Preference Elicitation and Winner Determination in Multi-Attribute Auctions

Farnaz Ghavamifar and **Samira Sadaoui** and **Malek Mouhoub**
sadaouis@uregina.ca, mouhoubm@uregina.ca
Department of Computer Science
University of Regina, SK, Canada

Abstract

Multi-Attribute Reverse Auctions (MARAs) are excellent protocols to automate negotiation among sellers. Eliciting the buyer′s preferences and determining the winner are both challenging problems for MARAs. To solve these problems, we propose two algorithms namely MAUT* and CP-net*, which are respectively the improvement of the Multi-Attribute Utility Theory (MAUT) and constrained CP-net. The buyers can now express conditional, qualitative as well as quantitative preferences over the item attributes. To evaluate the performance in time of the proposed algorithms, we conduct an experimental study on several problem instances. The results favor MAUT* in most of the cases.

1 Introduction

In MARAs the competing sellers place bids for an item based on several attributes (Bichler and Kalagnanam 2005). Sellers' bids should be sorted according to the buyer′s preferences and constraints over the item attributes (E.David, Azoulay-Schwartz, and S.Kraus 2006). Finding the best bid is actually looking for the optimal solution of a multi-criteria decision problem (Chandrashekar et al. 2007). The winner determination in most MARAs is a computationally hard problem (Bichler and Kalagnanam 2005). In existing auction mechanisms (Bichler and Kalagnanam 2005; Beil and Wein 2003), to rank the bids a numerical value is assigned to each bid. In this paper, we develop a MARA system in which the buyer can specify constraints and conditional preferences: (1) we allow the buyers to choose between quantitative and qualitative preference expressions, and (2) we enable the winner determination in case of conditional preferences. We first study the winner determination based on MAUT (Bichler and Kalagnanam 2005), and then we improve MAUT to be able to express conditional preferences. Constrained CP-net is another method that solves multi-attribute decision problems (Boutilier et al. 2004). CP-net is a graphical model to represent and manage conditional and qualitative preference relations (Prestwich et al. 2005). We apply CP-net to MARAs and extend it so that we can have a total ordering on the sellers′ bids. Finally, we explore experimentally how each method chooses the winner for a 5-attribute application.

Table 1: Comparing Methods.

Method	Constraints	Preferences	Comparing Outcomes	Time
MAUT	-	Quant.	Complete order	$O(KM)$
Const. CP-net	Hard	Qual., Cond.	No complete order	P, NP or PSPACE
MAUT*	Hard	Quant., Cond.	Complete order	$O(KM^2)$
CP-net*	Hard	Qual., Cond.	Complete order	P,NP or PSPACE

2 Improving MAUT and CP-net

In MAUT to determine the buyer′s preferences, the weight and utility function of each attribute should be specified. Qualitative and conditional preferences cannot be represented in MAUT. Thus, every preference has to be changed into a quantitative form. Consequently, the difficulty of applying MAUT is that it requires the buyer to elicit fully and quantitatively all his preferences. This task is not easily achievable. In CP-net when a Preference Graph (PG) is a poly or directed tree, finding the more preferred outcome can be executed in polynomial time based on the number of attributes (Boutilier et al. 2004). If PG is directed-path and singly-connected, the execution is NP-complete, and is NP-hard if the number of paths between any pair of nodes is polynomially bounded (Boutilier et al. 2004; Mindolin and Chomicki 2007). In general for CP-nets, consistency and dominance testing is in PSPACE-complete (Goldsmithand et al. 2005). In Table 2, we give the type of constraints, preferences and reasoning supported by MAUT and CP-net and compare them for winner determination. None of these two models is perfect for MARAs: in MAUT qualitative and conditional preferences cannot be described; in CP-net, the total ordering of outcomes is not feasible.

When the buyer has some constraints over the attributes, it is necessary to first check the constraint consistency of the bids. Then from the set of remaining bids, the best bid is computed based on the buyer′s preferences. In MAUT, the buyer can specify the utility function of an attribute which has conditional preferences based on the value assigned to the other attributes it depends on. We suppose that the preference of the buyer for attribute j is conditional and depends on the value of attribute k. Then for evaluating attribute j, we use the utility function $U_j(v_{ij})$ which has different values based on v_{ik} (value of attribute k in bid i). We add these features to MAUT and call the new method MAUT*. In CP-net, if two outcomes do not have paths in the PG, they cannot be compared. However to find the best bid in MARAs, we need a total ordering of the bids. To address this problem, we use the number of the violated buyer′s preferences as a clue to compare bids which do not have any path in PG. This means if the value assigned to an attribute is not what is preferred, this assignment is not desired by the buyer and it is a preference violation. In the case that the violations of two bids are the same, we can ask the buyer to complete his preferences. We include these two ways of bid comparison to CP-net and call the new method CP-net*. In Table 2, we show the characteristics of CP-net* and MAUT*. Compared to MAUT, MAUT* needs more time to find the best bid since it checks the bid consistency. The time complexity of CP-net* is the same as CP-net and depends on the type of PG.

3 Experimentation

We suppose the buyer is interested in five attributes to purchase a laptop. The sellers can register to our MARA system and submit their laptop configurations. The buyer submits some preferences and possible constraints based on the sellers'descriptions. He has two options to express his preferences: MAUT* and CP-net*. If the buyer wishes to express his preferences quantitatively, he selects MAUT*. Therefore, he has to specify the importance of attributes and their dependencies, and also the utility values for these attributes. If the buyer wants to express his preferences qualitatively and conditionally via CP-net*, he needs to specify dependency of attributes and their preference order. After the buyer′s preference model is set, the auction can start. Our auction protocol is called first score sealed-bid in which sellers have no visibility of the bids of their opponents. According to the buyer′s choice, one of the following two methods is selected to determine the winner: (1) MAUT*: first the consistency of all the bids with the buyer′s constraints is checked. If a bid violates any of these constraints, it is deleted. The overall utility of each remaining bid is calculated. The best bid is the bid with the highest utility; (2) CP-net*: first the consistency of bids are checked. After that, each of two bids are compared respectively based on the path in the induced graph and preference violations. If the best bid cannot be found in this way, we need to ask the buyer to complete his preferences. We have conducted several experiments on different instances of our application, which are obtained by varying the number of conditional preferences, constraints and sellers. As we can see from Table 3, when the number of conditional preferences or sellers is increased, the execution time is increased too since more comparisons are needed. However, when the number of constraints is increased, some of the bids may be deleted in the constraint consistency step. As a consequence, the execution time is decreased too. In MAUT* since the winner is determined from the group of feasible bids in one step, this method is faster than CP-net* which has two steps to find the winner.

Table 2: Execution time by varying the number of variables

PROBLEM					
Attributes	Sellers	Constraints	Conditional Preferences	CP-net* Time	MAUT* Time
5	5	2	**1**	0.101	0.081
5	5	2	**2**	0.105	0.083
5	5	2	**3**	0.106	0.092
5	5	2	**4**	0.106	0.093
5	5	**1**	2	0.107	0.086
5	5	**2**	2	0.105	0.083
5	5	**3**	2	0.102	0.080
5	5	**4**	2	0.101	0.076
5	**2**	2	2	0.060	0.051
5	**3**	2	2	0.081	0.062
5	**4**	2	2	0.098	0.078
5	**5**	2	2	0.105	0.083
5	**6**	2	2	0.110	0.091

4 Future Work

We want to improve CP-net* by incorporating quantitative preferences to make it an efficient method for MARAs. This will enable the buyers to express their preferences over some attributes quantitatively and over the others qualitatively.

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