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A Comparative Study of Two Models for Handling Transportation Cost in Combinatorial Auctions

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ABSTRACT

Although combinatorial auctions have been extensively studied, the factor of transportation cost has not been considered in most studies. Without considering transportation cost, the profits of the seller cannot be determined accurately. The goals of this article are to propose models, develop a solution methodology for the winner determination problem (WDP) in combinatorial auctions and study the effects of transportation cost on the seller's profits. Two models are proposed: one model considers transportation cost in WDP whereas the other one does not take transportation cost into account in WDP but calculates the transportation cost based on the solution obtained. The author formulates the WDPs for these two models and proposes a solution method. The author then analyzes and compares the two models to illustrate the advantage of taking transportation cost into account in combinatorial auctions. Finally, the author studies the influence of transportation cost on combinatorial auctions by examples and demonstrate effectiveness of our approach.

KEYWORDS

Combinatorial Auction, Decision Support, Transportation, Cost, Winner Determination

1. INTRODUCTION

One of the recent trends in the development of auction mechanisms is combinatorial auctions. In combinatorial auctions, bidders can place bids on a combination of goods according to personal preferences rather than just individual items. It is beneficial to adopt combinatorial auction model if complementarities exist between the items to be auctioned. There are many well-known combinatorial auction examples, including the auctioning of Federal Communications Commission's radio spectrum licenses, the sales of airport time slots, allocation of delivery routes, carpool and trading goods (de Vries & Vohra 2003; Rassenti et al. 1982; Zhang, et al. 2019; Hsieh & Guo 2019; Hsieh et al. 2019). For example, application of combinatorial auctions in carpooling systems can be found in (Hsieh et al. 2019). Combinatorial double auctions also provide an efficient mechanism to trade goods in an electronic marketplace (Hsieh & Guo 2019). Combinatorial auctions have been extensively studied (Abrache et al. 2004; Catalán et al. 2009; Harsha et al. 2010; Leskelä et al. 2007; Meeus et al. 2009; Özer & Özturan 2009; Perugini et al. 2005; Sandholm, 2000; Yang et al. 2009). An excellent survey on combinatorial auctions can be found in the papers of de Vries & Vohra (2003) and Pekeč & Rothkopf (2003).

Combinatorial auctions can improve the efficiency of trading goods between buyers and sellers. However, the winner determination problem (WDP) is notoriously difficult to solve from a computational point of view (Rothkopf et al., 1998), (Xia et al., 2005) due to the exponential growth

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of the number of combinations. The combinatorial auction problem can be modelled as a set packing problem (SPP) (Andersson et al., 2000), (Fujishima, 1999), (Hoos and Boutilier, 2000), (Vemuganti, 1998), (Xia et al., 2005) . Sandholm mentioned that determining the winners so as to maximize revenue in combinatorial auction is NP-complete (Sandholm, 1999), (Sandholm, 2000), (Sandholm, 2002). Many algorithms have been developed for combinatorial auction problems. Exact algorithms have been developed for the SPP problem, including iterative deepening A* search (Sandholm, 2000) and the direct application of available CPLEX IP solver (Andersson et al., 2000). Gonen and Lehmann proposed branch and bound heuristics for finding optimal solutions for multi-unit combinatorial auctions (Gonen and Lehmann, 2000). Jones and Koehler studied combinatorial auctions using rule-based bids (Jones and Koehler, 2002). In (Guo et al., 2005; Hsieh & Lin, 2012; Hsieh & Liao, 2015a; Hsieh & Liao, 2015b), the authors proposed a Lagrangian heuristic and a Lagrangian relaxation approach (Fisher, 2004) for combinatorial auctions and combinatorial reverse auctions, respectively.

Although combinatorial auctions have been extensively studied, the factor of transportation cost for delivering goods from the seller to the winners (buyers) is largely ignored in most existing literature with the exception of (Hsieh & Wu, 2014) and (Hsieh & Wu, 2015), which consider the factor of transportation cost in combinatorial auctions. The fact that transportation cost may have impact on the determination of winners in combinatorial auctions can be illustrated by a simple example. For example, suppose in a combinatorial auction with two buyers, B1 and B2 and one seller, S1. Suppose buyers B1 and B2 and place two bids on all the bundle of items supplied by S1 with different bid price, say p1 and p2. Suppose the transportation cost for delivering the items to b1 and b2 is t1 and t2, respectively. Suppose $p1 > p2$ and $p1-t1 < p2-t2$. If transportation cost is not taken into consideration, the winner will be B1. If transportation cost is taken into consideration, the winners will be B2. This simple example indicates that transportation cost may influence the decision.

In (Hsieh and Wu, 2015), Hsieh and Wu studied the effects on transportation cost on the surplus of the seller by proposing two models: (1) Model 1, which considers transportation cost in determining the winners; (2) Model 2, which does not take transportation cost into account in determining winners but calculates the transportation cost based on the solution obtained. For both Model 1 and Model 2, it is considered that there are a number of buyers and a seller in a combinatorial auction. Each buyer places bids based on the required items (goods) to be purchased. Goods are non-dividable. It is assumed that all the participants tell truth. The transportation fee for delivering goods from the seller to the winner(s) is paid by the seller. The surplus of Model 1 as the difference between buyers' total payment and the transportation cost. For the WDP of Model 1, the objective is to maximize total surplus while determining winners. For the WDP of Model 2, the objective is to maximize total payment of the winners while determining winners. In (Hsieh and Wu, 2015), Hsieh and Wu compared the performance of Model 1 and Model 2 by an example. However, no property and theoretical analysis/proof have been given in (Hsieh and Wu, 2015) to characterize the influence of transportation on combinatorial auctions by showing that Model 1 is more effective than Model2.

Motivated by the discussion above, this paper aims to propose a decision support model that considers transportation cost in combinatorial auctions and develop a methodology to characterize the influence of transportation cost on combinatorial auctions by extending and analyzing Model 1 and Model 2 proposed in (Hsieh & Wu, 2015). The Model 1 and Model 2 proposed in this paper are extended by considering transaction fee, which is not considered in the works of (Hsieh & Wu, 2014) and (Hsieh & Wu, 2015). In this paper, two important properties will be established to characterize the influence of transportation on combinatorial auctions based on theoretical analysis to compare Model 1 and Model 2. These two properties differentiate this paper from the results presented in (Hsieh & Wu, 2014) and (Hsieh & Wu, 2015). In addition, this paper significantly extends the study of (Hsieh & Wu, 2014) by a comparative study of Model 1 and Model 2 based on theoretical analysis and numerical results to illustrate the benefits of considering transportation cost in combinatorial auctions. This paper is also different from the previous results reported in (Hsieh & Lin, 2012; Hsieh & Liao, 2015a; Hsieh and Liao, 2015b) on combinatorial reverse auctions and combinatorial double auctions.