

## Tutorial Outline

1. Introduction to automatic negotiations
2. Bilateral bargaining
3. Auctions
4. Auction platforms
5. References

M. Fasli, N. Gatti, EASSS 2009

Tutorial on

## “*Agent-based negotiations and auctions*”

Prof. Maria Fasli – [mfasli@essex.ac.uk](mailto:mfasli@essex.ac.uk)

School of Computer Science and Electronic Engineering, University of Essex, Colchester, United Kingdom

Prof. Nicola Gatti – [ngatti@elet.polimi.it](mailto:ngatti@elet.polimi.it)

Dipartimento di Elettronica e Informazione, Politecnico di Milano, Milano, Italy

M. Fasli, N. Gatti, EASSS 2009

## Negotiations

- **What are negotiations:**
  - Negotiation is a **process of communication** whereby two or more parties, each with its own viewpoint and objectives, **attempt to reach a mutually satisfactory result** on a matter of common concern
- **Why are mutually satisfactory results needed:**
  - Otherwise one party at least does not take part to the negotiation
- **What is the peculiarity of a negotiation:**
  - Parties' viewpoint and objectives are **in conflict**
- **What is the object of a negotiation:**
  - Essentially, the price of goods, services, etc.

M. Fasli, N. Gatti, EASSS 2009

## Part 1

## Introduction to Automatic Negotiations

M. Fasli, N. Gatti, EASSS 2009

## Negotiation Models

- A negotiation is essentially a **strategic interaction situation** and is modelled as a **strategic game** [Kraus, 2000]
  - **Negotiation protocol:** sets the **rules** of the dispute
    - Actions available to the agents (e.g., make an offer, accept, etc.)
    - Sequence of the interaction (e.g., agents act concurrently or in alternating fashion)
  - **Agents' strategies:** define the **behaviour** of each agent
    - Actions to be employed by each agent at each single decision node
- Furthermore, as is in a game:
  - **Agents' preferences:** each agent has preferences over all the possible negotiation outcomes
  - **Agents' knowledge:** agents' preferences can be known by the others or can be uncertain or can be unknown
  - **Agents' rationality:** each agent act in order to maximize its expected payoff relying on its knowledge

## A Simple Protocol Example

- **Agents:**
  - One seller
  - Many buyers
- **Allowed actions:**
  - Seller: "**open**", "**close**"
  - Buyer: "**offer**"
- **Payoffs:** utility functions, e.g.,  $U = RP - price$
- **Interaction sequence:** any buyer can act at  $t$
- **Information:** private other agents' preferences ( $RP$ )

## Protocol Characteristics [Kraus, 2000]

- **Distribution:** the decision making process should be distributed
- **Negotiation time:** negotiations that end without delay are preferable to negotiations that are time-consuming
- **Efficiency:** the efficiency of the agreement increases the number of agents that will be satisfied by the negotiation result
- **Simplicity:** negotiation processes that are simple and efficient are preferable to complex processes
- **Stability:** a set of negotiation strategies is stable if, given that all the other agents are following their strategies, it is beneficial to an agent to follow its strategy too; protocols with stable strategies are preferable
- **Money transfer:** side payments can be required from or provided to agents to resolve the conflicts; protocols without money transfer are preferable

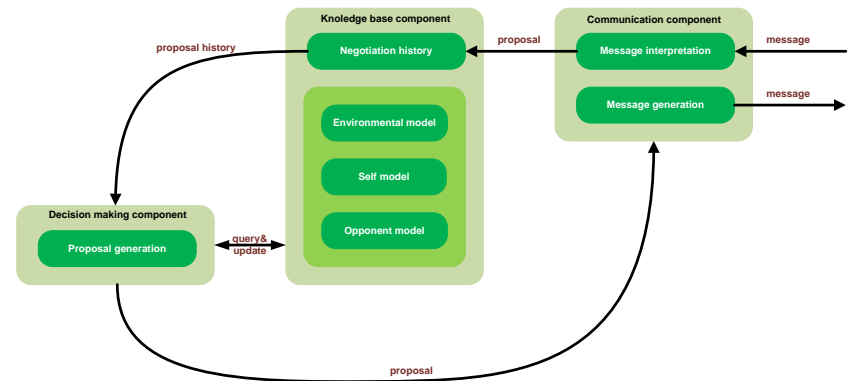
## Protocol Classification

- **Number of attributes:**
  - One (e.g., price)
  - Many (e.g., price and response time)
- **Number of agents:**
  - One-to-one (e.g., bilateral bargaining)
  - One-to-many (e.g., multilateral bargaining and auctions)
  - Many-to-many (e.g., auctions)
- **Number of units:**
  - One
  - Many

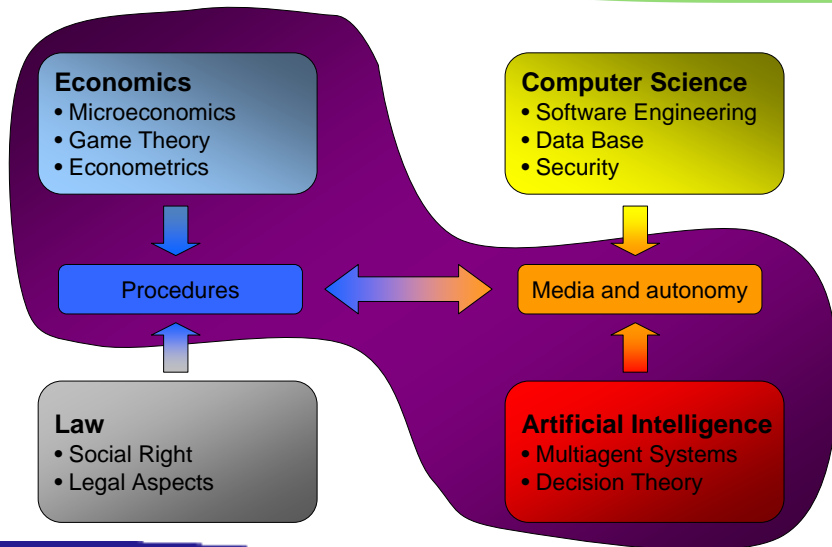
# Automatic Negotiations

- **What are automatic negotiations:**
  - Electronic negotiations in which **intelligent self-interested software** agents **negotiate** with other agents **on behalf of users** for buying or selling services and goods [Sandholm, 2000]
- **Why do we need to develop automatic negotiations:**
  - Increasing efficiency by saving resources
    - **Human work:** the agents act on behalf of the man
    - **Time:** the agents are faster than man
    - **Money:** market competition is higher
- **What are the application domains:**
  - eCommerce (electronic markets)
  - Resource allocation

# Agent Abstract Architecture [Fasli, 2007]



# Involved Areas



# Part 2 Bilateral Bargaining

## The Bargaining Problem [Nash, 1950]

- Bargaining is a socioeconomic problem involving **two parties**, who can **cooperate** towards the creation of a commonly desirable **surplus**, over whose **distribution** both parties are in **conflict**
- **Example:** two agents divide a pie
  - Each player prefers to reach an agreement, rather than abstain from doing so (disagreement)
  - Each agent prefers that agreement which most favors her interests (the largest piece of pie)



## Bargaining in Economic Domains

- **Bilateral exchange situation:**
  - A buyer that wants to buy an item
  - A seller that wants to sell an item
  - They negotiate over the price  $p$
- **Agents' utility function:**
  - Buyer agent:  $U_b(p) = RP_b - p$   
 $U_b(\text{Disagreement}) = 0$
  - Seller agent:  $U_s(p) = p - RP_s$   
 $U_s(\text{Disagreement}) = 0$
  - The surplus to be divided is:  $RP_b - RP_s$
- **The bargaining problem:**
  - What is the optimal price?

## Cooperative vs Non-Cooperative Bargaining Models

- **Cooperative approaches:**
  - Cooperative solutions attempt a prediction of what agreement two agents can be expected to reach in an **unspecified negotiation process**
  - They state **assumptions** on the **expected agreement** and find the agreement that satisfies the assumptions
  - **Examples:** Nash Bargaining solution [Nash, 1950], Kalai-Smorodinsky solution, Kalai solution, egalitarian solution, utilitarian solution
- **Non-cooperative approaches:**
  - Non-cooperative models consider bargaining as a **fully specified game**
  - **Example:** Rubinstein's alternating-offers protocol [Rubinstein, 1982]

## Nash Bargaining Solution (1)

- **Nash's axioms**
  - **Individual rationality (IR):** the optimal agreement  $\mathbf{a}$  must be such that  $U_b(\mathbf{a}) \geq 0$  and  $U_s(\mathbf{a}) \geq 0$
  - **Pare efficiency (PAR):** the optimal agreement  $\mathbf{a}$  must be Pareto efficient for the agents
  - **Invariance to equivalent utility representations (INV):** it satisfies affine transformations
  - **Independence of irrelevant alternatives (IIA):** removed all the non-optimal agreements, the optimal agreement holds to be
  - **Symmetry (SYM):** if the agents have the same preferences, then the agreement  $\mathbf{a}$  must give the same utilities to them



# Protocol Enrichments in Computer Science

- Agents' preferences:
  - Multiplicity of Issues
    - The evaluation of each item takes into account several attributes  $x^i$
    - Each offer is defined on all the attributes of the item, being a tuple  $\mathbf{x} = \langle x^1, \dots, x^m \rangle$
  - Reservation Values ( $RV_j$ )
    - $RV_b^j$ : the maximum value of attribute  $j$  at which the agent  $b$  will buy the item
    - $RV_s^j$ : the minimum value of attribute  $j$  at which the agent  $s$  will sell the item
  - Deadlines ( $T_j$ ): The time after which agent  $i$  has not convenience to negotiate any more
- Agents' actions:
  - Exit Option: Agent can make **exit** at any time point it plays

# Revised Alternating-Offers Protocol

- Players
 
$$\begin{cases} b & (\text{buyer}) \\ s & (\text{seller}) \end{cases}$$
- Player function
 
$$\begin{cases} t(0) = i \\ t(t) \neq t(t-1) \end{cases}$$
- Actions
 
$$\begin{cases} offer(x) \\ accept \\ exit \end{cases}$$
- Preferences
 
$$U_b(\text{NoAgreement}) = U_s(\text{NoAgreement}) = 0$$

$$U_b(\mathbf{x}, t) = \begin{cases} \sum_{i=1}^M (RV_b^i - x^i) \cdot (\delta_b^i)^t & t \leq T_b \\ -1 & t > T_b \end{cases}$$

$$U_s(\mathbf{x}, t) = \begin{cases} \sum_{i=1}^M (x^i - RV_s^i) \cdot (\delta_s^i)^t & t \leq T_s \\ -1 & t > T_s \end{cases}$$

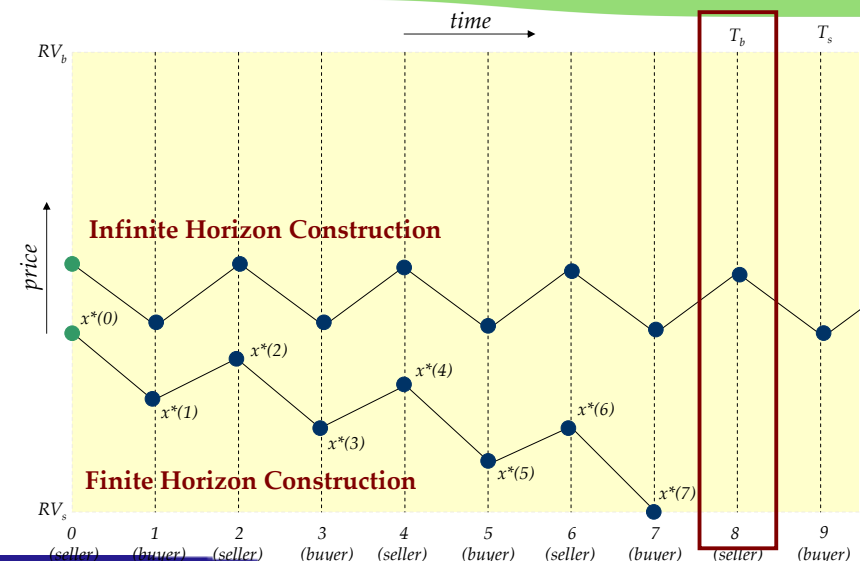
# Solution with One Issue and Complete Information

- By backward induction
  - The game is not rigorously a finite horizon game
  - However, no rational agent will play after its deadline
  - Therefore, there is a time point from which we can build backward
  - We call it the **deadline of the bargaining**, i.e.  $T = \min\{T_b, T_s\}$
  - The agents' optimal offers are function of time  $t$ , we call  $x^*(t)$
  - $x^*(t)$  is such that  $x^*(T-1) = RV_{i(T)}$  and  $U_{i(t+1)}(x^*(t), t) = U_{i(t+1)}(x^*(t+1), t+1)$

$$\sigma_b(t) = \begin{cases} accept & \text{if } \sigma_s(t-1) = offer(x) \text{ with } x \leq x^*(t-1) \\ offer(x^*(t)) & t < T_b \\ exit & t \geq T_b \\ \end{cases} \text{ otherwise}$$

$$\sigma_s(t) = \begin{cases} accept & \text{if } \sigma_b(t-1) = offer(x) \text{ with } x \geq x^*(t-1) \\ offer(x^*(t)) & t < T_s \\ exit & t \geq T_s \\ \end{cases} \text{ otherwise}$$

# A Graphical View



## Significant Results in Literature (1)

- **Multi-issue bargaining:**
  - With complete information the problem of bargaining with multiple issue can be cast in the problem of bargaining one issue in time polynomial in the number of issues [Di Giunta *et al.*, 2006], [Fatima *et al.*, 2006]
- **Bargaining with uncertainty:**
  - In presence of uncertainty the bargaining game is a imperfect information extensive-form game and the appropriate solution concept is the **sequential equilibrium** of **Kreps and Wilson**
  - Examples of bargaining with uncertain information are [Gatti *et al.*, 2008a], [Rubinstein, 1985], [Sandholm *et al.*, 1999]
- **Bargaining in markets:**
  - Within markets, buyers are in **competition** over the purchase of an item and sellers over the sale of an item
  - Refinements of the bargaining protocol are considered to capture this competition [Serrano, 2008], [Gatti *et al.*, 2008b]
- **Learning in bargaining:**
  - Learning is an interesting and promising technique to address negotiation, specially when agents are not perfectly rational
  - An example of the employment of learning techniques in bargaining is [Lazaric *et al.*, 20078]

M. Fasli, N. Gatti, EASSS 2009

## Significant Results in Literature (2)

- **Bargaining with bounded rationality:**
  - Agents can follow predefined tactics, not searching for their optimal actions
  - Examples are [Binmore, 2007], [Faratin *et al.*, 1998], [Fatima *et al.*, 2002], [Fatima *et al.*, 2004]
- **Evolutionary models of bargaining:**
  - Bargaining is studied as an evolutionary process by employing evolutionary game theory tools
  - Examples are [Binmore, 2007], [Napel, 2004]

M. Fasli, N. Gatti, EASSS 2009

## Part 3 Auctions

M. Fasli, N. Gatti, EASSS 2009

## Introduction to Auctions [Vidal, 2007]

- Auctions ask and answer the most fundamental questions in economics: **who should get the goods and at what prices?** [Cramton *et al.*, 2006]
- Auctions provide the micro-foundation of markets
- Typically,
  - **An auctioneer:**
    - A seller who wants to sell goods
    - A buyer who wants to buy a good
  - **The bidders:**
    - Buyers who want to acquire goods
    - Sellers who want to sell their goods
- The agents are **self-interested** and **rational**: they play in the attempt to maximize their own payoffs
- The reservation prices are **private** information

M. Fasli, N. Gatti, EASSS 2009

## Terms

<b>Bid</b>	Bids are offered by bidders to buy or sell the auctioned item
<b>Buy bid</b>	The price that a bidder is willing to pay to own an item
<b>Sell bid</b>	The price that a bidder is willing to accept to sell an item
<b>Reservation price</b>	The maximum (minimum) price that a buyer (seller) is willing to pay (accept) for an item
<b>Process bid</b>	The auctioneer checks the validity of a bid according to the rules of the auction protocol
<b>Price quote generation</b>	The auction house via the auctioneer or by other means may provide information about the status of the bids
<b>Bid quote</b>	The amount a seller would have to offer to sell an item
<b>Ask quote</b>	The amount a buyer would have to offer to buy an item
<b>Clearance</b>	Through clearance buyers and sellers are matched and the transaction price is set
<b>Clearing price</b>	The final transaction price that the buyer pays and the seller receives

M. Fasli, N. Gatti, EASSS 2009

## Classification of Auctions [Fasli, 2007] (1)

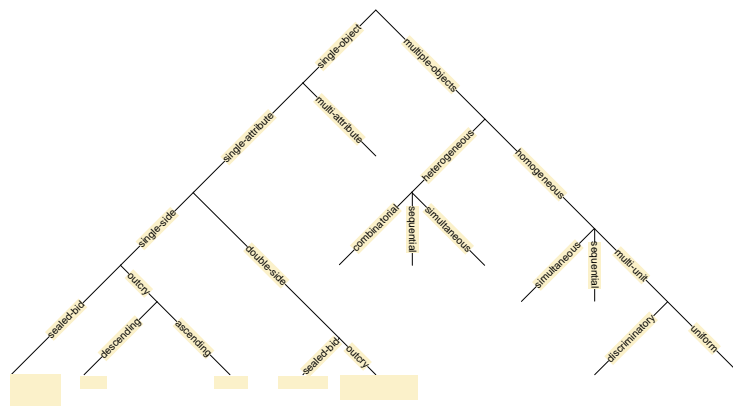
- **Three dimensions:** bidding rules, information revelation policy, and clearing policy

### 1. Bidding rules:

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

M. Fasli, N. Gatti, EASSS 2009

## Classification of Auctions [Fasli, 2007] (2)



M. Fasli, N. Gatti, EASSS 2009

## Classification of Auctions [Fasli, 2007] (3)

### 2. Information revelation policy:

- When to reveal information: on each bid, at predetermined points in time, on inactivity, on market clears
- 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

### 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 prices: first, second price or other

M. Fasli, N. Gatti, EASSS 2009

## Auctions and Mechanism Design

- Each auction is essentially a mechanism
  - A **mechanism** (from mechanism design) is an implementation of **social function**
  - Given the preferences of all the participants and a social function, the mechanism chooses the winner
- Exactly as in mechanism design, the maximum efficiency is when agents are **truth-revealing**
  - Agents are truth-revealing when the mechanism is incentive-compatible
- The aim is the design of auction mechanism that be **incentive-compatible**

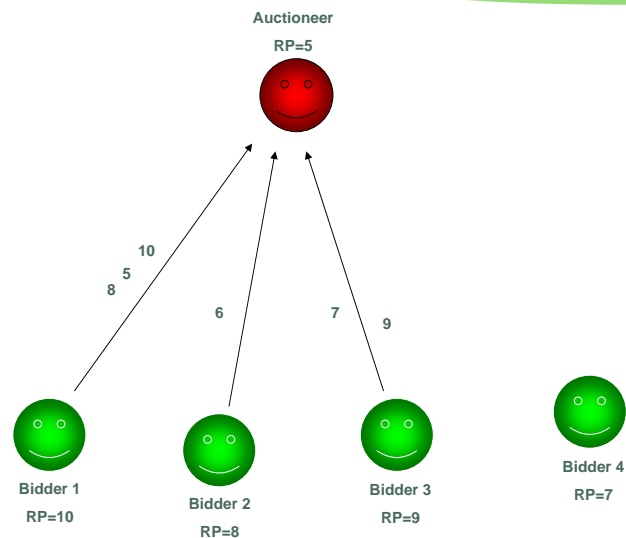
M. Fasli, N. Gatti, EASSS 2009

## English Auction (1)

- **Protocol (open-outcry ascending-price):**
  - The auctioneer announces an opening 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
- **Dominant strategy:**
  - It is to bid a small amount above the previous high bid until one reaches its private value and then stop

M. Fasli, N. Gatti, EASSS 2009

## English Auction (2)



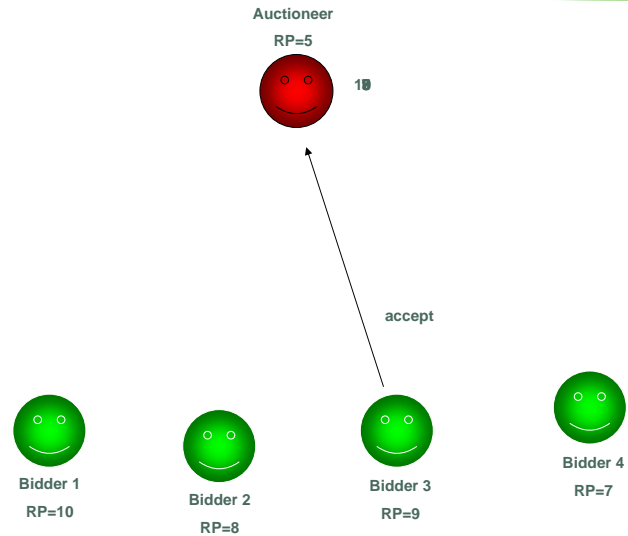
M. Fasli, N. Gatti, EASSS 2009

## Dutch Auction (1)

- **Protocol (open-outcry descending-price):**
  - The auctioneer announces a very high opening bid
  - The auctioneer keeps lowering the price until a bidder accepts it
  - The first bidder that accepts is the winner of the auction
- **Dominant strategy:**
  - No dominant strategy there is
  - Each agent acts on the basis of its prior

M. Fasli, N. Gatti, EASSS 2009

## English Auction (2)



M. Fasli, N. Gatti, EASSS 2009

## Dutch Auction (3)

### • Properties:

- The non-existence of the dominant strategy introduces inefficiencies in the solution
- Real-time efficient: the auction closes really fast and the auctioneer can make it move even faster by lowering the price faster
- It used in The Netherlands for selling fresh flowers

M. Fasli, N. Gatti, EASSS 2009

## First-Price Sealed-Bid Auction (1)

### • Protocol (sealed-bid):

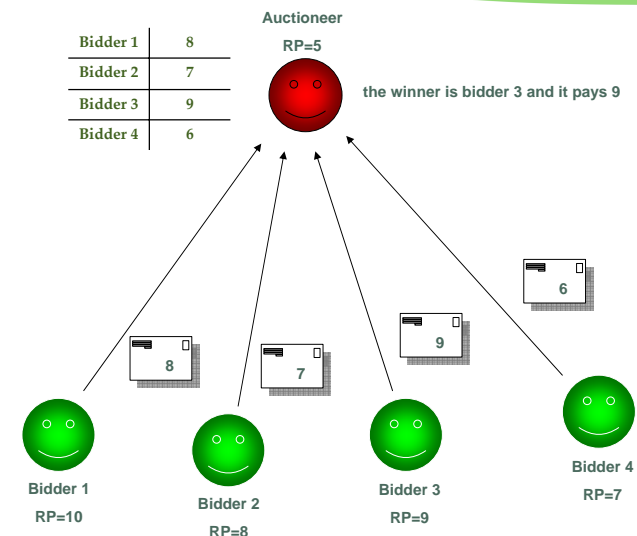
- Each bidder submits its own bid without knowledge of the bids of the other bidders
- The bids are opened and the winner is determined
- The highest bidder wins and pays the amount it bids

### • Dominant strategy:

- No dominant strategy there is
- Each agent acts on the basis of its prior

M. Fasli, N. Gatti, EASSS 2009

## First-Price Sealed-Bid Auction (2)



M. Fasli, N. Gatti, EASSS 2009

## First-Price Sealed-Bid Auction (3)

- **Properties:**

- The non-existence of the dominant strategy introduces inefficiencies in the solution

## Second-Price Sealed-Bid Auction – Vickrey (1)

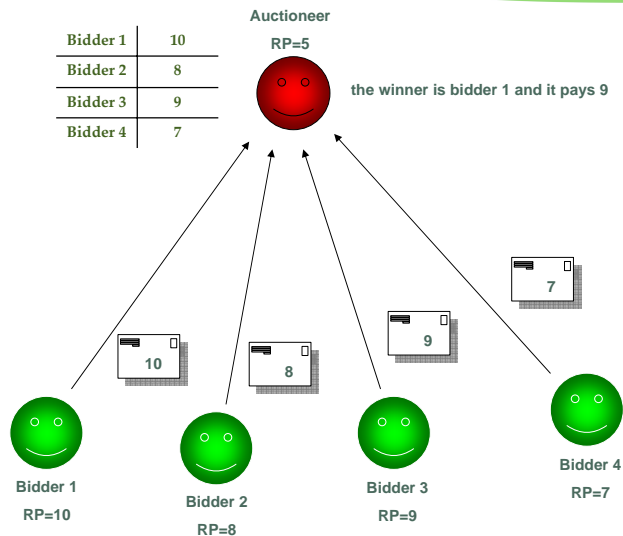
- **Protocol (sealed-bid):**

- Each bidder submits its own bid without knowledge of the bids of the other bidders
- The bids are opened and the winner is determined
- The highest bidder wins and pays the amount of the second-highest bid

- **Dominant strategy:**

- The dominant strategy of an agent is to bid its reservation price

## Second-Price Sealed-Bid Auction – Vickrey (2)



## Second-Price Sealed-Bid Auction – Vickrey (3)

- **Proof of truth-reveling** (it is similar to prove that a strategy is a Nash equilibrium):

- Suppose that bidder  $b_i$  bids  $x < v$  where  $v$  is its true valuation
  - Suppose that that the other highest bid is  $w < v$ 
    - If  $x > w$ , then  $b_i$  wins and pays  $w$ , therefore  $b_i$  does not gain more by bidding  $x$  rather than  $v$
    - If  $w > x$ , then  $b_i$  loses and gains 0, therefore  $b_i$  gains lesser by bidding  $x$  rather than  $v$
  - When the other highest bid is  $w > v$ ,  $b_i$  cannot gain more by bidding  $x$
- Suppose  $x > v$ 
  - Suppose that that the other highest bid is  $w < v$ 
    - If  $x > w$ , then  $b_i$  wins and pays  $w$ , therefore  $b_i$  does not gain more by bidding  $x$  rather than  $v$
    - If  $w > x$ , then  $b_i$  loses and gains 0, therefore  $b_i$  gains lesser by bidding  $x$  rather than  $v$
  - When the other highest bid is  $w > v$ ,  $b_i$  cannot gain more by bidding  $x$

## Auction Properties

- An auction is **incentive compatible** if **truth-revelation** is a dominant strategy for the agents
- An auction is **individually rational** if its allocation does not make any agent worse off than had the agent not participated
- An allocation of goods is **efficient** if there can be no more gains from trade
  - No mechanism is individually rational, efficient and incentive compatible for both sellers and buyers

## Strategic Equivalence of Dutch and FPSB

- The “strategy space” is the same in the Dutch and FPSB auctions, hence they are said “**strategically equivalent**”
- Since these auction mechanisms do not admit any dominant strategy, we resort to **Bayes-Nash**
- We assume that agents be risk neutral and that their valuations are drawn uniformly from  $[0,1]$
- We assume that the information is common
- The **equilibrium strategy** of each bidder  $b_i$  is to bid exactly  $(N-1/N) \cdot v_{b_i}$  where  $N$  is the number of bidders

## Revenue Equivalence Theorem

- **Theorem:** Assume that each of  $n$  **risk-neutral** agents has a cumulative distribution  $F(v)$  that is strictly increasing and atomless on  $[0,1]$ . Then any auction mechanism in which:
  - the good will be allocated to the agent with valuation 1, and
  - any agent with valuation 0 has an expected utility of 0,yields the **same expected revenue**, and hence results in any bidder with valuation  $v$  making the same expected payment
- The theorem shows that in presence of a Bayesian prior **all the auctions mechanism are equivalent** for the auctioneer

## Auction Advantages and Drawbacks

- **Advantages:**
  - Flexibility, as protocols can be tailor-made
  - Less time-consuming and expensive than negotiating a price, e.g. in bargaining
  - Simplicity in determining the market prices
- **Drawbacks:**
  - Collusion
  - Lying auctioneer

## Collusion (1)

- Bidders can collude and form an auction ring
- In order for rings to be successful, agreement has to be **self-enforcing**
- In the **Dutch** auction and the **first-price sealed-bid** auction the collusion agreement is **not self-enforcing**:
  - Bidders decide what is the designated “winner”
  - This bidder make a bid equal to the seller’s reservation price
  - All the other ring members are asked to refrain from bidding
  - However, each of the ring members can gain by placing a slightly higher bid in violation of the ring agreement
  - Therefore agreement is not self-enforcing

## Collusion (2)

- In the **English** auction and in the **Vickrey** auction the collusion agreement is **self-enforcing**:
  - Bidders decide what is the designated “winner”
  - This bidder make a bid equal to its reservation price
  - All the other ring members are asked to refrain from bidding
  - None can gain from breaching the agreement, because none will ever exceed the designated bidder’s limit
  - Therefore agreement is self-enforcing

## Collusion (3)

- Consider a setting wherein there are two bidders  $b_1$  and  $b_2$  with  $v_1=100$  and  $v_2=50$ , and with agreement **40**
- In the **English** auction:
  - $b_1$  can observe  $b_2$ 's bids, if  $b_2$  decides to bid more than the agreed 40,  $b_1$  can observe this and adjust its bid
  - Therefore,  $b_2$ 's optimal strategy is to bid no more than **40**
- In the **Vickrey** auction:
  - $b_1$  submits its reservation price (**100**) while  $b_2$  submits **40**
  - $b_2$ 's utility cannot increase if its bid exceeds the agreed price **40**

## Lying Auctioneer

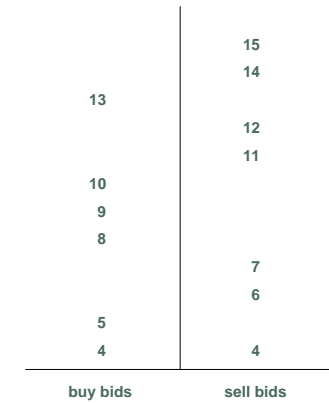
- Overstate reservation price
- Phantom bidders
- In the English auction: use of shills that constantly raise the bids
- In the Vickrey auction: the auctioneer may overstate the second highest bid to the winner in order to increase revenue

## Double Auctions (1)

- They capture the settings wherein there are **more buyers** and **more sellers**
- Each buyer and each seller make **one bid**
- The sellers' and buyers' bids are **ranked** highest to lowest
- **Two issues:**
  - What is the **clearing price**?
  - What are the **matchings** between buyers and sellers?

M. Fasli, N. Gatti, EASSS 2009

## Double Auction (2)



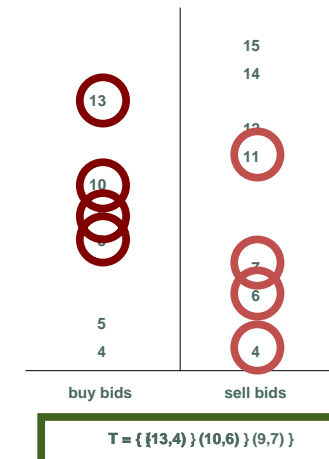
M. Fasli, N. Gatti, EASSS 2009

## Double Auction (3)

- **Matching:**
  - The **transaction set**: it is the set composed of the matched buyers and sellers, e.g.  $T = \{(4,4), (8,6), \dots\}$
  - The determination of  $T$  is tackled as follows:
    - $T$  is initialized as empty
    - While the highest remaining buy bid is greater than or equal to the lowest sell bid, remove these bids and add this pair of bids to  $T$

M. Fasli, N. Gatti, EASSS 2009

## Double Auction (4)



M. Fasli, N. Gatti, EASSS 2009

## Double Auction (5)

- **Matching:**
  - The **transaction set**: it is the set composed of the matched buyers and sellers, e.g.  $T = \{(4,4), (8,6), \dots\}$
  - The determination of  $T$  is tackled as follows:
    - $T$  is initialized as empty
    - While the highest remaining buy bid is greater than or equal to the lowest sell bid, remove these bids and add this pair of bids to  $T$
- **Clearing price:**
  - Set the clearing price equal to the  $M$ th highest bid ( $M$ th price rule), where  $M$  is the number of the sellers
  - Set the clearing price equal to the  $M$ th highest bid ( $M+1$ st price rule), where  $M$  is the number of the sellers

## Double Auction (6)

With  $T = \{(13,4), (10,6), (9,7)\}$

- **$M$ th price rule:**
  - Clearing price = **9**
  - (13,4): the buyer pays 9 and the seller receives 9
  - (10,6): the buyer pays 9 and the seller receives 9
  - (9,7): ...
- **$M+1$ st price rule:**
  - Clearing price = **8**
  - (13,4): the buyer pays 8 and the seller receives 8
  - (10,6): the buyer pays 8 and the seller receives 8
  - (9,7): ...

## Combinatorial Auctions (1)

- The most useful auction for multiagent systems is the combinatorial auction
  - **$M$  items** to sell/buy there are
  - Agents' preferences are complex, depending on the set of items they buy (sell)
  - Agents can place bids for sets of items
- **Example** (4 items and 2 bidders):
  - Items = {A, B, C, D}
  - Bidder 1's bids:
    - 1 for {A}
    - 2 for {B}
    - 1 for {C}
    - 4 for {A,B}
    - ...

## Combinatorial Auctions (2)

- Bidder 2's bids:
  - 2 for {A}
  - 2 for {B}
  - 1 for {C}
  - 5 for {A,B}
  - ...
- The largest number of bids for each bidder is  $2^M$
- A bidder may not bid over some possible sets of items
- **Example:**

Items	Bidder 1	Bidder 2
A, B, C, D	1 for {A}	2 for {B}
	2 for {B}	1 for {C,D}
	3 for {A,B}	3 for {A,C,D}
	4 for {A,B,C}	4 for {B,C,D}
	5 for {A,B,C,D}	6 for {A,B,C,D}

## Combinatorial Auctions (3)

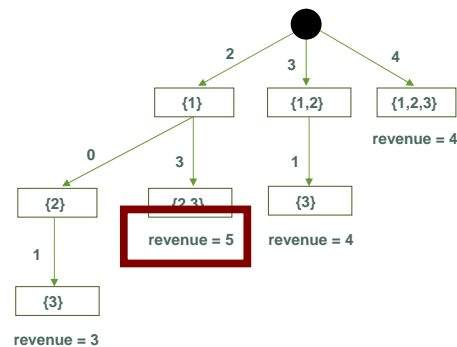
- The principal problem in a combinatorial auction is the determination of the **winning bids** in order to maximize the auctioneer's revenue
- The winner determination is **NP-hard** [Rothkopf *et al.*, 1998]
- If prices can be attached to single items** in the auction, the winner problem can be reduced to **linear programming problem** and, therefore, solved in polynomial time [Nisam, 2000]
- An approach is to conduct one of the standard **AI-search** over all possible allocations, given the bids submitted
- Two approaches:**
  - Branch-on-items** search tree
  - Branch-on-bids** search tree

## Branch-on-Items (1)

- If there is not any **singleton bid** on item, this is added with price zero
- All the children of the root are bids that have a 1 in them
- The children of every node will be all the bids that contain the smallest number is not on the path from the root to the node
- If the node is a leaf and the set of bids from root to leaf constitutes one possible working bid set
- Depth-first search** (non mandatory)

## Branch-on-Items (2)

{1}	2
{2}	0
<del>{1,2}</del>	3
{2,3}	3
<del>{1,2,3}</del>	4
{1,2,3}	4



## Significant Results in Literature

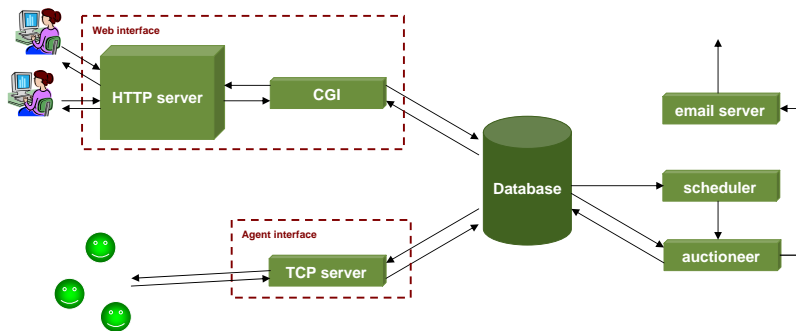
- In branch-on-items search**
  - [Fujishima *et al.*, 1999] has developed a branch and bound algorithm that reduces the space of search on the basis of heuristics
- A different search strategy:**
  - Branch-on-bids:** it produces a binary tree wherein each node is a bid and each edge represents whether or not that particular bid is in the solution [Sandholm, 2002]
  - [Sandholm *et al.*, 2003] shows that the branch-on-bids search is much more efficient than branch-on-items search

## Auction Design Problem

- **Auction design** problem is a **mechanism design** problem
- The problem is to design protocols that are:
  - Incentive compatible
  - Individually rational
- Moreover, the mechanism should be robust with respect to **collusions** (group deviation)

## Part 4 Auction Platforms

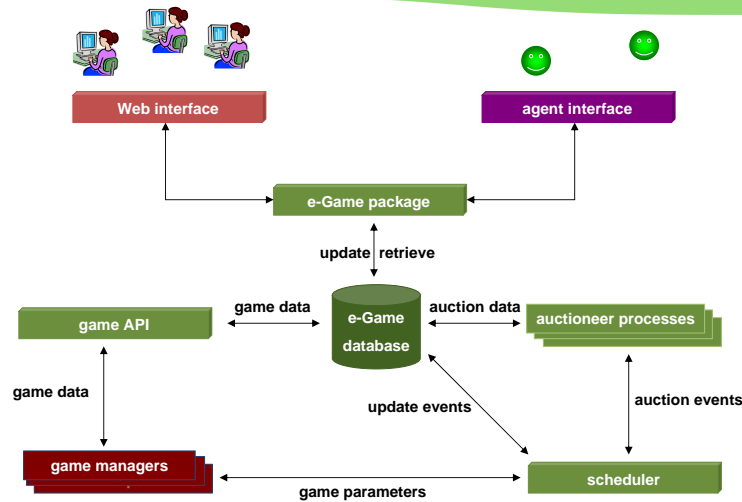
## AuctionBot Architecture [Wurman *et al.*, 1998]



## AuctionBot Description

- **Web interface**: interface for humans via web forms
- **TCP/IP intercafe**: interface for software agents
- **Database**: store the bids
- **Scheduler**: a daemon process that continuously monitors the database for auctions that have events to process or bids to verify
- **Auctioneer**: it loads the auction parameters and the set of current bids from the database
- **Bidding restrictions**:
  - **Participation**: {1 : many}, {many : 1}, {many : many}
  - **Bid rules**:
    - An agent's new bid must dominate its previous bid
    - The bids must be discrete

# e-Game Architecture [Fasli et al., 2007]



# e-Game Description [Fasli et al., 2007]

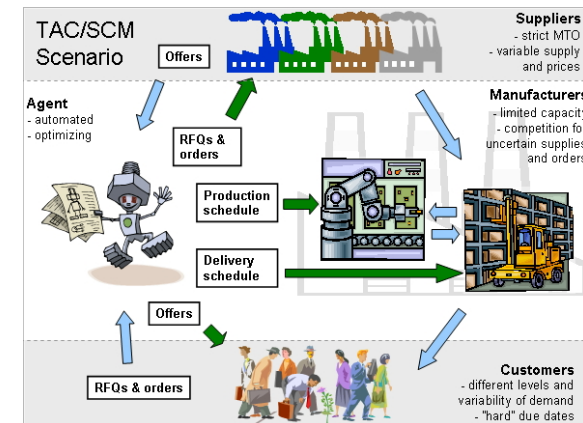
## Main features:

- Both human and artificial agents can access to
- It supports a range of auction protocols that can be parameterised
- More auction and other negotiation protocols can be developed
- It supports the development of market scenarios by third parties
- It is developed in Java

# Trading Agent Competition

- A **non-profit organization** that aims to promote research in market mechanisms and trading agents
- The effort was started in 2000
- Three **benchmark** problems have been created as testbeds to test one's approaches and strategies:
  - The travel agent game (**CLASSIC**) – no more in use
  - The supply chain management game (**SCM**)
    - It simulates a dynamic supply chain environment where agents compete to secure customer orders and components required for production of these orders
  - The market design game (**CAT**)
    - CAT software agents represent brokers whose goals are to attract potential buyers and sellers as customers, and then to match buyers with sellers

# TAC SCM



## TAC SCM Description (1)

- Six agents play in the game and start with no order from customers, no inventory, 0 back balance
- Agents do not know who the identity of the player they are playing against
- The objective is to maximize the profit through assembling PCs from different types of components and selling them at a profit to customers
- Highest bank balance wins
- 16 different types of PCs can be manufactured from 10 components which can be purchased from suppliers
- Factory capacity is limited

M. Fasli, N. Gatti, EASSS 2009

## TAC SCM Description (2)

- An agent needs to perform the following tasks every day D
  - Negotiate supply contracts with suppliers
    - Send RFQs to suppliers
    - Receive offers on the RFQs sent on D-1
    - Decide which offers to accept from the suppliers
  - Bid for customer orders
    - Receive RFQs from customers
    - Decide which of these to bid on and send offers
    - Receive confirmations to orders for those offers sent on D-1
  - Manage assembly line and delivery schedule

M. Fasli, N. Gatti, EASSS 2009

## References

M. Fasli, N. Gatti, EASSS 2009

## References on Negotiations

- [Fasli, 2007] *Agent technology for e-commerce*, M. Fasli, Wiley & Sons, 2007.
- [Jennings *et al.*, 2001] *Automated negotiation: prospects, methods and challenges*, N. R. Jennings, P. Faratin, A. R. Lomuscio, S. Parsons, C. Sierra, and M. Wooldridge, *International Journal of Group Decision and Negotiation*, 10(2): 199-215, 2001.
- [Kraus, 2000] *Strategic negotiation in multiagent environments*, S. Kraus, 2000, The MIT Press.
- [Lomuscio *et al.*, 2003] *A classification scheme for negotiation in electronic commerce*, A. Lomuscio, M. Wooldridge, and N. R. Jennings, *International Journal of Group Decision and Negotiation*, 12(1):31-56, 2003.
- [Maes *et al.*, 1999] *Agents that buy and sell*, P. Maes, R. H. Guttman, and A. G. Moukas, *Communications of the ACM*, 42(3):81-91, 1999.
- [Sandholm, 2000] *Agents in electronic commerce: component technologies for automated negotiation and coalition formation*, T. Sandholm, *Autonomous Agents and Multi-Agent Systems*, 3(1):73-96, 2000.
- [Raiffa, 1982] *The art and science of negotiation*, H. Raiffa, Harvard Univ Press, 1982.
- [Rosenschein *et al.*, 1994] *Rules of encounter. Designing conventions for automated negotiations among computers*, J. S. Rosenschein and G. Zlotkin, The MIT Press, 1994.
- [Sardinha *et al.*, ] *An agent Based architecture for highly competitive electronic markets*, J. A. R. P. Sardinha, R. L. Milidiú, P. M. Paranhos, P. M. Cunha, and C. J. P. de Lucena, FLAIRS, 2005.
- [Tewari *et al.*, 2000] *Design and implementation of an agent-based intermediary infrastructure for electronic markets*, G. Tewari and P. Maes, EC, 2000.

M. Fasli, N. Gatti, EASSS 2009

## References on Bargaining

- [Binmore, 2007] *Does Game Theory Work? The Bargaining Challenge*, K. Binmore, The MIT Press, 2007.
- [Di Giunta *et al.*, 2006] *Bargaining over multiple issues in finite horizon alternating-offers protocol*, F. Di Giunta and N. Gatti, *Annals of Mathematics in Artificial Intelligence*, 47(3-4):251-271, 2006.
- [Faratin *et al.*, 1998] *Negotiation decision functions for autonomous agents*, P. Faratin, C. Sierra, and N. R. Jennings, *Robotic Autonomous Systems*, 24(3-4):159-182, 1998.
- [Fatima *et al.*, 2002] *Multi-issue negotiation under time constraints*, S. S. Fatima, M. Wooldridge, and N. R. Jennings, *AAMAS*, 143-150, Bologna, Italy, 2002.
- [Fatima *et al.*, 2004] *An agenda-based framework for multi-issue negotiation*, S. S. Fatima, M. Wooldridge, and N. R. Jennings, *Artificial Intelligence*, 152(1):1-45, 2004.
- [Fatima *et al.*, 2006] *Multi-issue negotiation with deadlines*, S. S. Fatima, M. J. Wooldridge, and N. R. Jennings, *Journal of Artificial Intelligence Research*, 27(1):381-417, 2006.
- [Gatti *et al.*, 2008a] *Alternating-offers bargaining with one-sided uncertain deadlines: an efficient algorithm*, N. Gatti, F. Di Giunta, and S. Marino, *Artificial Intelligence*, in press, 2008.
- [Gatti *et al.*, 2008b] *Towards automated bargaining in electronic markets: a partially two-sided competition model*, N. Gatti, A. Lazaric, and M. Restelli, *AMEC*, in press, Lisboa, Portugal, May, 2008.
- [Lazaric *et al.*, 2007] *Reinforcement learning in extensive form games with incomplete information: the bargaining case study*, A. Lazaric, E. Munoz de Cote, N. Gatti, and M. Restelli, *AAMAS*, 216-218, Honolulu, USA, 2007.
- [Ma *et al.*, 1993] *Bargaining with deadlines and imperfect player control*, C. A. Ma and M. Manove, *Econometrica*, 61(6):1313-1339, 1993.
- [Napel, 2002] *Bilateral bargaining: theory and applications*, S. Napel, Springer, 2002.
- [Nash, 1950] *The bargaining problem*, J. Nash, *Econometrica* 18: 155-162, 1950.
- [Rubinstein, 1982] *Perfect equilibrium in a bargaining model*, A. Rubinstein, *Econometrica*, 50(1):97-109, 1982.
- [Rubinstein, 1985] *A bargaining model with incomplete information about time preferences*, A. Rubinstein, *Econometrica*, 53(5):1151-1172, 1985.
- [Sandholm *et al.*, 1999] *Bargaining with deadlines*, T. Sandholm and N. Vulkan, *AAAI*, 44-51, Orlando, USA, 1999.
- [Serrano, 2008] *Bargaining*, R. Serrano, *The New Palgrave Dictionary of Economics*, 2<sup>nd</sup> edition, McMillan, 2008.
- [Stahl, 1972] *Bargaining theory*, I. Stahl, *Stockholm School of Economics*, Stockholm, Sweden, 1972.

## References on Auctions

- [Cramton *et al.*, 2006] *Combinatorial auctions*, P. Cramton, Y. Shoam, R. Steinberg, The MIT Press, 2006.
- [Fasli *et al.*, 2007] *Designing and developing electronic market games*, M. Fasli and M. Michalakopoulos, Springer, 2007.
- [Fujishima *et al.*, 1999] *Taming the computational complexity of combinatorial auctions: optimal and approximate approaches*, Y. Fujishima, K. Layton-Brown, Y. Shoam, *IJCAI*, 548-553, 1999.
- [Nisam, 2000] *Bidding and allocation in combinatorial auctions*, N. Nisam, *EC*, 1-12, 2000.
- [Rothkopf *et al.*, 1998] *Computationally manageable combinatorial auctions*, M. H. Rothkopf, A. Pekec, R. M. Hasrstad, *Management Science*, 44(8):1131-1147, 1998.
- [Sandholm, 2002] *An algorithm for winner determination in combinatorial auctions*, T. Sandholm, *Artificial Intelligence*, 135(1-2):1-54, 2002.
- [Sandholm *et al.*, 2003] *BOB: improved winner determination in combinatorial auctions and generalizations*, T. Sandholm and S. Suri, *Artificial Intelligence*, 145, 33-58, 2003.
- [Vidal, 2007] *Fundamentals of Multiagent Systems*, J. Vidal, 2007.
- [Wurman *et al.*, 1998] *The Michigan Internet AuctionBot: a configurable auction server for human and software agents*, P. R. Wurman, M. P. Wellman, and W. E. Walsh, *AGENTS*, 1998.