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RESEARCH ARTICLE

Impact of Information Feedback in Continuous Combinatorial Auctions: An Experimental Study of Economic Performance

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Appendix A

Design of Real-Time Bidder Support

We build upon the real-time bid evaluation metrics developed by Adomavicius and Gupta (2005) that can present bidders with exact price information whenever a bidder wants to explore her alternatives, thereby providing a continuous environment. In this appendix, we provide technical details of the computational real-time bidder support capabilities.

Let $\boldsymbol{I}$ be the set of distinct items to be sold in a combinatorial auction, and let $N = |\boldsymbol{I}|$. The terms *auction set* and *auction size* refer to $\boldsymbol{I}$ and N, respectively. Bidders can place bids on any *item set*, which refers to any non-empty subset of $\boldsymbol{I}$. A bid b can be represented by the tuple $b = (S, v, id)$. Here S denotes the item set the bid was placed on ($\varnothing \subset S \subseteq \boldsymbol{I}$), also called the *span* of the bid; v denotes the *value* of the bid ($v > 0$), for example, the monetary amount specified in the bid; and id denotes the *bidder* who submitted this particular bid. Given bid b, $S(b)$, $v(b)$, and $id(b)$ are used to refer to the span, value, and bidder of the bid, respectively. We also use the notion of *auction states*. In particular, auction state k (where $k = 0, 1, 2, \ldots$) refers to the auction after the first k bids are submitted. The bid set is denoted as B_k, that is, $B_k = \{b_1,\ldots,b_k\}$. Auction state 0 refers to the auction before any bids are made, i.e., $B_0 = \varnothing$. Obviously, $B_k \subseteq B_l$, for any k and l such that $k \leq l$.

Given an arbitrary set of bids B in a combinatorial auction, a bid set C (where $C \subseteq B$) is called a *bid combination in B* if all bids in C have non-overlapping spans, that is, for every $b_x, b_y \in C$ such that $b_x \neq b_y$, we have $S(b_x) \cap S(b_y) = \varnothing$. Let C_k denote the set of all bid combinations possible at auction state k, or, more formally, $C_k = \{ C \subseteq B_k \mid b_x, b_y \in C,\ b_x \neq b_y \Rightarrow S(b_x) \cap S(b_y) = \varnothing \}$. We assume that the winners of the auction are determined by maximizing the seller's revenue, that is, $\max_{C \in C_k} \sum_{b \in C} v(b)$, which is a standard assumption in the combinatorial auction research literature. The bid combination that maximizes this expression is called a *winning bid combination* and is denoted as WIN_k (for auction state k). Moreover, given auction state k, bid $b \in B_k$ is called a *winning bid* in B_k if $b \in WIN_k$. Furthermore, if bid $b \in B_k$ is not a winning bid in B_k and cannot possibly be a winning bid in *any* subsequent auction state, then b is called a *dead bid* in B_k. Formally, bid $b \in B_k$ is dead if $b \notin WIN_k$ and $(\forall B_l \supseteq B_k)(b \notin WIN_l)$. The set of all dead bids in B_k is denoted as $DEAD_k$. On the other hand, if $b \notin DEAD_k$ then bid $b \in B_k$ is called a *live bid* in B_k. The set of all live bids in B_k is denoted as $LIVE_k$. Based on the definitions of WIN_k, $DEAD_k$, and $LIVE_k$, it is easy to see that (1) $DEAD_k \cap LIVE_k = \varnothing$ and $DEAD_k \cup LIVE_k = B_k$ (i.e., at any auction state k any bid $b \in B_k$ can either be live or dead, but not both), (2) $WIN_k \subseteq LIVE_k$ (i.e., every winning bid is obviously live), and (3) $DEAD_k \subseteq DEAD_{k+1}$ (i.e., once a bid becomes dead, it can never become live again).

Now, assume that an auction participant is interested in bidding on a bundle, say $X \subseteq \boldsymbol{I}$. It is important for a bidder to know how much she should bid on X at a given time (i.e., at any auction state k) in order to guarantee that her bid is either winning or at least stands a chance of winning in the future (i.e., it is not dead). For this purpose the following bid evaluation metrics are used (Adomavicius and Gupta 2005):

1. Bid *winning level* (WL): for item set X at auction state k, $WL_k(X)$ denotes the minimal value that auction participants have to bid on item set X in order for this bid to be winning. In other words, after k bids have already been submitted, any bid b_{k+1} on item set X that has value above $WL_k(X)$ will be winning (i.e., $v(b_{k+1}) > WL_k(X)$ where $X = S(b_{k+1})$ implies $b_{k+1} \in WIN_{k+1}$).

2. Bid *deadness level* (DL): for item set X at auction state k, $DL_k(X)$ denotes the minimal value that auction participants have to bid on item set X in order for this bid to be *live*. Similar to above, after k bids have already been submitted, any bid b_{k+1} on item set X that has value above $DL_k(X)$ will be *live* (i.e., $v(b_{k+1}) > DL_k(X)$ where $X = S(b_{k+1})$ implies $b_{k+1} \in LIVE_{k+1}$).

References

Adomavicius, G., and Gupta, A. 2005. "Towards Comprehensive Real-Time Bidder Support in Iterative Combinatorial Auctions," *Information Systems Research* (16:2), pp. 169-185.

Appendix B

Screenshots of the Auction Interface

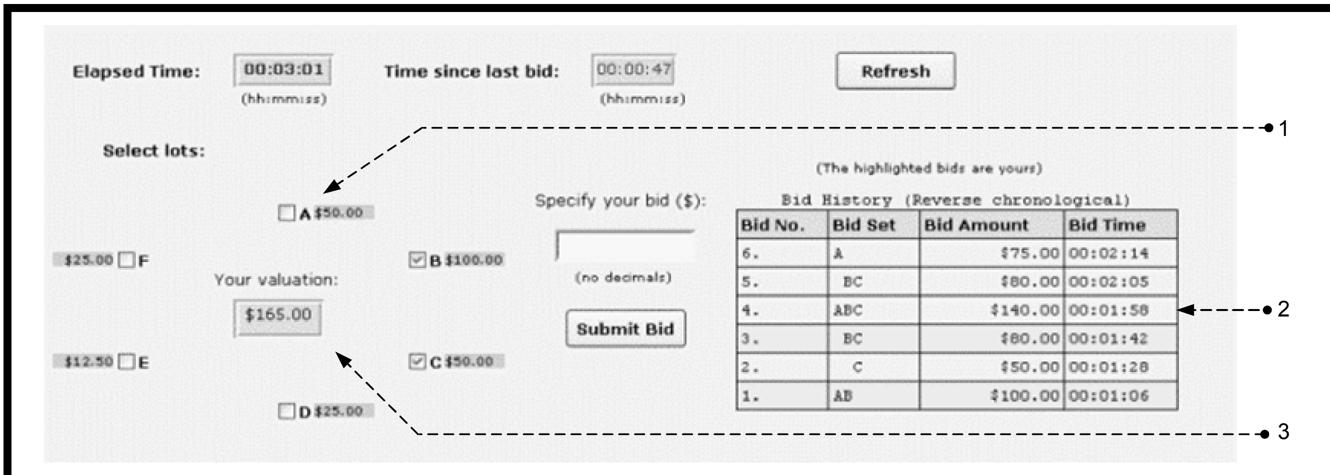

Figure B1. Auction Interface for Baseline Feedback

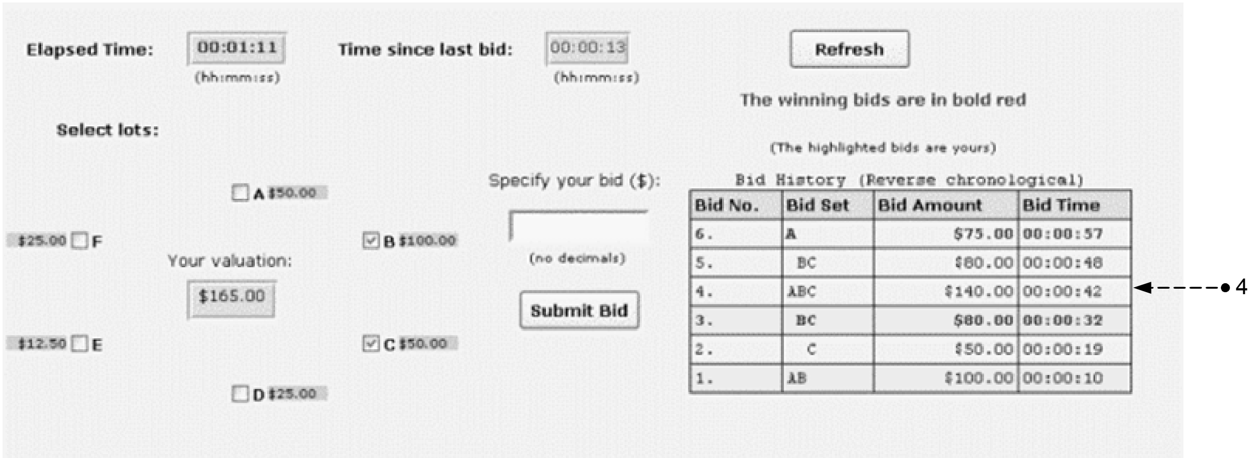

Figure B2. Auction Interface for Outcome Feedback

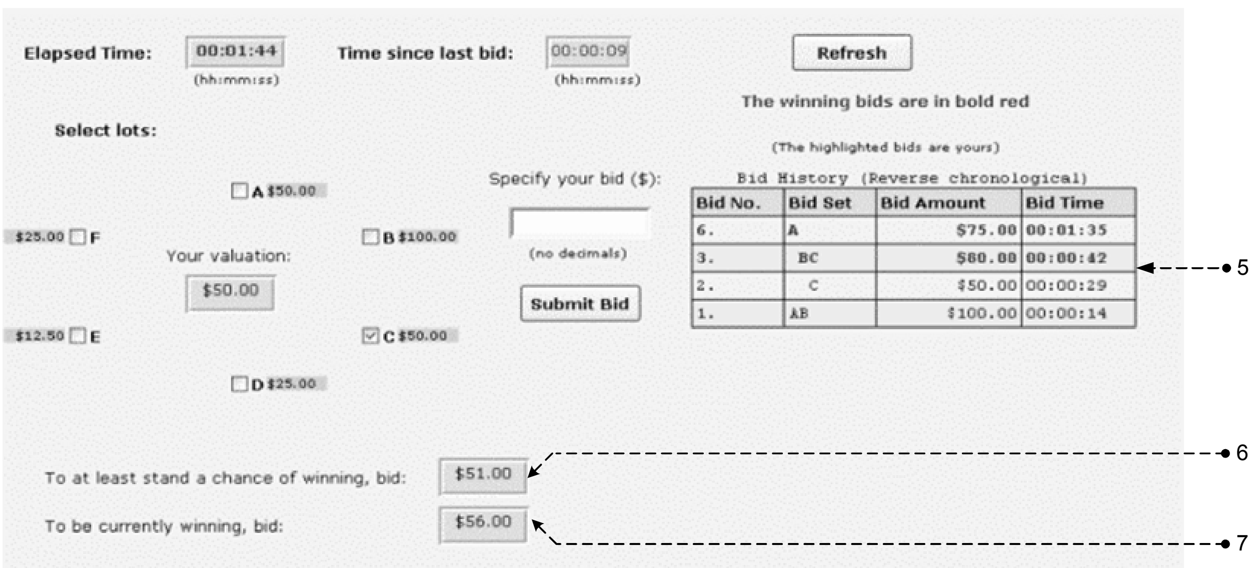

Figure B3. Auction Interface for Price Feedback

Appendix C

Descriptions of Experimental Interface Elements Marked in Appendix B

Interface Element	Description
1	Any individual lot or a combination of lots could be selected by simply clicking on the check boxes beside each lot. The amounts next to the check boxes denote the valuations of the individual property lots. These amounts were displayed during the entire course of the auction.
2	This table displayed all of the placed bids in the baseline feedback case. All of the bids placed by a particular bidder were highlighted on his/her screen.
3	This label displayed the valuation of the selected individual lot or bundle. The valuation of the bundle {B,C} in this example is $165.00.
4	This table displayed all of the placed bids in the outcome feedback case. All of the bids placed by a particular bidder were highlighted on his/her screen as in the baseline case. Furthermore, all of the provisionally winning bids were identified in bold red at all stages of the auction.
5	This table displayed all of the non-losing bids in the price feedback case. All losing bids were removed from display (e.g., as can be seen from this table, bids 4 and 5 are not displayed). All of the bids placed by a particular bidder were highlighted on his/her screen as in the other two cases. Further, all of the provisionally winning bids were identified in bold red at all stages of the auction as in the outcome feedback case.
6	This label displayed the minimum price for placing a non-losing bid on a chosen bundle. In this example, the current minimum price for placing a non-losing bid on Lot C is $51.00.
7	This label displayed the minimum price for placing a winning bid on a chosen bundle. In this example, the current minimum price for placing a winning bid on Lot C is $56.00.