A Classification of Auction Mechanism: Potentiality for Multi-Agent System (MAS) Based Modeling

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ABSTRACT

What are auctions and how are they applicable in Multi-agent systems (MAS). This study reviews the various auction mechanisms such as forward auctions, reverse auctions, and double auctions, along with the roots of the newer auctions that have been evolved over time. Subsequently, a classification of various auction mechanism are presented that will enable us to get a perspective on how auctions have evolved and thereby a better understanding on how to incorporate these mechanism into a MAS. Later, important auction properties are compared with the auction mechanism to get a better grasp of what a particular action might possess as strength and its related weakness. Auction mechanism have been applied in agent based modeling. This study illustrates the comprehensive set of current and emerging auctions mechanism that have the potentially to be tested through agent based modeling as well as serve as a basis for further development of Multi-agent systems.

INTRODUCTION

Auctions have been an important area of study for while. Some of the earlier work in traditional auctions can be found in Economic research [McAfee and McMillian, 1987, Milgrom, 1989]. With the importance to the study of auctions, there have been attempts to propose a theory of auctions too [Milgrom, 1982]. The differentiation between negotiations and auctions is that auctions have protocols that are enforced. This ensures transparency of the transaction and thereby lets the members of the auction feel that the process is not unfair [Pinker et al., 2003]. In the setting of intelligent agent study and Multi-agent systems (MAS), auctions provide coordination mechanisms for improved negotiation that can be emulated by agents. Therefore, this makes this an compelling area of research to incorporate agent based modeling.

There are several types of auction and literature is replete with auction studies. Most of the studies have looked at the auction mechanism from either the game theory perspective, the influence of internet and related technology and mechanism for single unit versus multiple unit auctions. There has been little to understand in entirety what are the auction and what are their relative advantages and how they all may relate to each other. A classification of various auction mechanism will enable us to get a perspective on how auctions have evolved and thereby a better understanding on how to incorporate these mechanism into MAS. The rest of this paper organized as follows. The next section discusses the auction properties that are considered desirable. This is followed by the discussion on the various auction mechanism and their adherence to the properties. That is, what are their relative advantages and weaknesses of each auction mechanism based on the desirable properties. Finally, we discuss, where agent based modeling has been used to overcome properties weaknesses in the auction mechanism and what are the potential areas of agent application.

AUCTION PROPERTIES

Before getting into the classification of auctions, we need to discuss several properties (goals) that are essential to a good auction mechanism. Several properties of auction mechanism have been suggested. However we follow Pekec and Rothkopf [2003]) suggestions on the properties. These are, the efficiency of allocation, profit maximization for the seller, reduction in transaction cost and fairness that encompasses minimization of collusion and fraud. They are discussed briefly below.

Allocation efficiency had been defined as the maximization of the values of an item to the auction winner participants. In other words, the object won by the winner from the pool of winners is understood to have been done in a way that is considered the most efficient way of allocating the resource (object). That is to say that the one who values the particular item, get to have it.

Revenue Maximization is another desirable property for an auction. Here, the objective is to generate maximum revenue for the seller. In case, the auction is simply of allocation of resources, such as governmental licenses, then the goal becomes to minimize costs.

Transaction cost is considered an important property for auctions. Here, the objective is to minimize transaction costs. Since there is a cost involved in participating in an auction for both the bidder and the seller, there is an inherent need to shrink costs. Related to this cost is the factor to time. Since faster the auction, the lesser will be the delays and this usually leads to reduced transaction cost.

Fairness is another important property. Under this main category there are several related issue. There are: equality of treatment to the bidders. In this, the bidders should be treated at par without any bias towards any one single bidder. Transparency is another important issue. When an auction is transparent, it ensure that the bidders are cognizant of the auction and its operating procedure. This leads to greater trust in the auction. Apart from these there are other issues such as collusion amongst the auctioneers and fraud by bidders. Reduction of fraud by bidders, has

become an increased property of many online auctions. Finally, there is an issue of auction failure, where the correct winner cannot be determined. All there properties if controlled, can ensure a fairer auction. This has a multiplier effect on the allocation efficiency.

AUCTION MECHANISMS

What is an auction. We follow the definition proposed by McAfee and McMillian [1987]), " An auction is an market institution, with an explicit set of rules determining resource allocation and prices on the basis of bids from the market participants." Traditionally, there have been four variants of auctions. These are, the English Auction, the Dutch Auction, First- Price Sealed bid and the Second Price Sealed Big. These are discussed in the following paragraphs.

English Auction

This auction is also referred to as first price open-cry auction. The mechanism of the auction is the most popular type. Essentially, the auction works by successively raising the price until, there is one last bidder, who then becomes the highest bidder. This auction has also been called as an ascending bid auction.

In terms of properties of an auction, this auction is skewed towards the auctioneer. There is some emphasis on allocation efficiency. However the greatest emphasis is on revenue maximization for the seller. There is little consideration for the buyer. Some of the downsides include the actual presence of bidders, collusion amongst bidders [Milgrom, 1989]) This escalates transaction costs and fairness. However, with the internet, this auction has become very popular and appears to be the dominant form of online auction. Since, the bidders do not have to be physically present and the bidding process is much quicker, there is lowering of transaction costs.

Dutch Auction

This auction is a reverse English auction. Also called a descending auction. The mechanism works by assigning a starting price and lower it, till a bidder is found. This auction was popularized by the Dutch Flower auction.

This auction has been modeled to support the notion of game theory. In this auction, there are trace amounts of support for allocation efficiency. The auction is usually favored for the seller but this is more dependent on the commodity being auctioned. Since the auction required the presence of bidders, there is cost involved and this increases the transaction costs. However, because of game theory, there is little support for collusion amongst bidders.

First Price Sealed Bid

In this form of auction, each bidder submits a bid without knowing, what the other bidders have bid. This type of auctions have primarily been popular in governmental auctions. They differ from English auction in the fact that the bidders are anonymous to each other. This forms of auction shares a bidder similarity with that of the ditch auction. This auction has also been

referred to as the discriminatory sealed bid auction [Harris, 1981]). The bidder's best choice always appears to be to select the highest price. This form of auction is slow and therefore has high transaction costs. On the other side, there is little evidence of fraud or collusion by bidders, since they are masked from each other.

Second Price Sealed Bid

This form was proposed by Vickery [1961]). The auction therefore has been referred to as the Vickrey auction. This auction has also been referred to as the competitive sealed bid auction [Harris, 1981]). Later on with some modification, the auction came to be know as the Generalized Vickrey Auction (GVA)[Varian, 1995]) and VCG (Vickers, Clark and Grover) auction. This follows the pattern of first Price Sealed Bid. In this type of auction, the highest bidder wins but has to pay the price of the second highest bidder. The logic to support is that no bidder should pay a value higher than theirs for the object that is being bid on. The auction supports efficient allocation of resources and is also considered truth revealing, since it encourages the bidders to place the bid close to the their true valuation of the object. However, it faces the criticisms of false-name bids and is often characterized by the "Winner's curse".

Newer Auction Mechanism

Over the years there have been several variants to these fundamental auctions that have been developed. Some of these have been put in practice and some have been proposed in literature. For the sale of clarity, we can classify auctions as forward and reverse. The traditional auctions mentioned so far form the basis of forward auctions. With the advent of the internet, the concept of reverse auction has come into prominence. We will discuss this in the latter paragraphs. Before we begin our discussion on the auctions variants, it's important to note that the influence of internet opened the doorways to these many variations. We first begin with the modification of the English auction, then the Vickrey auction, where most of the variants have been developed and proposed and then the double action. Figure 1, outlines the classification of these auction mechanism.

Yankee Auction

With the internet, it became possible to have an English open auction that could be escalated to a multi-unit format. In this scenario, multiple units of an item are sold to multiple bidders. Bidders have the choice of lumping together their bids for multiple units. Since there are multiple units, usually, the bids do not have to be greater than the previous bids. In sum, the Yankee auction allows an efficient multi bid that is progressive and discriminatory. The auction usually closes at a predetermined time. This is to encourage early participation by bidders. This auction supports the property of allocation efficiency. However, there is a trade off between the size of incremental bid and transaction efficiency. That is with smaller bid increments, it appears that the transactions costs increase inspite of larger revenues (Bapna et al., 2003). There is another danger of false bidding by participants that this mechanism cannot address.

Level Division Set (LDS)

This auction Protocol was developed in response to the types of auctions that are now pervasive on the internet, such as combinatorial auction. The classic Vickers-Clarks-Grovers (VCG) was found to be lacking in terms of being robust against false name bids. Therefore this, auction mechanism was proposed to over the weakness of the closed bid combinatorial auction that espoused the VCG auction.

The auction mechanism was proposed by Yokoo, et al (2001a). The auction mechanism works by creating levels of divisions. This set of leveled divisions are the all possible ways to dividing the items amongst the different bidders. Usually, the items get split into smaller groups as the levels increase. The auctioneer chooses the levels according to the declared value of the items by the bidders and then appliers the GVA within that level to determine the winning bidder.

Although this auction is able to lower the effects of false bidding and therefore, the effect of fraud, it suffers from greater probability of revenue loss to the auctioneer in case of items not sold. This usually happens if the reservation price and the leveled set are not accurately determined. However, there is little evidence of compromise of allocation efficiency and moreover, the transaction cost are reduced as a result of lowered communication and computational costs.

Leveled Partition Set (LPS)

This auction mechanism was developed primarily for the purpose of enhancing the aspect of security of online auctions. Again, this auction mechanism was proposed to overcome the lacunas found in the VCG auctions. This auction is a sealed bid multi-unit auction. This auction mechanism was proposed by Wang, et al (2001). It is considered a simplified version of the leveled division set protocol that deals with items that are identical. In this mechanism, each bidder declared a valuation for the items that depend on the quantum of the items that they would like to win. The auctioneer (seller) sets a reserve price (the minimum price) for a single item. This mechanism becomes simpler than LDs, since the items for auction are similar.

This auction gives similar results in terms of allocation efficiency, revenues to the seller and improved transaction costs along with fraud minimization. However, it's usefulness comes through only in combinatorial auctions where the items are similar.

Iterative Reducing

This protocol was developed in answer to the weakness of profits for the auctioneer as in the case of the Leveled Division Set protocol. The main emphasis of this mechanism it to automatically determine the bundles of items based on the declared evaluation of the bidders in a multi-unit setting (Yokoo et al., 2001b). Instead of determining all possible divisions of the units in advance, the divisions are determined sequentially from the larger divisions. In other words, the evaluation price by a bidder is checked against the reservation price for that set of units. If the reservation price is not found to be larger, then the units is a group are reduced by one. That is the iterative reduction.

This mechanism improves auction revenue for the auctioneer and the seller as well is able to tackle the issue of false name bids. However, there is little evidence how it performs in terms of transaction costs.

Trade Reduction

This mechanism is based on the VCG or the Vickery auction. The objective of this mechanism is to compensate for the lack of balanced budged that can be characterized by an Vickrey auction in a two way bidding in a supply chain. This auction mechanism is proposed to be incentive compatible, allows individual's rationality to be preserved and does not encourage loss of profits (Babaioff and Walsh, 2005). However, the mechanism suffers from loss of allocation efficiency because it of the uniqueness of it's applicability to the two way bidding in the supply chain process. This mechanism has been found in practice and is only been proposed in literature as a model. Fundamentally, the auction is a one shot, sealed bid auction.

Ausubel Auction

The Ausubel auction is a form of an open format auctions such as the Dutch and the English. The proliferation of open formats has primarily been in the ability of the auction participants to quickly learn the protocols. This way the Ausubel is easier for learning. The Ausubel auction is considered an open ascending price multi-unit auction (Ausubel, 2004). In this auction each bidder reveal their demand and the auctioneer announces its low price.

After aggregating the demand, the auctioneer increased the price until, all units of the items are allocated. The allocation to a bidder depends no on his/her individual demand but is a function of the demand of the other bidders (the clinching rule). The Ausubel action is supposed to yield the same outcome as that of the multi-unit Vickery auction but in an open format.

However, some of limitation of this auction is that it cannot take care of situation where a bidder needs all units or nothing (marginal value to the bidder). Secondly, the protocol is not robust against false-bidding by participants.

Ascending Price Option Allocation Protocol (AOP)

Since, in the case of Ausubel auctions, the bidders have a propensity to over or under declare and this is rectified in AOP by making the bidder pay uniform price for all the units they win. In addition, to prevent demand reduction that can occur from uniform pricing, the bidder is able to choose from multiple options. Therefore, in this auction a bidder does not instantly get awarded the units for the items rather, gets several options. These options guarantees that the bidder to buy certain quantities of the units at a certain price. In other words, the AOP (Iwasaki et al., 2005) is an ascending price auction much like the Ausubel auction. However, in this auction, the auctioneer announces a price and the bidders then give their demand for the units of items. After aggregating the demands of all bidders, the auctioneer raises the price until all the items are allocated. In the auction process, the auctioneer allocates options to the bidders. The options awarded are determined by the bidder's demand and the residual supply of the items

McAfee Double Auction (MCD)

This mechanism was proposed by McAfee (1992). The auction is a double auction, where the bidders reveal their true evaluation of the item that they are bidding on. This however, has a tendency to compromise the revenue maximization for the seller since there is little control over false-name bids. Since the bidders is expected to reveal their true evaluation of the item and payments of items do not change, there is little incentive to under report or over report. In this auction, the auctioneer is not trading.

Threshold Price Double Auction (TDP)

This protocol is quite similar to the MCD mechanism developed by Yokoo, et al (2005). Here also the auctioneer is non trading (not buying or selling). The auctioneer determines a threshold price in the beginning, before knowledge of the evaluation of the buyers and/or the sellers. The evaluation is done after the auctioneer has determined the threshold price.

The advantages of this protocol are that the double auction becomes more robust in a false-bid scenario as a result of setting up a threshold price. However, the revenue for the auctioneer trends to become larger than compared with that of the MCD auction. The issue with this effect is that, allocation efficiency may be comprised as buyers and seller may become discouraged and not participate in the auction. This may in turn lead to increased transaction costs.

Reverse Auctions

In the above sections we discussed the open as well as the closed bid auctions, along with their satisfying of the properties. Now we discuss, the reverse auction, which was popularized with the advent of the internet.

Procurement Auction

The reverse auction is often called the “Procurement auction”. A procurement auction is where vendors of items bid. That is, the vendors of items offer their goods and services, while competing for a set of buyers. In this process, they bid for the sale of their products. Typically, the buyer posts a Request for Purchase (RFP) and the seller of receipt of such RFP, prepare a bid that includes a asking price and other relevant information. Ostensibly, the buyer chooses the best bid. Since there are multiple steps involved, the transaction costs are high in such types of auction.

Never-the-less, the cost are considered less, when it’s understood that search costs for the buyer finding vendors or vendors finding buyers is reduced (Snir and Hitt, 2003). For the buyer, there is a great likelihood of get the lowest cost. However, the seller has offer discounted bid prices to possibly beat out other competitors and such an act may decrease their profits. In terms of fraud, there is a chance now for a group of seller to collude and manipulate the market. The procurement auction is similar to sealed bid auctions and suffers from the same weaknesses that affect sealed bid auctions.

There have been some other variants of the reverse auctions that have been proposed. These are discussed in the following paragraphs.

Multiround Open Ascending (MOA)

The MOA auction mechanism is proposed for a multiattribute auction. In such auctions, the auctioneer provides the bidders not only price information (RFQ) but also non price information such as a 'scoring rule'. In essence, in a MOA, the auctioneer learns the bidders cost functions to determine a scoring rule to maximize his utility function within an open ascending auction.

The auctioneer announces the number of rounds and then before each round announces the scoring rule. Bidding takes place at reach round and the bidder has to make a new bid at each new subsequent round. In the end , the auctioneer ranks the bids according to the scoring rule delineated earlier, without disclosing the bidder's identity or the details of the bid (Beil and Wein, 2003).

Name Your Own Price

This type of auction was popularized by the internet and especially by websites such as pricelien.com. In this model of reverse auction, the price that the auctioneer is willing to pay for the items is fixed and price is non public. However, the buyer is committed to buy at the first offered price (Laudon and Traver, 2004).

Since there is buyer's bias, there is cost benefits to the buyer. There is possibility for collusion by seller as they can group and fix prices. The cost of search is reduced for the buyer; therefore, there are lowered transaction costs.

Auction Mechanisms	**Properties**			
	Allocation Efficiency	Profit Max Cost Min	Transaction Cost	Fairness
Forward				
English	✓	✓	✓	x
Dutch	✓	✓	✓	x
FPSB- Discriminatory sealed bid	✓	x	x	x
SPSB (Vickrey) -Competitive sealed bid	✓	x	x	x
Generalized Vickrey Auction (GVA)	✓	✓	x	x
Yankee	✓	✓	✓	x
Leveled Partitioned Set (LPS)	✓	x	✓	✓
Leveled division Set (LDS)	✓	x	✓	✓
Iterative Reduction (IR)	✓	✓	?	✓
Trade Reduction Auction	x	✓	✓	✓
Threshold Price Double (TPD)	x	✓	x	✓
McAfee Double (MCD)	x	✓	✓	x
Ausubel	✓	✓	x	x
AOP	✓	✓	x	✓
Reverse				
Procurement	✓	x	x	✓
MOA	✓	x	x	x

Name you own price	✓	✓	✓	x

Table 1: Auction Mechanism and their Properties

Table 1 summarizes the various auction discussed with the desirable properties of efficiency of allocation, profit maximization for the seller, reduction in transaction cost and fairness. The check mark indicates that the particular property is addressed by that auction mechanism and the cross indicates that the auction mechanism is not been able to effectively address that particular property.

In table 2, we have further classified the auction mechanism by their ability to support the various product unit that are auctioned. With the internet based technologies, the traditional auctions have been able to support not only single unit but also multiple unit and combinations of units. The other developed models of auctions mechanism primarily appear to be designed to support multiple units and/or combinational units.

Auction Mechanisms	**Product Unit to be auctioned supported**			
	Single Unit	Multiple Unit	Combinational	Double Auction
Forward				
English	▪			
Dutch	▪			
FPSB- discriminatory sealed bid			▪	
SPSB (Vickrey) -Competitive sealed bid	▪	▪	▪	
Generalized Vickrey Auction (GVA)	▪	▪	▪	
Reputation			▪	
Leveled Partition Set (LPS)			▪	
Yankee		▪	▪	
Trade Reduction Auction	unknown	unknown	unknown	
Leveled Division Set (LDS)			▪	
Iterative Reducing (IR)		▪		
MCD				▪
TPD		▪		▪
Ausubel		▪		
AOP		▪		
Reverse				
Procurement	▪	▪	▪	
Multiround open-ascending	▪	▪	▪	
Name you own price	▪	▪	▪	

Table 2: Application of Auction mechanism

DISCUSSION ON PROPERTIES AND CLASSIFICATION

In table 1, we discussed the various properties that are satisfied by the various auction mechanisms. It's almost impossible to satisfy all the properties, without loosing out on some. Through agent modeling it is possible to develop further mechanism that enhanced the earlier traditional mechanism. The developments that tool place in the auction mechanism are classified below in Figure 1, 2 and 3. Figure 1 and 2 classifies the forward mechanisms. The open auction

formats have been developed to the stage of the Yankee auction and the AOP auction. There has been no other improvement in design from there on. From figure 1, we can discern that most of the mechanism development and refinement work has been with reference to closed sealed bids or the Vickery auction. This has been the main area of interest and has benefited from agent modeling and simulation, as most of these advanced designs have been proposed through them. Another area of auction mechanism is that of reverse auction (Figure 3) and there is little evidence of developmental work in it. This is perhaps because the impetus to study these areas has come up only recent through the proliferation of the internet.

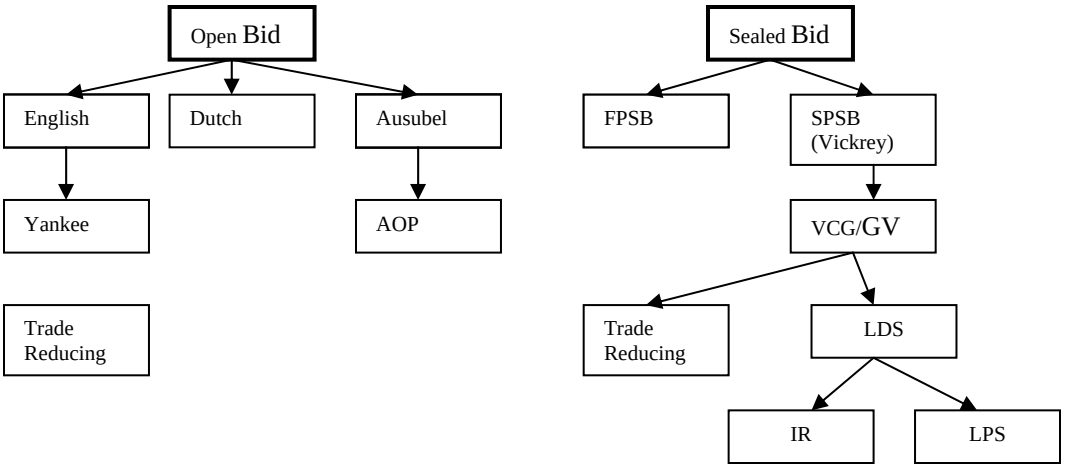

Figure 1: Forward Auctions- Mechanisms Hierarchies 1

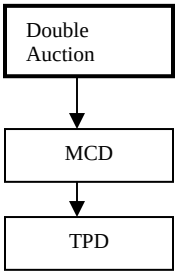

Figure 2: Forward Auctions- Mechanisms Hierarchies 2

Figure 3: Reverse Auctions- Mechanisms

CONCLUSION

The objective of this paper was to ascertain the classification of the various auction mechanisms that have been studied in literature. Study of auction has been a dominant area in Economics and with the increase in the study of Multi-agents systems; it has also become popular in the study of agents.

Therefore, there was a need to classify the fragmented work, in order it get a clearer picture. The classification enables us to get a grip on the areas where most of the developments have taken place, the mechanism properties that motivated such additional modification to the mechanisms. In addition, to expanding out understanding, the classification allows us to ascertain, emerging areas, such as reverse auctions, were development work appears promising and the potentiality for agent modeling to validate such proposed mechanism. For instance, the Multiround Open Ascending Auction Mechanism can be validated through a multi-agent simulation.

References:
Available upon request