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Bidding strategy for agents in multi-attribute combinatorial double auction

Q1 Faria Nassiri-Mofakham [a,*], Mohammad Ali Nematbakhsh [b], Ahmad Baraani-Dastjerdi [b], Nasser Ghasem-Aghaee [b], Ryszard Kowalczyk [c,d]

[a] Department of Information Technology Engineering, University of Isfahan, P.O. Code 81746-73441, Hezar Jerib Avenue, Isfahan, Iran
[b] Department of Computer Engineering, University of Isfahan, P.O. Code 81746-73441, Hezar Jerib Avenue, Isfahan, Iran
[c] Faculty of Information and Communication Technologies, Swinburne University of Technology, Melbourne, 3122 Victoria, Australia
[d] Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland

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ABSTRACT

In a multi-attribute combinatorial double auction (MACDA), sellers and buyers' preferences over multiple synergetic goods are best satisfied. In recent studies in MACDA, it is typically assumed that bidders must know the desired combination (and quantity) of items and the bundle price. They do not address a package combination which is the most desirable to a bidder. This study presents a new packaging model called multi-attribute combinatorial bidding (MACBID) strategy and it is used for an agent in either sellers or buyers side of MACDA. To find the combination (and quantities) of the items and the total price which best satisfy the bidder's need, the model considers bidder's *personality*, *multi-unit trading item set*, and *preferences* as well as *market* situation. The proposed strategy is an extension to *Markowitz Modern Portfolio Theory* (MPT) and *Five Factor Model* (FFM) *of Personality. We use mkNN learning algorithm* and *Multi-Attribute Utility Theory* (MAUT) to devise a personality-based multi-attribute combinatorial bid. A test-bed (MACDATS) is developed for evaluating MACBID. This test suite provides algorithms for generating stereotypical artificial market data as well as personality, preferences and item sets of bidders. Simulation results show that the success probability of the MACBID's proposed bundle for selling and buying item sets are on average 50% higher and error in valuation of package attributes is 5% lower than other strategies.

1. Introduction

Combinatorial auction (CA) is one of the best suited mechanisms for trading a bundle of different synergetic items (goods or services) in comparison to sequential or parallel auctions. When the items are substitutes, the bidder desires to acquire at most one of them. However, for the complementary items, the bidder's valuation for the whole bundle is super-additive; that is, it is higher than the sum of the bidder's valuations for the individual items. Therefore, the more complement the items, the more valuable the bundles (Cramton, Shoham, & Steinberg, 2006; De Vries & Vohra, 2003; Milgrom, 2004; Rothkopf, Peke, & Harstad, 1998).

Multi-attribute combinatorial double auction (MACDA) is the most general but complex auction. This combinatorial auction considers other attributes than only price and better satisfies bidder's preferences compared to auctions where the bidder is uncertain about or uninterested in attribute values that will later be settled during the contract phase (Bichler, Shabalin, & Pikovsky, 2009). In addition, while single-side auctions are of interest to the sellers in the forward and to the buyers in the reverse auctions[1], double auction clears with fairer outcomes and is of interests to both the buyers and the sellers. A seller can use CA for promotional offers to customers, since procuring a bundle of items rather than individual items can lead to savings in logistics costs,

* Corresponding author. Tel.: +98 31 3793 4510; fax: +98 31 3793 4038.
Q1 *E-mail addresses:* fnasirimofakham@yahoo.com, fnasiri@eng.ui.ac.ir (F. Nassiri-Mofakham), nematbakhsh@eng.ui.ac.ir (M. Ali Nematbakhsh), ahmadb@eng.ui.ac.ir (A. Baraani-Dastjerdi), aghaee@eng.ui.ac.ir (N. Ghasem-Aghaee), rkowalczyk@groupwise.swin.edu.au (R. Kowalczyk).
Q1 *URLs:* http://eng.ui.ac.ir/~fnasiri (F. Nassiri-Mofakham), http://eng.ui.ac.ir/~nematbakhsh (M. Ali Nematbakhsh), http://eng.ui.ac.ir/~ahmadb (A. Baraani-Dastjerdi), http://eng.ui.ac.ir/~aghaee (N. Ghasem-Aghaee), http://www.ict.swin.edu.au/personal/rkowalczyk (R. Kowalczyk).

[1] A single sided auction leads to an equilibrium close to the (bid taker) maximum competitive equilibrium outcome (Roh & Yang, 2008)

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time, payment and the overall cost savings for the customers, while the seller provides packages, which bring him[2] the highest returns. A buyer can benefit in CA from efficient allocations when she has some preferences over combinations of items or a limited budget. Therefore, "multi-attribute combinatorial double auction" can better answer multi-attribute preferences of both buyers and sellers where fair outcomes satisfy synergies among goods that bidders' desire. MACDA has two prominent problems to be addressed: Winner determination (WDP) and bid generation (BGP). Similar to WDP, BGP is also an NP-Hard problem (Park & Rothkopf, 2005; Parkes, 2000; Triki, Oprea, Beraldi, & Crainic, 2014). Bidders would like to benefit for winning the goods. That is, not only a bidder likes to be a winner, but to prevent a winners' course she/he also prefers to gain rather than loose if she/he wins. Bidding is an important issue which also affects WDP (Rothkopf & Harstad, 1994; Rothkopf et al., 1998).

In recent years, several bidding strategies have been proposed by studies in combinatorial auctions (An, Elmaghraby, & Keskinocak, 2005; Leyton-Brown & Shoham, 2006; Parkes & Ungar, 2000; Pikovsky, 2008; Triki et al., 2014; Wilenius, 2009). However, none of the existing solutions addresses a multiple-attribute, double sided, and multiple-unit bidding scenario together (see Section 2). It is also worth noting that previous studies typically do not model bidder's willingness to trade a bundle among many combinations that can be defined. Some works let the bidders to prioritize combinations (Park & Rothkopf, 2005). However, they do not show how the provided packages could be the best package of bundles a specific bidder most prefers. In other words, these studies assume that the bidders must know the desired bundles and priorities. Moreover, all the bidders in a market are not willing to be a profit maximizer so that they behave differently and prefer different packages. Market history is another source of information that a bidder needs to consider in devising a bid. This need for considering the history of the market and the bidder's decision making model for prioritizing the packages makes efficient bidding in one-shot MACDA mechanism a very complex task.

The complexity of bidding a package among an exponential number of potential bundles of items with synergies comes back to the fact that besides the above mentioned requirements, bidders in MACDA should also address several important issues such as (1) size of the package, (2) items to place in the package, (3) quantities of each item in the package, (4) attribute values of each item in the package, (5) attribute values of the package, (6) price of the package, (7) limitations regarding items' quantities for sellers, and (8) limitations regarding bidder's budget for buyers (Leyton-Brown & Shoham, 2006; Vinyals, Giovannucci, Cerquides, Meseguer, & Rodriguez-Aguilar, 2008). Moreover, real markets do not necessarily reveal pricing made by all the bidders. The market exposes the bundles along with the prices at which the bundles traded. That is, the market hides individual valuations which each participant assumes for each individual item. The bidder faces the problem of which combination (and quantity) of items and in what values for the package price and attributes is the best combination regarding information resources (market history and policy) and his/her item set and bidding behavior. The bidder's decision-making would depend on the winning/losing risk of the bundles and his/her risk and cooperation attitude towards the market.

This paper addresses the sellers and buyers' bidding in MACDA. It proposes a strategy for the bidders in order to provide a multi-attribute combinatorial bid (MACBID) that addresses different behaviors of the bidders in a market. We model a bidder as a personified[3] agent that interacts with MACDA by observing a history of the previous trades in the market and submitting her/his own bids (ask bids or sell bids) to MACDA in one-shot, where only traded bundles (not all the proposed bids) are revealed to the bidders. The traded bundle in the history consists of only quantities of each item in the bundle, values of each package attribute, and the package price. A bidder can make personality-based decisions different from the other bidders –with even the same item set and valuations – that observe the same market trades history. This strategy employs the bidder's *personality*, *multi-unit item set*, and *preferences* as well as *market* situation. To be informed of the prices of the items and finding the most synergetic and desirable package for devising a personality-based and market-based multi-attribute combinatorial bid, we extend *Markowitz Modern Portfolio Theory* (Markowitz, 1952; Prigent, 2007), *Five Factor Model of Personality* (Liebert & Speigler, 1998; McCrae & Costa Jr, 1999; Nassiri-Mofakham et al., 2009; Norman, 1963; Oren & Ghasem-Aghaee, 2003), *mkNN learning algorithm* (Nassiri-Mofakham et al., 2009), and *Multi-Attribute Utility Theory* (Fasli, 2007; Lewicki, Saunders, & Barry, 2006; Nassiri-Mofakham, Ghasem-Aghaee, Ali Nematbakhsh, & Baraani-Dastjerdi, 2008; Raiffa, 1982; Wooldridge, 2009). Markowitz MPT and FFM of personality help the bidder in bundling multi-unit complementary goods by considering market data as well as the bidder's item set and personality, while FFM of personality, combinatorial *mk*NN learning, and MAUT are employed for selecting the best MACBID among substitutes of the devised bundle.

As we focus on the bidding process, issues regarding WDP to design a complete MACDA mechanism are outside the scope of this study. Therefore, we evaluate the proposed MACBID using benchmarking in a test suite. The study develops a multi-attribute combinatorial double auction test suite called MACDATS. This test suite provides algorithms for generating realistic artificial market data, personality, preferences, and multi-unit item sets of bidders. MACDATS which also operates as a support tool in helping humans in efficiently devising bids in the complex market, benchmarks efficiency, validation, and confidence of MACBID against other strategies.

The remainder of the paper is organized as follows. We overview related works in Section 2. In Section 3, we describe the MACDA market design space. Section 4 details MACBID strategy and presents the architecture of bidding agents. MACDATS and evaluation of MACBID is presented in Section 5. Section 6 concludes the paper by summarizing the contributions of the study and outlining future avenues of this research.

2. Related work

After the Smith's seminal work on modeling the market behavior in 1962 (Smith, 1962) and reconsidering the importance of bidding by Rothkopf and Harstad in 1994 (Rothkopf & Harstad, 1994), several studies have significantly advanced bidding strategies in double auctions (Gjerstad & Dickhaut, 1998; He, Leung, & Jennings, 2003; Rapti, Karageorgos, & Ntalos, 2014; Vytelingum, Cliff, & Jennings, 2008). In ZI strategy (MacKie-Mason & Wellman, 2006) buyer/seller propose a random offer between the best bid/ask and the current value. In FM strategy (Tan, 2007) the best bid/ask added with a positive/negative value is proposed. GD strategy (Gjerstad & Dickhaut, 1998) records all bids/asks history and propose a bid/ask by cubic-spline extrapolation for com-

[2] In this study, from now on, "she/her" and "he/his" refer to the "buyer" and "seller", respectively.

[3] We assume the agents emotion-free. By considering emotions motivated from notifications and trades history that the participant observes, his/her personality traits and then decision-making parameters may change in long term. Dynamic personalities exerted temporarily by emotions are not considered in this study. In addition, we assume the market is not multi-national and we do not consider cultural differences among bidders.