = S(\mathbf{v}_i) = \sum_{j \in J} w_j S_j(v_{ij}) \text{ and } \sum_{j \in J} w_j = 1$$

Multi-attribute auctions: Example - 1000 units by 31/03

S1: 500 units, 28/03, 30 euros/unit
S2: 1000 units, 4/04, 38 euros/unit
S3: 700 units, 2/04, 37 euros/unit
S4: 300 units, 30/03, 42 euros/unit

- If completeness is preferred => S3+S4 or S2
  - S2 (1000 units, 38000 €, by April 4th)
  - S3+S4 (1000 units, 38500 €, by April 2nd)
- If sole-sourcing is preferred => S2
  - S2 (1000 units, 38000 €, by April 4th)
- If deadline has to be kept => S1+S4
  - S1+S4 (800 units, 27600 €, by March 30th)

Multi-attribute auctions: Advantages

- They allow more degrees of freedom for bidders: price may not be the only attribute of interest
- More efficient information exchange among the market participants

Combinatorial auctions

- Auctioning multiple *distinguishable* items when bidders have preferences over combinations of items: *complementarity* & *substitutability*

- Example: auctioning a three-seater sofa, a two-seater one, two armchairs and a coffee table
  - What's the best way to sell these goods? As a complete set? Each item separately? Allow combinations?





Combinatorial auctions: Sequential vs parallel

- Sequential auctions: run individual auctions one after the other
  - Impossible to determine best strategy
  - Inefficiencies can result from future uncertainties
- Parallel auctions: run individual auctions in parallel
  - Difficult to keep track of several simultaneous auctions with substitutable and interdependent goods (at least for human agents)

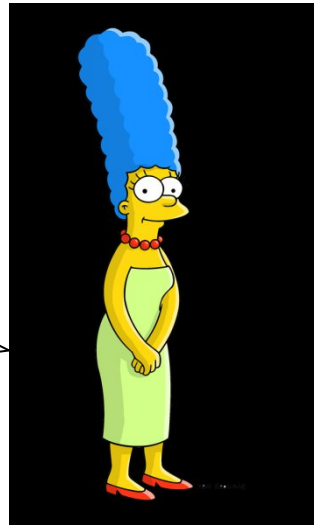
Combinatorial auctions: Bundles of items

- *Combinatorial* auctions: bids can be submitted on combinations (bundles) of items
- Example
  - Bundle1: the two-seater sofa and the table
  - Bundle2: the armchairs and the table
  - Bundle3: the two-seater sofa and the armchairs

275 $

350 $

400 $



300 $

325 $

Combinatorial auctions: Interest

- Bidder's perspective
  - Avoids the need for lookahead
  - Optimal bundling of items
- Auctioneer's perspective
  - Winner determination problem: Decide on the winning bids so as to maximize the sum of bid prices (i.e., revenue)

Combinatorial auctions: Issues

- Should the combinations of items on which bids are allowed be restricted?
  - Limits number of possibilities to be considered
- Single-shot or iterative combinatorial auctions?
  - In an iterative auction, what information should be made available to bidders from round to round?
- What is the objective of the auctioneer?
  - Sell all items
  - Maximise revenue
  - Minimise number of buyers

Combinatorial auctions: Advantages

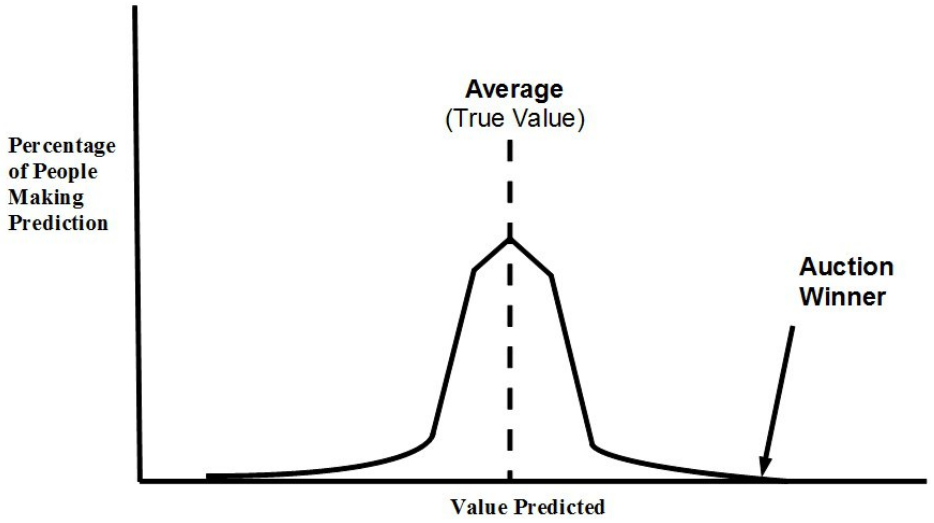
- Flexibility, as protocols can be tailor-made
- Less time-consuming and expensive than negotiating a price
- Simplicity in determining the market prices

Disadvantages of auctions

- Winner's curse
- Lying auctioneer
- Sniping
- Others: rings, revelation of private information, …

Disadvantages of auctions - Winner's curse

- What bidders suffer when they win an auction by overestimating how much something is worth and therefore bidding too much – the most optimistic bidder wins
- *A win may actually mean a loss …*



Disadvantages of auctions – Facing the winner's curse

- Anticipate the effects of the winner's curse before bidding:
  - Assume that you have the highest estimate
  - Rational bidding: correct downwards
- Any piece of information is useful to the bidder – beware of rings!!!
  - How aggressively others bid
  - How many remain in the bidding
  - When others apparently drop off the bidding

Disadvantages of auctions – Lying auctioneer

- In the Vickrey auction, the auctioneer may overstate the second-highest bid
  - Solution: use of cryptographic electronic signatures
  - It cannot happen in the other 3 protocols
- In English auctions: shills
- In sealed-bid auctions: Auctioneer may place a bid himself (reservation price)

Disadvantages of auctions – Sniping

- Sniping: bidding very late in the auction in the hope that other bidders do not have time to respond and you can snatch a bargain. This is an issue, in particular in online auctions
- Bidders may bid late in order to avoid:
  - Increasing the price of the item early on in the auction
  - Revealing their preferences early in the auction (especially experts)
  - Bidding wars with other like-minded agents

Disadvantages of auctions – Sniping

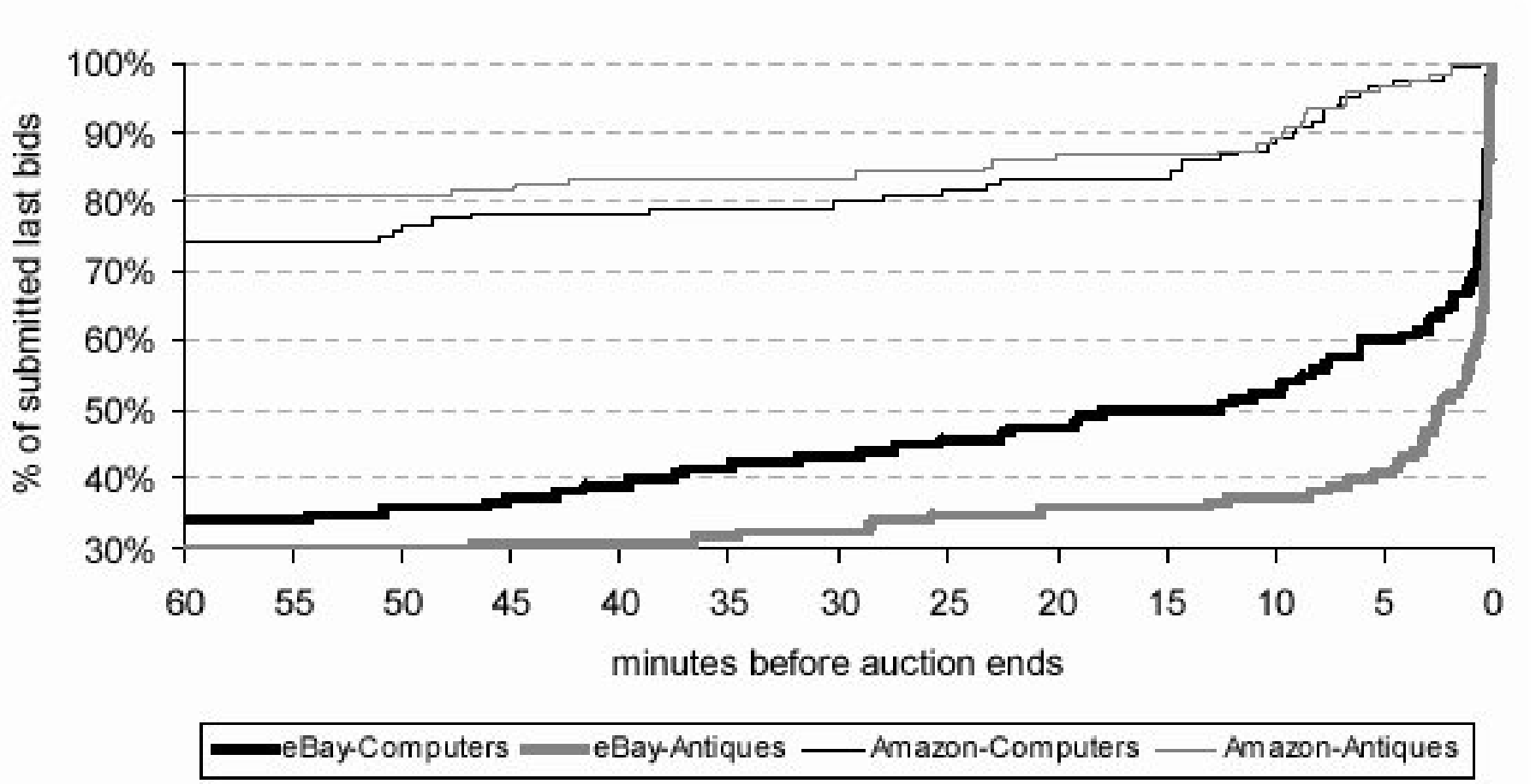


Figure 1b–Cumulative distributions over time of auctions' last bids

Proposed readings

- Chapter 8 in M.Fasli's book (*Agent technology for e-commerce*)
- Chapter 14 in M.Wooldridge's book (*An Introduction to MultiAgent Systems*), 2nd edition