Tutorial on "*Automatic Negotiations in Electronic Markets*"

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Tutorial Outline

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

Part 1
Introduction to Automatic Negotiations

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.

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

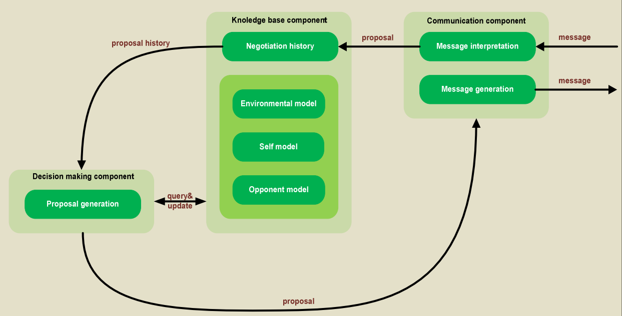
Protocol Classification

- **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

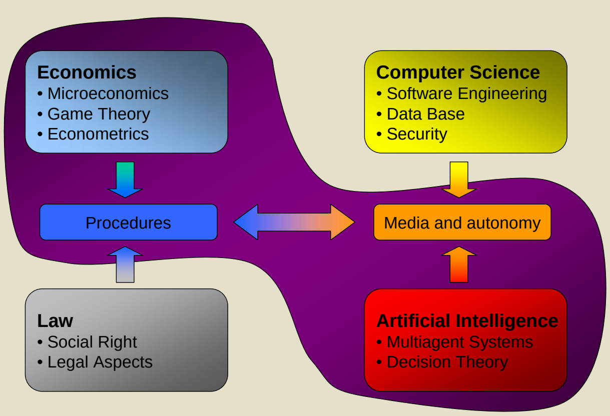
Automatic Negotiations

- **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]



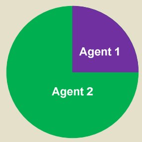
Involved Areas



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: $U_b(p) = RP_b - p$
    $U_b(Disagreement) = 0$
  - Seller agent: $U_s(p) = p - RP_s$
    $U_s(Disagreement) = 0$
  - 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]

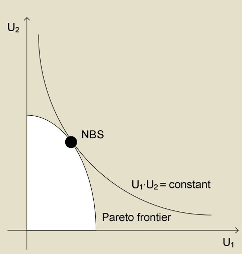
Nash Bargaining Solution (1)

- **Nash's axioms**
  - **Individual rationality** (**IR**): the optimal agreement a must be such that $U_b(a) \geq 0$ and $U_s(a) \geq 0$
  - **Pare efficiency** (**PAR**): the optimal agreement 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 a must gives the same utilities to them

Nash Bargaining Solution (2)

$NBS = arg\ max_a \{ U_b(a) \cdot U_s(a) \}$

(It is the tangency point between the Pareto frontier and a hyperbole of the form $U_b \cdot U_s = constant$)



Alternating-Offers Protocol [Rubinstein, 1982]

- **The informal model**
  - Two agents want to divide a pie of size 1
  - Opposite preferences with temporal discounting factors
  - Extensive form game wherein agents alternately act
  - Infinite horizon
- **The formal model**
  - **Players** $\begin{cases} 1 \\ 2 \end{cases}$
  - **Player function** $\begin{cases} \iota(0) = i \\ \iota(t) \neq \iota(t-1) \end{cases}$
  - **Actions** $\begin{cases} offer(x) \\ accept \end{cases}$
  - **Preferences** $U_1(x,t) = (1-x) \cdot (\delta_1)^t$
    $U_2(x,t) = x \cdot (\delta_2)^t$

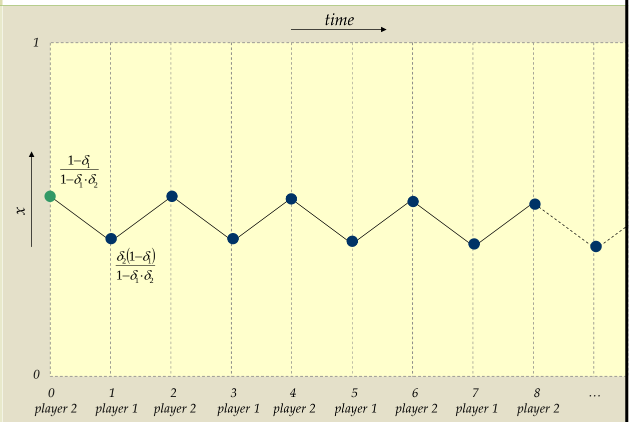
Equilibrium in Alternating-Offers Protocol

- **Subgame Perfect Equilibrium** [Selten, 1972]
  - It defines the equilibrium strategies of each **agent** in each possible **subgame**
  - Typically, addressed by employing **backward induction**, but not in this case since the horizon is infinite
- **Rubinstein Solution** [Rubinstein, 1982]

$$\sigma_1(t)=\begin{cases} accept & \text{if } \sigma_2(t-1)=offer(x) \text{ with } x\le \frac{1-\delta_1}{1-\delta_1\cdot\delta_2} \\ offer\left(\frac{\delta_2(1-\delta_1)}{1-\delta_1\cdot\delta_2}\right) & \text{otherwise} \end{cases}$$

$$\sigma_2(t)=\begin{cases} accept & \text{if } \sigma_1(t-1)=offer(x) \text{ with } x\ge \frac{\delta_2(1-\delta_1)}{1-\delta_1\cdot\delta_2} \\ offer\left(\frac{1-\delta_1}{1-\delta_1\cdot\delta_2}\right) & \text{otherwise} \end{cases}$$

A Graphical View



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 **x** = < x^1, …, x^m >
  - **Reservation Values** (RV_i^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_i): 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** $\begin{cases} b & (buyer) \\ s & (seller) \end{cases}$
- **Player function** $\begin{cases} \iota(0)=i \\ \iota(t)\neq\iota(t-1) \end{cases}$
- **Actions** $\begin{cases} offer(x) \\ accept \\ exit \end{cases}$
- **Preferences**

$$U_b(NoAgreement)=U_s(NoAgreement)=0$$

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

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

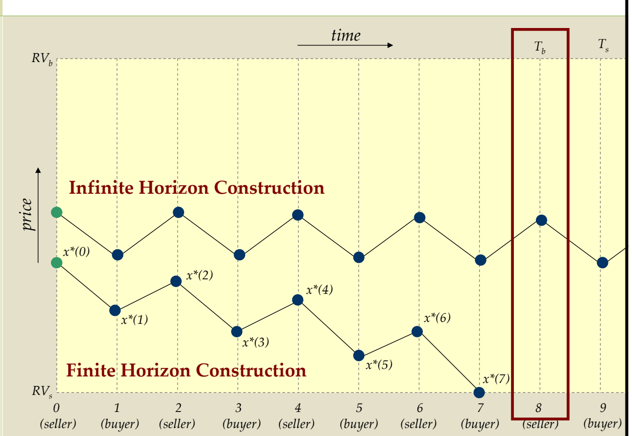
Solution with One Issue and Complete Information

- **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 $x^*(T-1)=RV_{\iota(T)}$ and $U_{\iota(t+1)}(x^*(t),t)=U_{\iota(t+1)}(x^*(t+1),t+1)$

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

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

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]

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]

Part 3
Auctions

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

Terms

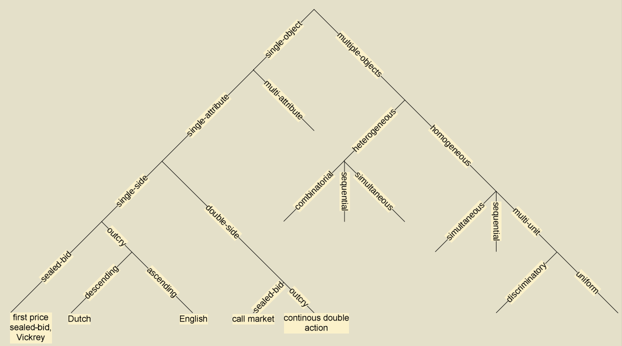
Bid	Bids are offered by bidders to buy or sell the auctioned item
Buy bid	The price that a bidder is willing to pay to own an item
Sell bid	The price that a bidder is willing to accept to sell an item
Reservation price	The maximum (minimum) price that a buyer (seller) is willing to pay (accept) for an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

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

Classification of Auctions [Fasli, 2007] (2)



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

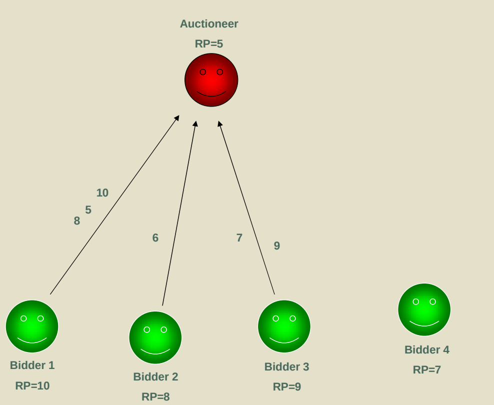
Auctions and Mechanism Design

- 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-revelling**
  - Agents are truth-revelling when the mechanism is incentive-compatible
- The aim is the design of auction mechanism that be **incentive-compatible**

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

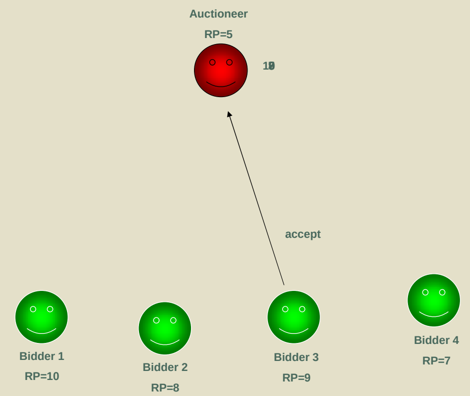
English Auction (2)



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

English Auction (2)



Dutch Auction (3)

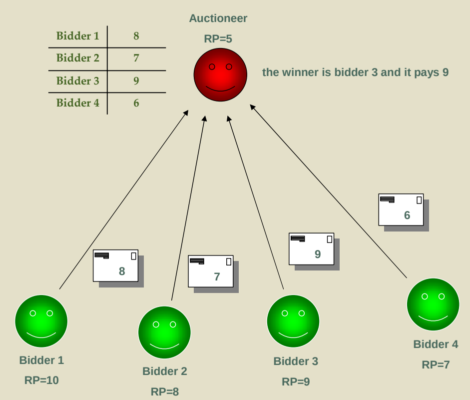
- **Properties**:
  - The non-existence of the dominant strategy introduces inefficiencies in the solution
  - Real-time efficient: the auction closes really fast and the auctioneer can make it move even faster by lowering the price faster
  - It used in The Netherlands for selling fresh flowers

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

First-Price Sealed-Bid Auction (2)

Bidder 1	8
Bidder 2	7
Bidder 3	9
Bidder 4	6



First-Price Sealed-Bid Auction (3)

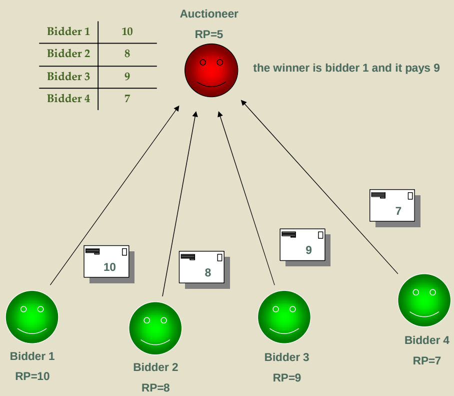
- **Properties**:
  - The non-existence of the dominant strategy introduces inefficiencies in the solution

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)

Bidder	RP
Bidder 1	10
Bidder 2	8
Bidder 3	9
Bidder 4	7



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 looses 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 looses 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** is 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,

  yealds 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***

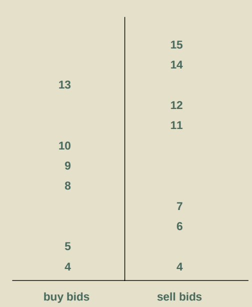
Lying Auctioneer

- 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?

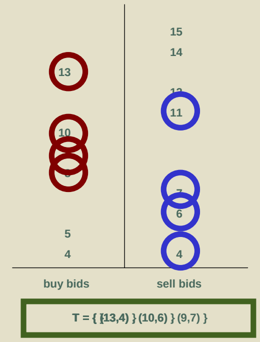
Double Auction (2)



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),…}***
  - The determination of ***T*** is tackled as follows:
    - ***T*** is initiliazed 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***

Double Auction (4)



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),…}***
  - The determination of ***T*** is tackled as follows:
    - ***T*** is initiliazed 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***+1st 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*+1st 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} 3 for {A,B} 4 for {A,B,C} 5 for {A,B,C,D}	2 for {B} 1 for {C,D} 3 for {A,C,D} 4 for {B,C,D} 6 for {A,B,C,D}

Combinatorial Auctions (3)

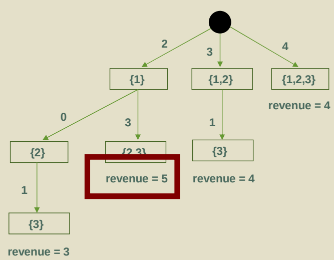
- The principal problem in a combinatorial auction is the determination of the **winning bids** in order to maximize the auctioneer's revue
- The winner determination is **NP-hard** [Rothkopf *et al.*, 1998]
- **If prices can be attached to single items** in the auction, the winner problem can be reduced 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 possibile working bid set
- **Depth-first search** (non mandatory)

Branch-on-Items (2)

{1}	2
{2} / {3}	0 / 1
{1,2} / {3}	3 / 1
{2,3} / {1,2}	3
{1,2,3} / {2,3}	4 / 3
{1,2,3}	4



Significant Results in Literature

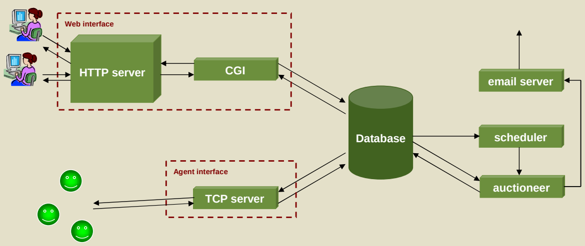
- **In branch-on-items search**
  - [Fujishima *et al.*, 1999] has developed a branch and bound algorithm that reduces the space of search on the basis of heuristics
- **A different search strategy**:
  - **Branch-on-bids**: it produces a binary tree wherein each node is a bid and each edge represents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

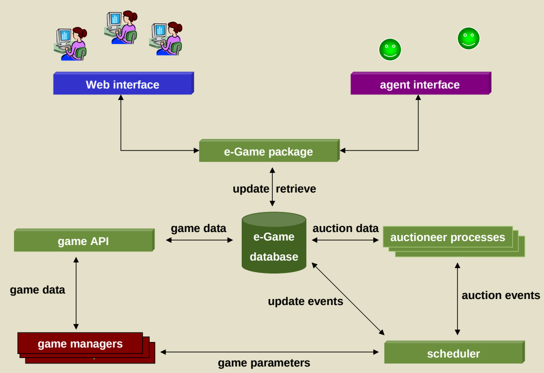
AuctionBot Architecture [Wurman *et al.*, 1998]



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]



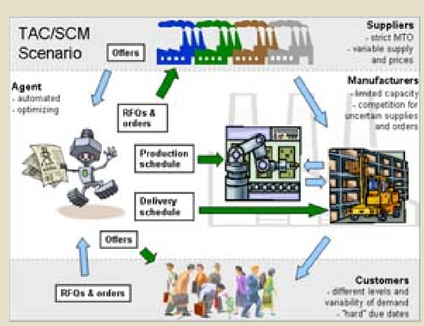
e-Game Description [Fasli *et al.*, 2007]

- 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 is 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 palyer they are playing against
- The objective is to maximize the profit through assembling PCs from different types of compoenents 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

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

References

References on Negotiations and Multi-Agent Systems

- [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.

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° 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.