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Multiple Criteria Combinatorial Auction: A B2B Allocation Mechanism for Substitute Goods

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Abstract

We present business-to-business electronic auction mechanism as an alternative to sales usually accomplished through negotiation. The mechanism allows bids that are incompletely specified yet provide an evaluative framework to facilitate the allocation of complementary goods when substitutes are available. The auction form allows the consumer to create a unique combination of goods upon which to place a multiple criteria bid. Bidders are given the flexibility to change and or modify their bids and bundles until a stopping criterion has been reached. The allocation to bidders requires solving a complex combinatorial problem in real-time. Since the proposed integer program model may become computationally intractable as the number of bidders increase, we present simplifying heuristics to make the problem manageable on a large scale. (Combinatorial Auction, Integer Programming, Constraint Programming, Multi-criteria Auction, Greedy Algorithm, Advertising)

Introduction

This research presents a new business-to-business electronic auction mechanism designed to replace a traditional negotiated environment for a bundle of complimentary goods. Auctions provide an effective, alternative means of price discovery, especially for products hard to price a priori or when information asymmetries are present. (Englbrecht-Wiggans, 1980; Milgrom, 1989; Choi & Whinston, 1998). However, incorporating the negotiation process into an auction mechanism requires the bid to contain extended specifications. The complexities generated by the required modifications to existing auctions have discouraged widespread use of electronic negotiation models (Choi, Stahl & Whinston, 1997). Our mechanism and satisficing heuristics effectively incorporate these enigmatic characteristics.

The Auction

A combinatorial auction is a particular multi-item auction type that allows package bidding. This type of auction has been shown to be effective when complementarities exist among the items being sold and or in complex environments such as those involving overlapping demand for the various products to be bundled (Banks, Ledyard & Porter, 1989; Demartini, Kwasnica, Ledyard & Porter, 1999). Our Incompletely Specified Combinatorial Auction (ISCA) builds upon the advantages of the combinatorial auction by incorporating characteristics inherent in negotiated sales. Negotiated environments are often characterized by the presence of multiple evaluation criteria and loosely defined demand specifications, properties not supported by current auction mechanisms. The ISCA allows the buyer to submit a bid amount together with a variety of constraints on the collective allocation. The bid itself is inexact in that it may not specifically identify the individual items desired but provides a framework that the mechanism uses to identify appropriate units to satisfy the buyer's needs based on some evaluative measure(s).

The Model

Specifically, we model the purchase of television airtime for annual advertising campaigns. Termed "up-front" by the industry, these negotiations take place once a year to sell television ads spanning an entire broadcast year. Contractually, there is no after-market for the products involved. A campaign can be viewed as a collection or bundle of 15-second units from various shows. Media buyers desire a specific amount of demographic reach, or number of people with target characteristics exposed to their commercial. There are a variety of demographic categories upon which a show is rated and the number of people viewing determines the

reach or gross impressions for that category. Each show includes a number of substitute units that are equally capable of satisfying show demand and a variety of show combinations that will meet or exceed the buyer's demographic requirement.

In our auction, buyers specify demographic gross impression requirements, a selection of desired and forbidden shows, the campaign commercial length (15-seconds, 30, 45, 60 or mixed), product type and an overall bid amount. Also included in the bid is an upper and lower bound indicating the bidder's willingness to deviate from her collection of program choices and the maximal number of ads allowed per show. The inexact nature of the bid suggests that bidder specification of desired shows may not on its own entirely satisfy the demographic demand requirement. Additional units needed to achieve the desired demographics will be selected by the auction mechanism so as to maximize seller revenue. Industry specific constraints include requirements to separate competing advertisements, referred to as "pod protection," retain inventory to be sold throughout the remainder of the season for shorter term campaigns, and regulate the number of commercials appearing in each commercial break. Our mechanism takes the bid information and determines an allocation that ensures ad placement to achieve all the constraints imposed by the bid, constraints unique to the environment and competitive demand among participants for a finite supply of goods.

The ISCA is conducted in rounds with soft closing rules that act as an inducement to ensure participation in all rounds. Bidders may change their bids until a stopping criterion has been reached. To reduce churning, bid modifications will be limited to a defined incremental dollar increase, loosening bidder imposed constraints or both.

A generalization of our model can be adapted to any environment where multiple complementary goods are desired when substitutes are available and the allocation of goods is based on constraints imposed by both the buyer and seller.

Solution Methodology:

The prime challenge is to develop a solution methodology that is tractable, scales to the sizes needed and reaches a solution in real time. Combinatorial auctions are NP-Complete and as such a heuristic must be developed to obtain a satisficing solution in real time (Rothkopf, Pekec & Harstad, 1998). At the start of each round of bidding our auction mechanism will be supplied with the new bid information from which to determine an allocation. The rounds are at most 12 hours apart and thus the algorithm's performance is critical to the successful implementation of the auction mechanism as the computational time is the limiting factor.

We model our auction as an integer program. Attempts to solve the IP using the latest solver software, CPLEX have been unsuccessful – at least within the time-

frame specified. The problem is simply too large for CPLEX to obtain an answer in real time. 783 units distributed over 109 pods or "commercial breaks" in 24 shows make up a typical week of airtime. Approximately 100 to 200 buyers compete for these units. This translates to approximately 150,000 binary variables and 900,000 constraints.

We are currently exploring the use of Constraint Programming (CP) as a potential real time solution methodology. Constraint programming finds variable instantiations that simultaneously satisfy all specified constraints while optimizing a stated objective (Macworth, 1992). Although, constraint programming is our overarching methodology we incorporate a number of other techniques such as traditional relaxation, decomposition, aggregation, branch and bound, and dynamic and linear programming into our heuristic.

Defining the television commercial time allocation problem as a constraint programming problem involves specifying the variables, domains and constraints as well as determining the order of variable instantiation and value assignment. Our constraints are well defined in the integer program and do not require modification. However, the implementation of these constraints can be accomplished more directly, often with simple programming logic. Domains are not enumerated as is usually the case in constraint programming. Rather, we decompose the problem formulation into sub-problems involving various constraints. The sub-problems represent implicit domains.

We are currently experimenting with variable and value ordering. Our initial investigation gives preference to bidders with the highest bid per thousand demographic exposures (BPM). This approach was chosen to ensure that the buyers with the highest valuation for the units desired will have the largest domain from which to create their bundle. Normal branch-and-bound search is used to handle complicating constraints such as protection from competitive advertising in the same pod.

Preliminary evidence suggests that constraint programming will facilitate expeditious and efficient allocations upon which to base our auction mechanism. Once the ultimate model has been established we will evaluate its performance through simulation. Experiments will involve using automated agents to simulate bidder types discovered from actual data and varying the demand characteristics of the market. Additionally, we will study our solution methodology by comparing its results with the solutions obtained by a commercial integer programming package on representative problems that are sufficiently small for it to reach a solution to the combinatorial optimization. We will also evaluate our heuristic's performance in terms of running time and allocative efficiency.

Summary

Our Incompletely Specified Combinatorial Auction incorporates the characteristics needed to act as a viable alternative to negotiation. Due to the complexity of the multi-item, multi-criteria combinatorial allocation problem we are investigating heuristic methodologies to achieve a satisficing solution in real time. Our experiments will test the performance and efficiency of our auction mechanism through simulation.

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