An Adaptive Bidding Strategy for Combinatorial Auctions-based Resource Allocation in Dynamic Markets

(Extended Abstract)

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ABSTRACT

Combinatorial auctions, where bidders are allowed to submit bids for bundles of items, are preferred to single-item auctions when bidders have complementarities and substitutabilities among items and therefore achieve better social efficiency. A large unexplored area of research is the design of bidding strategies. In this paper, we propose a new adaptive bidding strategy for combinatorial auctions-based resource allocation. The bidder adopting this strategy can adjust his profit margin constantly, and thus perceive and respond to the market in a timely way. Experiment results show that the adaptive strategy performs fairly well when compared to an intelligent strategy, which is artificially generated according to prior knowledge of the market.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence–Intelligent agents, Multi-agent systems

General Terms

Economics

Keywords

Adaptive strategy, Bidding, Combinatorial auctions

1. INTRODUCTION

Combinatorial auctions, where bidders are allowed to submit bids for bundle of items, receive much attention from researchers in both computer science and economics. Combinatorial auctions can lead to more economical allocations of resources than traditional single-item auctions when bidders have complementarities and substitutabilities among them. Such expressiveness can lead to an improvement of efficiency, which has also been demonstrated in airport landing allocation and transportation exchanges[1].

Although many works have be conducted on combinatorial auctions, most of them focus on winner determination problem [1] and auction design [1]. An large unexplored area of research in combinatorial auctions is the design of bidding strategies. In this paper, we consider a scenario where first-price sealed-bid combinatorial auctions are employed to distribute computational resources among a group of users and propose a new adaptive bidding strategy. The bidder adopting this kind of strategy can adjust his profit margin constantly, and thus perceive and respond to the market. Experiment results show that the adaptive strategy performs fairly well and generates high utilities in different markets when compared with the intelligent strategy which is artificially generated by prior knowledge.

This paper is structured as follows. Section 2 describes the adaptive bidding strategy. Section 3 shows experiment results. Section 4 concludes this paper.

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2. THE ADAPTIVE BIDDING STRATEGY

We first introduce some basic concepts.

DEFINITION 1. A *bidding record* of a bid b for bidder i is a tuple $br_b = (T_b, v_i(T_b), p_i(T_b), pm_b, wait_b, win_b)$, where T_b is the requested bundle in b, $v_i(T_b)$ is i's valuation of T_b, $p_i(T_b)$ is bidder i's price for T_b, $pm_i = 1 - p_i(T_b)/v_i(T_b)$ is called i's profit margin, $wait_b$ is the number of rounds the bidder has kept on waiting before b is accepted or dropped, and win_b=1 if b is finally accepted, otherwise 0.

DEFINITION 2. The *approximate utility* of a bidding record br_b, denoted as $u_{br}(br_b)$, is defined as:

$$u_{br}(br_b) = pm_i \times \frac{win_b}{win_b + wait_b} \tag{1}$$

DEFINITION 3. The *bidding history* of a bidder is the sequence of recent λ bidding records.

DEFINITION 4. We define the *age* of a bidding record br_b as the number of times that the bidding history is updated since br_b is inserted into the bidding history.

DEFINITION 5. A *weight function* is a decreasing function on the age of a bidding record that $w : N \to [0, 1]$.

The function value of a bidding record represents how important the information contained in that bidding history is. The newer the bidding record is, the more representative it is of the market environment, and the higher the function value is. Our current implementation of the weight function is illustrated in Figure 1.

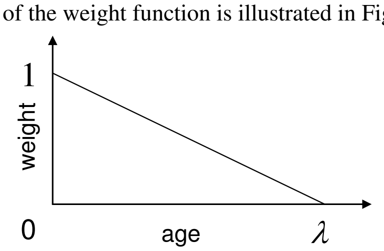


Figure 1: A Weight Function

DEFINITION 6. The *approximate utility* of a bidding history bh, denoted as $u_{bh}(bh)$, is defined as:

$$u_{bh}(bh) = \frac{\sum_{br_b \in bh} w(br_b) \times u_{br}(br_b)}{\sum_{br_b \in bh} w(br_b)} \quad (2)$$

Based on definition 6, we give two notations.

NOTATION 1. $u_{bh}(bh|_{\geq\sigma}) = \frac{\sum_{br_b \in bh, pm_i \geq \sigma} w(br_b) \times u_{br}(br_b)}{\sum_{br_b \in bh, pm_i \geq \sigma} w(br_b)}$

NOTATION 2. $u_{bh}(bh|_{\geq\sigma}) = \frac{\sum_{br_b \in bh, pm_i \leq \sigma} w(br_b) \times u_{br}(br_b)}{\sum_{br_b \in bh, pm_i \leq \sigma} w(br_b)}$

Based on the basic concepts defined above, we describe the adaptive strategy. We refer to the increase and decrease of the profit margin as a positive and negative adjustment respectively and use a variable δ to indicate it: if the previous adjustment is positive, then $\delta = 1$, otherwise $\delta = -1$. We use u and u' to denote the approximate utilities of the most and the second most recent bidding records. We also use pm to denote the current profit margin, and use pm' to denote the profit margin before the previous adjustment.

Algorithm 1 Adaptive strategy

1: $pm = \eta$, $step = \theta$, $\delta = 1$ and $u' = 0$.
2: **while** auction does not finish **do**
3: Use profit margin of pm to bid for the current round
4: **if** a new bidding record br_b is formed **then**
5: Update bh and compute $u_{br}(br_b)$.
6: $u = u_{br}(br_b)$ and $pm' = pm$.
7: ChangeStep();
8: **if** $u = 0$ and $u' = 0$ **then**
9: $pm = pm - step$
10: **else if** $u \neq 0$ and $u' \neq 0$ **then**
11: **if** $u < u'$ **then**
12: $pm = pm - \delta \times step$
13: **else if** $u \geq u'$ **then**
14: $pm = pm + \delta \times step$
15: **end if**
16: **else if** $u = 0$ or $u' = 0$ **then**
17: Compute $u_{bh}(bh|_{\geq\sigma})$ and $u_{bh}(bh|_{\leq\sigma})$
18: **if** $u_{bh}(bh|_{\geq\sigma}) > u_{bh}(bh|_{\leq\sigma})$ **then**
19: $pm = pm + step$
20: **else if** $u_{bh}(bh|_{\geq\sigma}) \leq u_{bh}(bh|_{\leq\sigma})$ **then**
21: $pm = pm - step$
22: **end if**
23: **end if**
24: **if** $pm > pm'$ **then**
25: $\delta = 1$
26: **else if** $pm < pm'$ **then**
27: $\delta = -1$
28: **end if**
29: $u' = u$
30: **end if**
31: **end while**

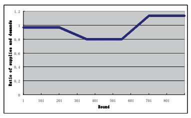
The adaptive strategy is illustrated in Algorithm 1. Its general idea is that the bidder use pm as his profit margin to bid in the auction, and change its value every time when encountering a new bidding record. In the first case where both u and u' are 0, it is believed that the current profit margin is too high to win and should be decreased by a certain degree (line 8-9). In the second case that neither u and u' do not equal to 0, the profit margin is adjusted as follows: if the previous adjustment of the profit margin, which is recorded by δ, has led to a decrease of the approximate utility, a different adjustment will be made, otherwise, a same adjustment will be made (line 10-15). A different and same adjustment means that the previous and next adjustment are different and same respectively. In the last case when only one of the two approximate utilities is 0, the bidder first computes $u_{bh}(bh|_{\geq\sigma})$ and $u_{bh}(bh|_{\leq\sigma})$, and then make the decision according to their relationship. If the former is smaller than the latter, which means that decreasing the profit margin will obtain a higher average approximate utility, the bidder will make a negative move, otherwise the bidder will make a positive move (line 16-22). Note that the function "ChangeStep" (line 7) will decrease or increase $step$ under certain conditions to ensure the convergence accuracy and speed of the adaptive strategy, which is not discussed here due to space limitation.

3. SIMULATION RESULTS

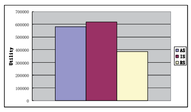
We compare the performances of the random strategy (RS), the adaptive strategy (AS) and the intelligent strategy (IS) by the accumulated utility of the test bidder using them in the market. Random strategy is a strategy that bidder use random numbers as profit margins for different bidding records. Intelligent strategy is a strategy that artificially generated according to prior knowledge of the market, which is estimated by iterative runs in static markets.

We use the ratio of total supplies and demands to denote a market and say it is a n:1 market if such ratio equals to n:1.

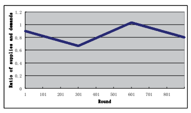
Figure 2 shows the experiment results. The left column shows three dynamic markets which are characterized by the ratio of supplies and demands, and the right column shows the accumulated utilities of the test bidder using three strategies in these markets. From the results, we can see that the performance of the adaptive strategy is fairly well when compared with the intelligent strategy and the random strategy. The bidder using the intelligent strategy can be regarded as having prior knowledge about the market and will always use the optimal profit margin; while the bidder using the random strategy can be regarded as having no prior knowledge about the market and will use a random profit margin for each bidding record. Therefore, it it very impressive that the bidder using the adaptive strategy can obtain high utilities in different markets even without any prior knowledge.



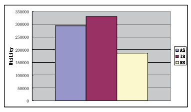
(a) Dynamic Market I



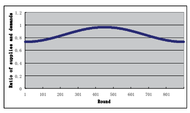
(b) Comparison of Strategies



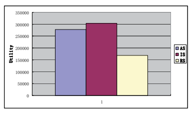
(c) Dynamic Market II



(d) Comparison of Strategies



(e) Dynamic Market III



(f) Comparison of Strategies

Figure 2: Performances of AS, RS and IS in Dynamic Markets

4. CONCLUSIONS

In this paper, we propose a new adaptive bidding strategy for combinatorial auctions-based resource allocation. The bidder adopting this strategy can adjust his profit margin from time to time according to his bidding history and thus perceive and respond to the changing market environment. Through experiments, we show that the adaptive strategy performs fairly well in different dynamic markets and the bidder using this strategy can obtain high utilities when compared to the bidding using the random strategy and the intelligent strategy, even without any prior knowledge.

5. REFERENCES

[1] P. Cramton, Y. Shoham, and R. Steinberg. *Combinatorial Auctions*. MIT Press, Cambridge, Massachusetts, 2006.