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Bidding in sealed-bid and English multi-attribute auctions☆

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Abstract

In this paper we consider an extension of the traditional auction mechanism, the multi-attribute auction, which enables negotiation on several attributes in addition to the price of the item. In particular, we consider a procurement auction in which the buyer is the auctioneer and the sellers are the bidders. Such domains include auctions on task allocation, services, etc. We focus on three auction protocols for the case of multi-attribute items; a variation of the first-price sealed-bid protocol termed *first-score sealed-bid*, a variation of the second-price sealed-bid protocol termed *second-score sealed-bid*, and a variation of the English auction protocol termed *sequential full information revelation*. We analyze a specific model for these protocols and we provide optimal and stable strategies for the auctioneer agent and for the bidder agents participating in multi-attribute auctions. In addition, we analyze the auctioneer's/buyer's expected payoff and suggest an optimal scoring rule to be announced according to the protocol. Finally, we reveal that the buyer's expected payoff in all three protocols, the first-score-sealed-bid auction, the second-score sealed-bid auction and the English auction, differ only by a predefined constant. We prove that the optimal scoring rule is equal in all three protocols. This result can be interpreted as the extension of the *equivalence theory* of the single attribute for the case of multi-attribute items.

Keywords: Multi-attribute auctions; Automated agents; Electronic commerce

1. Introduction

Auction mechanisms have become very popular within electronic commerce and have been implemented in many domains with assorted environments (e.g., one-to-many, many-to-one, many-to-many, seller-to-buyers and buyer- to-sellers auctions). To date, most of the research on automated auctions considers models where the price is the unique strategic dimension [7,14,23,24,30]. However, in many real world situations, competition and negotiation involve many quality dimensions in addition to the price. Such auctions are termed multi-attribute auctions and a consequence of these additional dimensions, is that the traditional bidding strategies and auction

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design mechanisms should be reconsidered and adjusted.

A multi-attribute item is defined as an item characterized by several negotiable dimensions. For example, in the supply chain management domain, contracts are typically composed of multiple negotiable attributes, such as the supply time, the number of items delivered, the duration of the product's warranty and the price. In a task or resource allocation scenario, a task might be defined by its size, starting time, deadline and accuracy level. Finally, in the case of an Internet portal or video-on-demand supplier, storage capacity may be negotiated depending on capacity, the access rates to the data, the availability time and the level of security. Currently, complex contracts such as these are usually finalized using human negotiation or the non-price dimensions are fixed, and the auction relates only to the price. In this paper we suggest an automatic tool based on agent technology to assist the human user confronting complicated tasks on a daily basis.

In contrast to the single-attribute auction, where each side of the auction knows the preferences of the other side regarding the price (the seller prefers a higher price and the buyer a lower one), in reverse multi-attribute auctions, the bidders (sellers) do not necessarily have any information about the auctioneer's (buyer's) preferences regarding these additional attributes. To overcome this problem, the auctioneer can either use a scoring function or explicitly guide the auction by revealing if a given bid is better than the best bid yet offered. The scoring function enables the auctioneer to articulate its preferences regarding the various attributes which are made public to all bidders at the beginning of the auction. Sellers use this scoring function to value specific configurations and thus can understand how changes to the various attributes will affect the overall desirability of the bid.

Given a scoring function, one may think that the multi-attribute auction can be mapped into a simple price only auction. However, this is not the case. The scoring function announced by the auctioneer, is not necessarily its real utility function (i.e. the one that reflects the auctioneer's actual preferences). The announced scoring function, is chosen by the auctioneer, in order to maximize its expected pay-off. Thus, the scoring function may have a different structure from the auctioneer's utility function or a similar structure but with different weights associated with the various attributes. Moreover, even when given the scoring function, it is still non-trivial for the bidders to identify its optimal bid (as we will show in Section 4.3).

Several interesting questions emerge when attempting to analyze the new concept of the multi-attribute auction, for example,

(1) How can the auctioneer choose the auction protocol that maximizes its expected payoff?
(2) What should the buyer (auctioneer) reveal at the start of an auction? Should it include all its preferences, only part of them, or should different modified preferences be revealed?
(3) How should a seller (bidder) formulate its bid considering the various attributes? What should the optimal bid of each seller be, given the protocol, and its beliefs?
(4) Assuming that an English protocol is used, how can a seller (bidder) suggest a better bid than the current best bid, if it does not completely know the buyer's preferences?

In this paper, we address these issues and propose ways to handle auctions using automated agents. In particular we analyze three auction protocols for the case of multi-attribute items; a variation of the first-price sealed-bid protocol termed *first-score sealed-bid*, a variation of the second-price sealed-bid protocol termed *first-score sealed-bid*, and a variation of the English auction protocol termed *sequential full information revelation*. Another possible protocol is to have a two-stage protocol. In the first stage the bidders offer bids using a sealed protocol, then a set of the best bidders get a second opportunity to compete in an open cry auction. There might be several such protocols which differ in the reservation price/initial bid allowed in the second stage. For example, if this reservation price is set to the price offered by the lowest bidder in the winning bidders set then the strategy in the first stage will be equivalent to the second-price auction. On the other hand, if the bidders are allowed to offer bids in the second stage which are higher than the one they proposed in the first stage then the bidding strategy of the first stage will be strategically equivalent to the first price. In any case by analyzing the three protocols we have suggested we have been able to cover a wide range of protocols.