WINNER DETERMINATION PROBLEM IN COMBINATORIAL AUCTIONS: AN EMPIRICAL STUDY

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Abstract

Auctions are an effective market mechanism for transacting items where the worth of the transaction is unknown and is determined by the participants interested in the transaction through a bidding process. The highest valuation in terms of price is found by the auction mechanism. This price as also the transaction partners are determined by the same auction process. In the traditional mechanism of conducting auctions preferences were expressed by the bidders for individual items under different auction mechanisms. These had the inbuilt limitations that they failed to address the needs of that market, where bidders had preferences for a set of items in a manner that the valuation for their entire set was higher than the summation of values of individual components of the set. This led to the birth of the combinatorial auction (CA) mechanisms in various forms and adaptations.

In Combinatorial Auctions, multiple goods (items) are available for auction simultaneously, and bidders bid for combinations of goods called bundles. The goods are considered indivisible. The prevalent basic forms of combinatorial auction mechanisms are single unit CA's with a single unit of each item available on auction and the multi unit CA's permitting the auction of multiple units of the items. In these two mechanisms, bidding is a one time process and the bidders bid on their combinations unaware of the

bids of their counterparts. This mechanism though in vogue, has still not been able to replace the traditional one as the dominant auction mechanism, where bidders have the flexibility of forming their valuations with the auction in progress, influencing and being influenced by it. However still these CA are welcome in those markets where complementarities exist between items on auction. In both these mechanisms of combinatorial auctions, there are a limited number of units of the items on auction. This forms the supply side constraint resulting in a need by the seller to decide on which bundles to allocate for maximizing the revenue. Determining these winning bundles is an NP-complete problem and is known by the name of Winner Determination Problem (WDP) in literature. The optimal heuristic search algorithms like CASS and CABOB proposed for solving the WDP take a lot of CPU time for solving large problem instances. Though they give optimal solution, they would be useful only in scenarios where for the auctioneer time is not at all a constraint, and the bidding is a one time affair. This however, also poses a limitation on the auction design as it favors one time bidding and hence hinders the widespread use of combinatorial auctions on the patterns of traditional English auction. The more advanced CA where bidders can revise their bids during multiple rounds is known as Iterative CA. However the results of each round need to be declared before commencing to the next round and a WDP needs to be solved for each one. In the second advanced form of CA that of combinatorial exchange the buyers and sellers exchange combination of goods so as to maximize the surplus. Faster solution of WDP holds the key to widespread use and popularity of these CA mechanisms especially if they are conducted online where the number of buyers and/or sellers is large. The effect would be more on the advanced form of CA.

This thesis focuses on methodologies for solving the WDP for single unit and multi unit combinatorial auctions so as to address the limitations to widespread use of these mechanisms. As the other two forms of CA's are a derived form of these two basic CA methodologies we limit the present work to single unit and multi unit case. This work is an empirical study. To address practical considerations, the algorithms developed as part of this work are tested on 'real world problem domains' generated by CATS 2.0 test suite developed at Stanford University in the process of a doctoral dissertation.

The work proposes a simple local search technique LSWDP (Local Search for Winner Determination Problem) that runs very fast and provides solutions quite close to optimal in a number of applications for the single unit combinatorial auction. LSWDP also outputs optimal solutions in many instances taking only a fraction of the CPU time taken by CASS. LSWDP was found to outperform the anytime algorithm CASS given a time cutoff.

LSCN (Local Search using Complimentary Neighbourhood) is developed as enhancement to LSWDP for the single unit case and this provides still better solutions in terms of close to optimal behavior and achieves a much better strike rate in hitting optimal solutions. LSCN still takes only a fraction of the CPU time taken by CASS thus encouraging the use of local search for combinatorial auctions. An extension to multi-partition search Local Search with multiple partitions (LSMP) has been proposed to experiment with relatively large problem instances of the single unit case. This experimentation sets the ground for the use of multi partitioning to solve the much more difficult multi unit WDP problem in combinatorial auction and develop it as a general purpose algorithm.

For the multi unit scenario, algorithm LSMU(β) is comprehensively developed with a multi partitioning approach to solve the WDP. β refers to the number of partitions in this algorithm. This is extensively tested on two domains that of uniform and decay distribution. LSMU(β) tested empirically outputs optimal in many cases and provides very close to optimal results in those cases where it fails to output optimal. The results are obtained very fast. For the very large instances which took hours and days of CPU time to give optimal, LSMU(β) empirical performance was excellent giving results almost instantaneously without any significant loss of revenue to the auctioneer. The effect of multiple partitioning on the test data is also analyzed to suggest scope for future research.

Keywords: Near optimal solutions, Random Search, Neighbourhood size, DFBB