AI Magazine Volume 23 Number 3 (2002) (© AAAI)

The Timing of Bids in Internet Auctions

Market Design, Bidder Behavior, and Artificial Agents

Axel Ockenfels and Alvin E. Roth

■ Many bidders in eBay use bidding strategies that involve late bids, incremental bids, or both. Based on field evidence, we discuss the manner in which late bids are caused both by sophisticated, strategic reasoning and by irrationality and inexperience; the interaction of late bidding with incremental bidding; and the relation between market design and artificial agent design.

Game theorists and market designers focus on the impact of the rules of the game on the behavior of the participants. Participants in internet markets can be human bidders bidding in person or artificial agents used by human bidders. Thus, the performance of market rules depends on what behavior the rules elicit from human and artificial agents. At the same time, the performance of software agents, and the decisions of bidders whether to use them, depends on how they interact with humans and other software agents in the market. Thus, market design and artificial agent design are closely related.

In this article, we report on an ongoing study of internet auctions. We focus here on how a small difference in the rules used in auctions run by eBay and Amazon, both of which supply bidders with simple software agents, elicit different behavior from bidders and different use of software agents. We briefly consider how these issues look from the perspectives of the buyers, the sellers, the market makers (the auction houses), and the third-party suppliers of software agents. (The results and data discussed here are taken from Ariely, Ockenfels, and Roth 2002; Ockenfels and Roth 2001; Roth and Ockenfels 2002).

One of the big attractions of internet auctions is that buyers do not all have to gather at the same place to participate, so that sellers can use internet auctions to sell even relatively low-value items to a potentially wide audience. However, the size of the market would be limited if all potential bidders had to be online at the same time, and for this reason, most auctions are conducted over a period of days, often a week. To make it simple for bidders to participate in a week-long auction, without having to be constantly vigilant, or to be online at the close of the auction, most internet auction houses make available a simple kind of software bidding agent; eBay calls it *proxy bidding*.

eBay asks the bidders to submit maximum bids (called *proxy bids*) and explains that "eBay will bid incrementally on your behalf up to your maximum bid, which is kept secret from other eBay users." That is, once a bidder submits his/her *maximum bid,* his/her resulting bid registers as the minimum increment above the previous high bid. As subsequent proxy bids by other bidders come in, the bid of the bidder in question automatically rises by the minimum increment until the second-highest submitted proxy bid is exceeded (or until his/her own maximum is exceeded by some other bidder). At the end of the auction, the bidder who submitted the highest proxy bid

Copyright © 2002, American Association for Artificial Intelligence. All rights reserved. 0738-4602-2002 / $2.00

wins the object being auctioned and pays a price that is a small increment above the second-highest maximum (proxy) bid.[1]

To understand the bidding behavior that the proxy bidding system elicits, it will help to first consider how different the auction would be if instead of informing all bidders about the bid history at each point of time during the auction, the auction were a second-price sealed-bid auction (in which nobody is informed about the proxy bids of other bidders until the auction is over). Then, the proxy bidding agent provided by eBay would make incremental or multiple bidding unnecessary. Suppose, for example, that your maximum willingness to pay for an antique coin auctioned on eBay were $100. Then, bidding your maximum willingness to pay in a second-price sealed-bid auction is your *dominant strategy;* that is, you can never do better than by bidding $100. The reason is that your proxy bid does not affect the price of the coin in case you win the auction (recall that the price is determined by the second-highest proxy bid). Your proxy bid only determines whether you win the auction. If you submit your maximum willingness to pay, you will win the auction if and only if your maximum is higher than the price; so, there is no reason to over- or understate your willingness to pay.

eBay explains the economics of second-price auctions to their bidders along these lines and extends the conclusion to its own auctions, in which bids are processed as they come in: "eBay always recommends bidding the absolute maximum that one is willing to pay for an item early in the auction. (…) If someone does outbid you toward the last minutes of an auction, it may feel unfair, but if you had bid your maximum amount up front and let the Proxy Bidding system work for you, the outcome would not be based on time." The underlying idea is, of course, that eBay's bidding agent will bid as high as the maximum bid only when some other bidder has bid as high or higher. If the bidder has submitted the highest proxy bid, he/she wins at the *lowest possible price* of one increment above the next-highest bid. Thus, similar to the second-price sealed-bid auction described earlier, at the end of the auction, a proxy bid wins only if it is the highest proxy bid, and the final price is the minimum increment above the second-highest submitted proxy bid, regardless of the timing of the bid. As we show later, however, proxy bidding does not necessarily remove the incentives for late or incremental bidding in these second-price auctions in which bids are processed as they come in, nor do bidders behave as if they thought it did.

A First Look at Bidding Behavior

Looking at the bid histories of completed auctions on eBay, two common properties of bidding strategies become quickly evident: First, a substantial fraction of (human or artificial) agents submit their bids in the closing seconds of an auction, a practice called *sniping*. Second, many bidders bid multiple times, which means that they increase a maximum bid submitted earlier in the auction.

Figure 1 shows the empirical cumulative probability distribution of the timing of bidders' last bids in a sample of 308 eBay auctions of computers and antiques with a total of 1339 bidders. It illustrates that although eBay auctions usually last one week, many bidders bid in the very last minutes of the auctions. For example, 14 percent of all bidders in this sample submitted their final bids in the last 5 minutes, 9 percent in the last minute, and more than 2 percent in the last 10 seconds before the deadline.

At least some bidders like to bid late, sometimes very late. A survey of late bidders reported in Roth and Ockenfels (2002) revealed that most are bidding late by hand, which requires them to be online at the end of the auction. However, because this involves a good deal of planning and effort, there is a market for *sniping agents* that will allow a bidder not only to submit a proxy bid but to do so at the last moment. Sniping agents take two forms: (1) downloadable programs that run on the bidder's own computer and (2) web-based services to which a bidder can subscribe. Both offer bidders the ability to decide on their maximum bid early in the auction, record when the auction is scheduled to end, and decide how many minutes or seconds before the end of the auction the sniping agent should (attempt to) submit the bid.

One of the most interesting of these bidder agents is the web-based service esnipe.com. It was originally developed as a free service, and after building a user base, it was sold, at auction, on eBay. The auction began on 21 November 2000 and was scheduled to end precisely 10 days later on 1 December. Figure 2 shows the bid history. Note that the auction ended at precisely 18:08:38 Pacific Standard Time. The very first bid in this 10-day auction was entered on day 10 of the auction, the last day. The last three bids, including the bid that won the auction at a final price of $35,877.77, came in the last minute during which time the price rose over $10,000, from $25,300 (one increment over the second-highest bid one minute before the end).

Note, incidentally, that the winning bid was

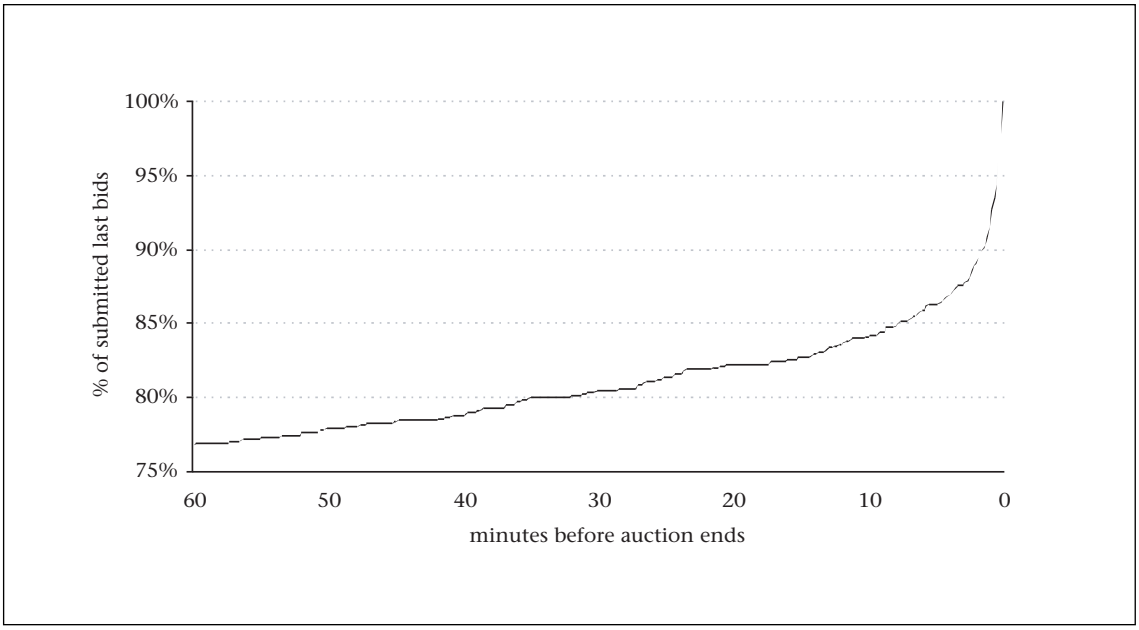


Figure 1. Cumulative Distributions of Bidders' Last Bids over Time (Ockenfels and Roth 2001).

not the last bid; the winning bid came in 10 seconds before the last bid but with a higher proxy bid.[2] However, these bids came in so late—the last bid came in only four seconds before the end of the auction—that the losing bidders had no time to revise their bids, even if they wanted to.

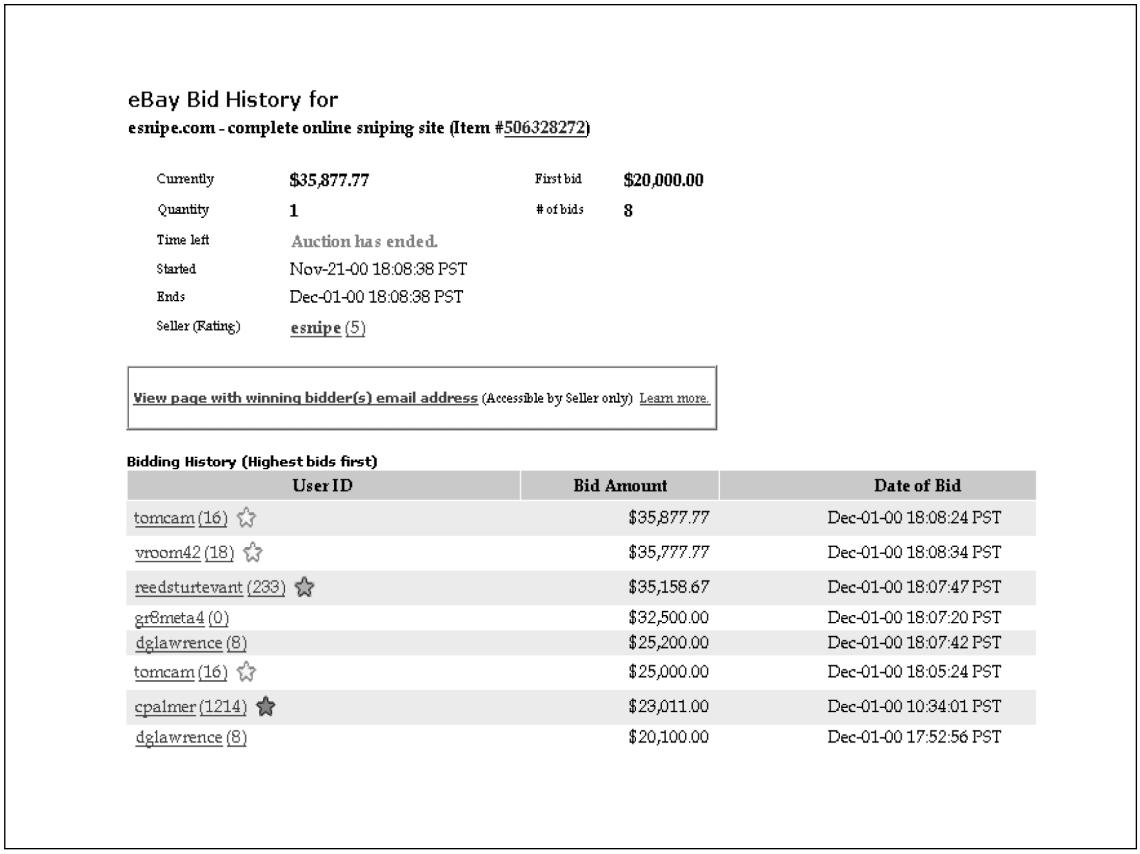
Note also that before the last seconds of the auction, some bidders did want to revise their bids after being outbid by other bidders. Two of the bidders, including the winning bidder, bid more than once. The bidder with user name *dglawrence* made the first bid, and later, with less than a minute until the end of the auction, raised his/her maximum by $5,100. The winning bidder, with user name *tomcam*, placed his/her first proxy bid with just over 3 minutes to go and then raised it by more than $10,000 with just seconds to go.

That is, not only do bidders want to bid late, they might want to bid more than once. This behavior is also not uncommon behavior. Although most (human or artificial) bidders (62 percent) from the sample represented in figure 1 bid only once, many bidders increase their bid in the course of the auction. The average number of bids for each bidder is 1.89.

Thus, we see that bidders are not using the eBay proxy bidding agent as eBay advises, to bid once early in the auction. This is what has opened the door for third parties to offer their own bidding agents to eBay bidders. To understand what is going on, we next consider why it is that bidders might want to bid late.

Last-Minute Bidding and Bidding Wars

There are risks in last-minute bidding. Because the time it takes to place a bid can vary considerably because of, for example, internet congestion or connection times, last-minute bids have a positive probability of being lost. In a survey of 73 bidders who successfully bid at least once in the last minute of an eBay auction, 86 percent replied that it happened at least once to them that they started to make a bid, but the auction was closed before the bid was received (Roth and Ockenfels 2002). Humans and artificial agents do not differ in this respect. The online sniping agent esnipe.com admits that it cannot make sure that all bids are actually placed: "We certainly wish we could, but there are too many factors beyond our control to guarantee that bids always get placed. While we have a very good track record of placed bids, network traffic and eBay response time can sometimes prevent a bid from being completed successfully. This is the nature of sniping."[3] However, although this danger creates an incentive not to bid too late, there are also incentives not to bid early in the auction, when there is still time for other bidders to react, avoiding a bidding war that will raise the final transaction price. In particular, we identify three distinct kinds of bidding wars: (1) with incremental bidders, (2) with like-minded late bidders, and (3) with uninformed bidders who look to others' bids to determine the value of an item.[4]



eBay Bid History for

esnipe.com - complete online sniping site (Item #506328272)

Currently	$35,877.77	First bid	$20,000.00
Quantity	1	# of bids	8
Time left	Auction has ended.		
Started	Nov-21-00 18:08:38 PST		
Ends	Dec-01-00 18:08:38 PST		
Seller (Rating)	esnipe (5)		

View page with winning bidder(s) email address (Accessible by Seller only) Learn more.

Bidding History (Highest bids first)

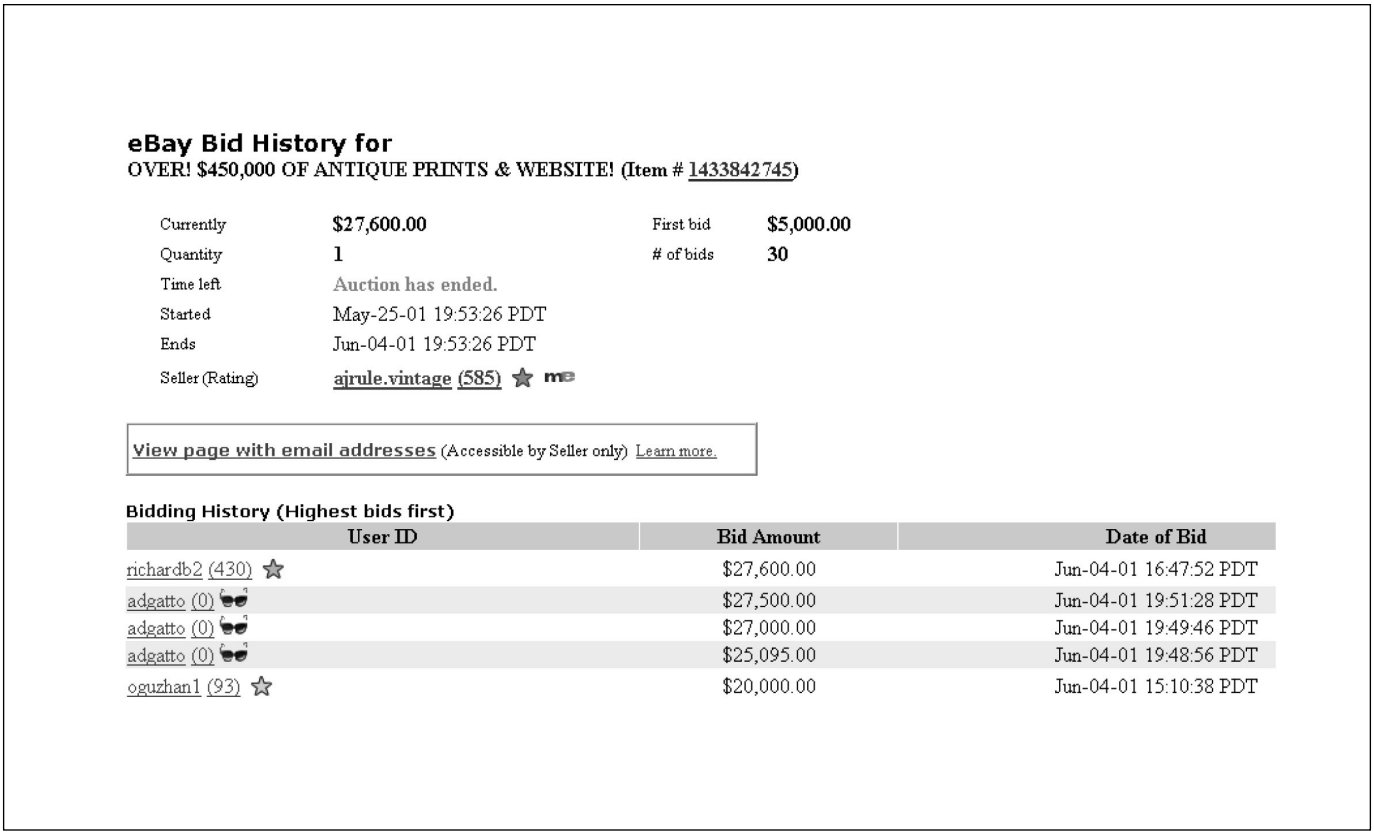
User ID	Bid Amount	Date of Bid
tomcam (16)	$35,877.77	Dec-01-00 18:08:24 PST
vroom42 (18)	$35,777.77	Dec-01-00 18:08:34 PST
reedsturtevant (233)	$35,158.67	Dec-01-00 18:07:47 PST
gr8meta4 (0)	$32,500.00	Dec-01-00 18:07:20 PST
dglawrence (8)	$25,200.00	Dec-01-00 18:07:42 PST
tomcam (16)	$25,000.00	Dec-01-00 18:05:24 PST
cpalmer (1214)	$23,011.00	Dec-01-00 10:34:01 PST
dglawrence (8)	$20,100.00	Dec-01-00 17:52:56 PST

Figure 2. The Bid History of the Auction of esnipe.com.

Bidding Late to Avoid Bidding Wars with Incremental Bidders

Last-minute bidding can be a best reply to incremental bidding. To see why, put yourself in the place of the bidder described earlier, who is willing to pay as much as $100 for an antique coin. Moreover, suppose that there is only one other potential bidder and that you believe that this bidder is willing to pay more than you for the coin, say, $110. This other bidder, however, bids incrementally, that is, he/she starts with a bid well below his/her maximum willingness to pay and is then prepared to raise his/her proxy bid whenever he/she is outbid as long as the price is below his/her willingness to pay. Last-minute bids can be a best response to this kind of incremental bidding because bidding near the deadline of the auction would not give the incremental bidder sufficient time to respond to being outbid. By bidding at the last moment, you might win the auction at the incremental bidder's initial, low bid, even though the incremental bidder's willingness to pay exceeds your willingness to pay. As esnipe.com puts it, "A lot of people that bid on an item will actually bid again if they find they have been outbid, which can quickly leading to a bidding war. End result? Someone probably paid more than they had to for that item. By sniping, you can avoid bid wars."[5]

Figure 3 shows the bid history of an auction that ended on 4 June 2001 at 19:53:26 PDT. The history reveals that until 16:47 of the last day of the auction, just before the eventual high bidder *richardb2* submitted his/her bid, *oguzhan1* was the high bidder. Then, *richardb2* became the high bidder, at a bid (well below his/her proxy bid) of $20,100, one increment over the then second-highest proxy bid of $20,000. With about 5 minutes left, bidder *adgatto* placed a proxy bid of $25,095 and, finding that this was not a winning bid, raised his/her bid twice in the next few minutes, without, however, becoming the high bidder. Thus, it appears likely that if *richardb2* had bid later than *adgatto,* and too late for him/her to respond, he/she would have saved over $2000 because *adgatto* would likely have been satisfied to be the high bidder with his/her initial proxy bid.



eBay Bid History for
OVER! $450,000 OF ANTIQUE PRINTS & WEBSITE! (Item # 1433842745)

Currently	$27,600.00	First bid	$5,000.00
Quantity	1	# of bids	30
Time left	Auction has ended.		
Started	May-25-01 19:53:26 PDT		
Ends	Jun-04-01 19:53:26 PDT		
Seller (Rating)	ajrule.vintage (585)		

View page with email addresses (Accessible by Seller only) Learn more.

Bidding History (Highest bids first)

User ID	Bid Amount	Date of Bid
richardb2 (430)	$27,600.00	Jun-04-01 16:47:52 PDT
adgatto (0)	$27,500.00	Jun-04-01 19:51:28 PDT
adgatto (0)	$27,000.00	Jun-04-01 19:49:46 PDT
adgatto (0)	$25,095.00	Jun-04-01 19:48:56 PDT
oguzhan1 (93)	$20,000.00	Jun-04-01 15:10:38 PDT

Figure 3. Late Bidding as Best Response to Incremental Bidding.

Bidding Late to Avoid Bidding Wars with Like-Minded Bidders

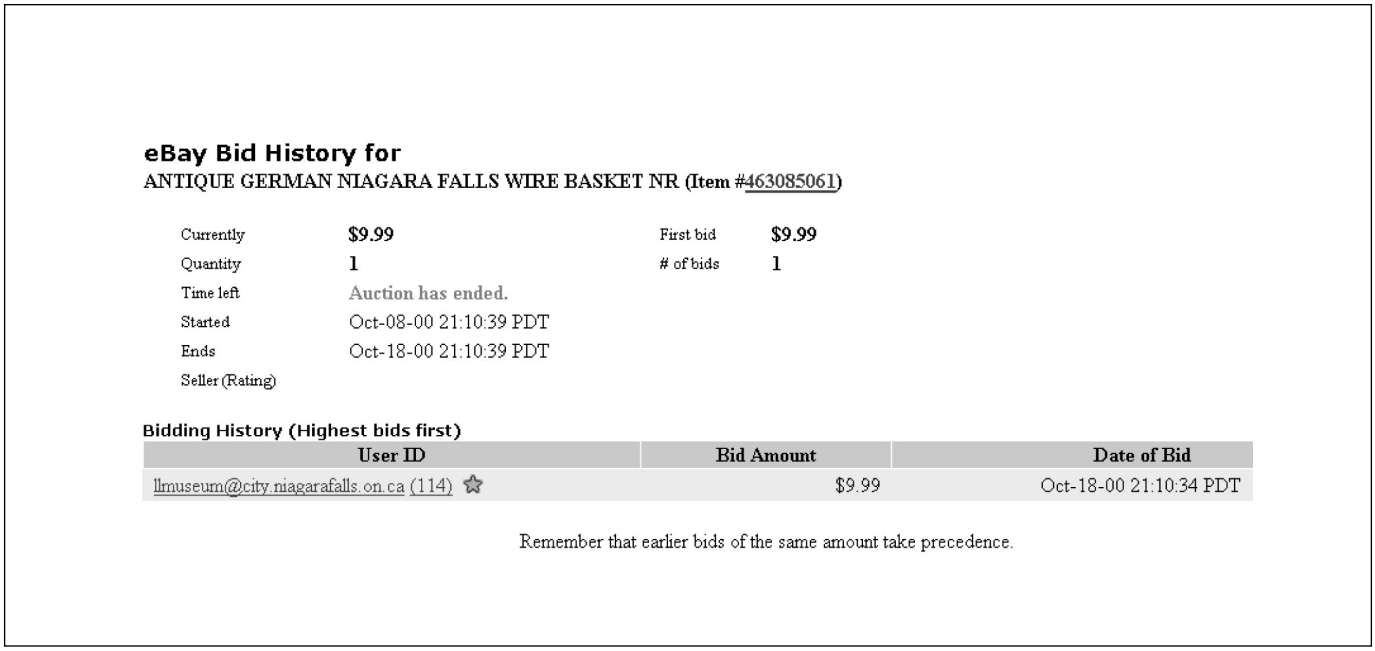
Bidding late can also be the best response to the late bidding strategies of like-minded bidders. As an example, suppose that you are willing to pay as much as $100 for an antique coin and that there is only one other potential bidder who you believe also has a willingness to pay about $100. If both of you submit your value early, you will end up with a second-highest submitted proxy bid of about $100, implying a price of about $100. Thus, regardless of whether you win, your *earnings* (calculated as your value minus the final price if you are the winner and zero if you are the loser) would be close to zero.

Now consider a strategy that calls for a bidder to bid $100 at the very last minute and not to bid earlier unless the other bidder bids earlier. If the other bidder bids earlier, the strategy calls for a bidder to respond by promptly bidding his/her true value. If both bidders follow this strategy and mutually delay their bids until the last minute, both bidders have positive expected profits because there is a positive probability that one of the last-minute bids will not be transmitted successfully; in which case, the winner only has to pay the (small) minimum bid. However, if a bidder deviates from this strategy and bids early, his/her expected earnings are (approximately) zero because of the early price war triggered by the early bid. Thus, following the last-minute strategy, expected bidder profits will be higher and seller revenue lower than when everyone bids true values early (see Ockenfels and Roth [2001] for a game-theoretic model and formal proof that mutual late bidding can constitute equilibrium behavior).[6]

Bidding Late to Protect Information in Auctions with Interdependent Values

There are additional strategic reasons to bid late in auctions with interdependent values (*common value auctions*). As an example, suppose you are a dealer of antique coins who can distinguish whether a coin is genuine or worthless. Suppose you identify an antique coin auctioned in eBay as genuine and that your maximum willingness to pay is $100. Another potential bidder, however, is not an expert and, thus, cannot tell whether the coin is genuine or worthless but values a genuine coin higher than you, say, $110. What should you do?

When values are interdependent, as in this



eBay Bid History for
ANTIQUE GERMAN NIAGARA FALLS WIRE BASKET NR (Item #463085061)

Currently	$9.99	First bid	$9.99
Quantity	1	# of bids	1
Time left	Auction has ended.		
Started	Oct-08-00 21:10:39 PDT		
Ends	Oct-18-00 21:10:39 PDT		
Seller (Rating)			

Bidding History (Highest bids first)

User ID	Bid Amount	Date of Bid
llmuseum@city.niagarafalls.on.ca (114) ☆	$9.99	Oct-18-00 21:10:34 PDT

Remember that earlier bids of the same amount take precedence.

Figure 4. Late Bidding to Protect Information.

example, the bids of others can carry valuable information about the item's value that can provoke a bidder to increase his/her willingness to pay. This creates incentives to bid late because by bidding late, less informed bidders can incorporate into their bids the information they have gathered from the earlier bids of others, and experts can avoid giving information to others through their own early bids. Specifically, in the scenario described earlier, if the minimum bid is positive, and the probability that the coin is worthless is sufficiently high, the uninformed bidder should not bid unless the expert submitted a bid earlier and, thus, signaled that the coin is genuine. Bidding without such a signal from the expert would run the risk of losing money by paying the minimum price for a worthless coin. Such conditional bidding behavior of uninformed bidders creates, in turn, an incentive for experts to submit the bid for a genuine item very late to, as esnipe.com puts it, "prevent other bidders from cashing in on their expertise." Last-minute bids do not leave sufficient time to uninformed bidders to respond to and outbid experts' bids (see Ockenfels and Roth [2001] for a game-theoretic model).

As an illustration, figure 4 displays the bid history of a completed auction that gives reason to speculate that we might be seeing an expert protecting information. The auction had only one bid, placed so late—five seconds before the deadline—that nobody could respond. This is an antique auction, and antiques might reasonably be expected to have significant scope for asymmetric information among bidders about the authenticity and value of items. The bidder's feedback number of 114 indicates that the bidder is familiar with the rules and bidding strategies in eBay auctions because the bidder must have completed at least 114 eBay auctions as a seller or a high bidder. Finally, the bidder's ID is the e-mail address of Lundy's Lane Historical Museum in the city of Niagara Falls, Canada, suggesting that the bidder is indeed likely to have special expertise on antiques related to Niagara Falls, such as the one in this auction.

Strategic versus Nonstrategic Hypotheses for Late Bidding

There are other, nonstrategic reasons for late bidding, including procrastination, use of search engines that make it easy to find auctions about to end, endowment effects, or management of bidding in multiple auctions in which similar objects might be offered. In a recent article (Roth and Ockenfels 2002), we considered the extent to which strategic and nonstrategic reasons cause late bidding with the help of bid history data from eBay and Amazon. Amazon auctions, although operating under otherwise similar rules as eBay, are automatically extended if necessary past the scheduled end time until 10 minutes have passed without a bid. Although the risks of last-minute bidding remain, the strategic advantages of last-minute bidding are eliminated or severely attenuated in Amazon-style auctions.

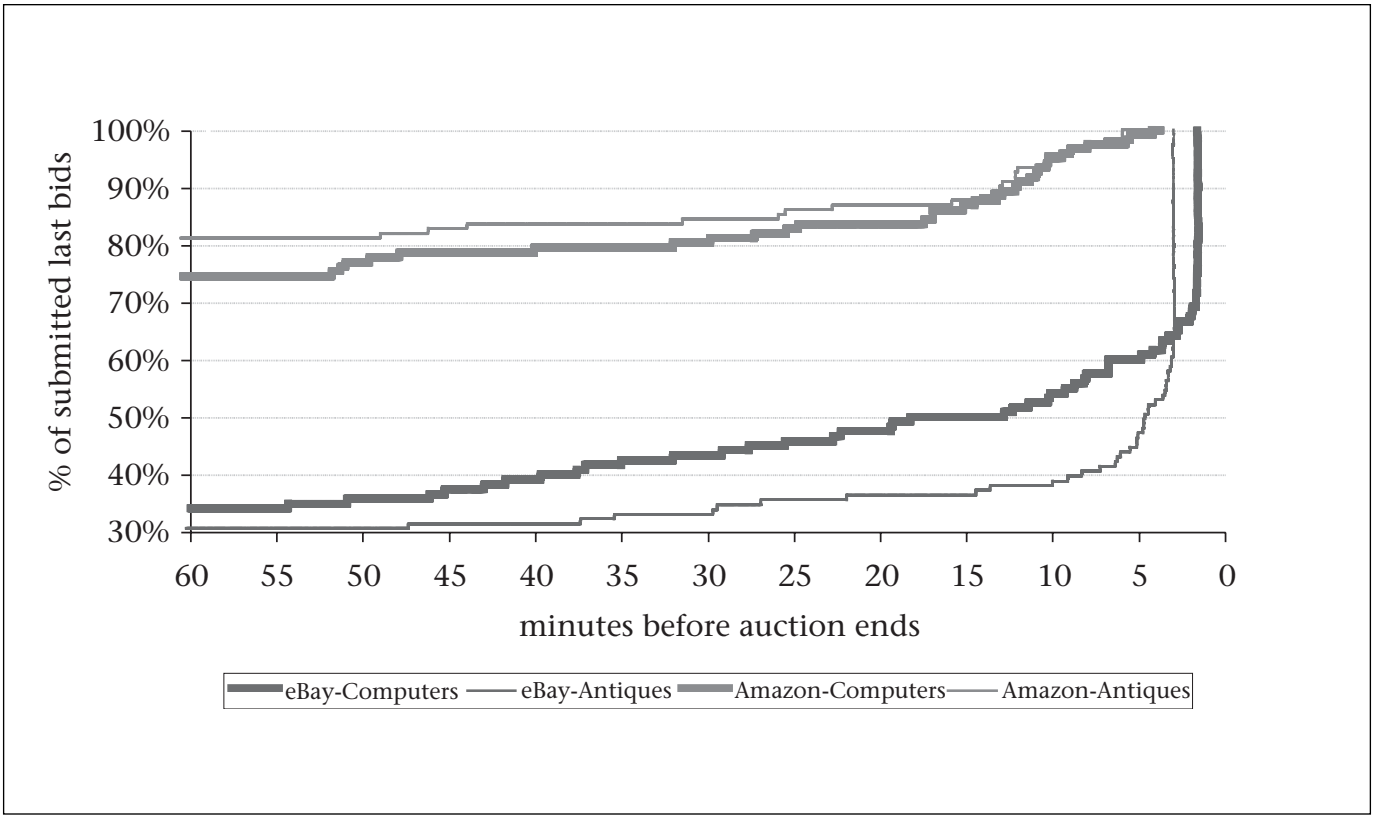


Figure 5. Cumulative Distributions over Time of Auctions' Last Bids (Roth and Ockenfels 2002).[7]

That is, a bidder who waits to bid until the last seconds of the auction still runs the risk that his/her bid will not successfully be transmitted in time. However, if his/her bid is successfully transmitted, the auction will be extended for 10 minutes, so that no matter how late the bid was placed, other bidders will have time to respond. Thus on Amazon, an attentive incremental bidder, for example, can respond whenever a bid is placed. The nonstrategic motives for late bidding, however, should be relatively unaffected by the difference in closing rules between eBay and Amazon. Thus, a comparison of bidding patterns between eBay and Amazon auctions offers the possibility of discerning whether the strategic factors we have been discussing do indeed play a significant role in causing bidders to bid late.

Figure 5 shows the empirical cumulative probability distributions of the timing of the last bid in each auction for a sample of 480 eBay and Amazon auctions of antiques and computers with a total of 2279 bidders.

Figure 5 shows that there is significantly more late bidding on eBay than on Amazon. For example, 40 percent of eBay computer auctions and 59 percent of eBay antique auctions in our sample have last bids in the last 5 minutes, compared to about 3 percent of both Amazon computer and Amazon antiques auctions that have last bids in the last 5 minutes before the initially scheduled deadline or later. Further analyses reveal that the impact of the bidders' feedback numbers on late bidding is significantly positive in eBay and negative in Amazon, suggesting that more experienced bidders on eBay bid later than less experienced bidders, but experience in Amazon has the opposite effect. Figure 5 also reveals that significantly more late bidding can be found in antiques auctions than in computer auctions on eBay, suggesting that the expertise effect described in the previous subsection is reflected in the timing of bids.

Both the difference in late bidding between eBay and Amazon auctions and the different amount of late bidding between eBay auctions of computers and antiques suggest that late bidding arises in large part from the rational response of the bidders to the strategic environment.[8] It is worth noting in this context that Amazon auctions have attracted much less interest from third-party suppliers of sniping software. Most of the sniping agents seem to be aimed squarely at eBay, and many (including esnipe) seem to have eBay as their only target.

Incremental Bidding and How It Interacts with Late Bidding

In the data set of Ockenfels and Roth (2001), 38 percent of the bidders bid at least twice. Among these bidders, the large majority submit a new bid after being outbid. In particular, 53 percent of the last bids of incremental bidders are placed after the previous bid was automatically outbid by eBay's *proxy bidding agent* (that is, by another bidder's proxy that was submitted earlier in the auction), 34 percent are placed after the previous bid was outbid by a newly submitted proxy bid of another (human or artificial) bidder, and only 13 percent are placed by the current high bidder (so that the current price is not changed).

One way to explain the multiple-bid phenomenon without positing inexperience or irrationality on the part of the bidders is to note that bidders sometimes can get information from others' bids that causes them to revise their willingness to pay in auctions with interdependent values (see subsection Bidding Late to Protect Information in Auctions with Interdependent Values).[9] However, incremental bidding might also be caused by naïve, inexperienced bidders, who mistakenly treat the eBay auctions like English first-price auctions in which the high bidder pays his/her maximum bid.[10] However, regardless of the causes for incremental bidding, incremental bidders are likely to drive last-minute bidding. First, as explained in Last-Minute Bidding and Bidding Wars, last-minute bidding can be the best response of sophisticated (one-bid) bidders to incremental bidding, regardless of whether incremental bids are caused by unsophisticated first-price bidding or sophisticated information updating over time in auctions with interdependent values. Second, incremental bidders themselves might bid late because bidders who increase their bids after being outbid have an incentive to come back to the auction close to the deadline to check whether they are outbid or just because incremental bidding takes more time than placing a single bid. Indeed, a substantial share of both, one-bid bidders (12 percent) and multiple bidders (16 percent), bid as late as in the last 10 minutes of the eBay auctions (Ockenfels and Roth 2001). However, the data also reveal that among these late bidders, one-bid bidders submit their bid later than incremental bidders.

Thus, many incremental bidders bid late, but one-bid bidders tend to bid even later. Moreover, the data indicate that incremental bidding significantly diminishes with experience (as measured by the bidders' feedback numbers), but last-minute bidding increases with experience. Overall, the analysis of multiple bids supports the hypothesis that last-minute bidding arises at least in part as a response by sophisticated bidders to unsophisticated incremental bidding.

Conclusions

Whether the timing of bids matters depends on the rules of the game. Artificial last-minute bidding agents such as esnipe.com might support human bidders in eBay auctions, but they would hardly help on Amazon, where the closing rule removes or greatly attenuates the incentives to snipe. By the same token, human bidders on Amazon have more reason to make use of the proxy bidding agent provided by the auction houses than bidders on eBay, where the fixed deadline can create incentives to submit the bid late, depending on other (human or artificial) bidders' behavior. Thus, how well different kinds of software agents perform depends on the rules of the game.

As bidders learn from experience how to better take into account the incentives that the rules of the market create, their demand for helpful software agents grows. Changes in bidder behavior and in the availability of bidding agents both also change the strategic environment and the incentives of the other market participants. For example, if sniping and sniping agents become even more widespread on eBay than they are today, eBay would be gradually transformed into a sealed-bid second-price auction. If a large part of the bidding action were taking place on third-party sites such as esnipe, eBay would face a number of choices. One would be to recapture the sniping market by offering a sniping option on eBay itself. (Under this option, last-minute bids submitted in advance directly to eBay could all be counted at the same time, immediately after the auction close, thus giving bidders certainty both that their bids would successfully be transmitted and that there would be no time for other bidders to react.) Of course, if all bidders used this option, the auction would precisely be a sealed-bid auction. eBay, and sellers who list items for sale on eBay, might prefer not to encourage this development (for example, if they believe that bidders are likely to bid more in auctions in which they can form some estimates of how much other bidders value the item for sale). In such a case, eBay's managers could explore other options, such as changing the ending rule of the auction (which, in turn, raises other design issues).

In summary, the problems facing market

designers involve anticipating how participants will respond to the market rules. Internet markets make the adoption of software agents one possible part of this response, and the game-theoretic analysis of the market rules helps anticipate and understand the incentives that drive these responses. Because artificial agents have to be adopted by human agents and have to interact with human, as well as artificial, agents under the rules of the market, the task of the artificial agent designer is also closely related to the strategic analysis facing human agents. Thus, there is going to be a lot of room for market designers and agent designers to talk to, and learn from, each other.[11]

Acknowledgments

Ockenfels acknowledges partial support from the Deutsche Forschungsgemeinschaft through the Emmy Noether-Program. Roth acknowledges partial support from the National Science Foundation.

Notes

1. In case two bidders are tied for the highest bid, the one who submitted it first is the winner. In the following analyses, we assume for simplicity that the price increment is negligibly small. Vickrey (1961) offered the first theoretical analysis of the sealed-bid second-price auction. Since then, economists often refer to the sealed-bid second-price auction as a *Vickrey auction.*

2. The bid history reveals all but the highest proxy bid. The highest proxy bid is not recorded because the final price is one bid increment ($100 at this price level) above the second-highest proxy bid.

3. www.esnipe.com/faq.asp.

4. The following sections are based on Ockenfels and Roth (2001), who offer a game-theoretic analysis of late and incremental bidding strategies; Roth and Ockenfels (2002), who provide field evidence for strategic late bidding; and Ariely, Ockenfels, and Roth (2002), who focus on experimental evidence on the interaction between incremental and multiple bidding.

5. esnipe.com/faq.asp.

6. The fact that late bidding can constitute an equilibrium behavior means that even if bidders initially learn to bid late as a best response to the behavior of inexperienced bidders, there is no reason to expect it to be a transient phenomenon that will disappear as bidders become more experienced.

7. Because Amazon auctions cannot close until 10 bidless minutes have passed, we calculated a *hypothetical deadline* for Amazon auctions for the comparison in figure 5. This hypothetical deadline relevant to a given bid is defined as the current actual deadline at the instant before the bid is placed; that is, it is the time the auction would have ended if the current bid, and any subsequent bids, had not been submitted. Note that this presentation can lead us to overestimate the extent to which Amazon bidders bid late, which would only strengthen our comparative results (Roth and Ockenfels 2002).

8. Experiments of Ariely et al. (2002) reproduce the private-goods effect in a laboratory setting in which the only difference between auctions is the ending rule. The experiment thus controls for differences other than the closing rule that might affect behavior on Amazon and eBay, such as the number of auctions being conducted at any time.

9. Ockenfels and Roth (2001) prove that there can also exist equilibria in auctions with independent values at which bidders can bid both early and very late. Other strategic reasons for multiple bidding include bidding below a secret reservation price because auctions in which the high bid is less than the reserve price sometimes lead to postsale negotiations; so, there is an incentive for a bidder not to bid against himself/herself if he/she is the current high bidder for fear of going over the reservation price and having to pay it in full.

10. Other nonstrategic reasons for multiple bidding include various psychological reasons why a bidder's maximum willingness to pay increases over time.

11. In this connection, see also Roth and Peranson (1999) which describes the design of the *smart market,* which is used to match about 20,000 American physicians a year to their first jobs. In that market, each job applicant, and each employer, submits a preference ordering over the agents on the other side of the market (as well as some other information), and then the market itself is conducted by artificial agents acting on behalf of each applicant and employer.

References

Ariely, D.; Ockenfels, A.; and Roth, A. E. 2002. An Experimental Analysis of Ending Rules in Internet Auctions, Working paper, Harvard University.

Ockenfels, A., and Roth, A. E. 2001. Late Bidding in Second Price Internet Auctions: Theory and Evidence Concerning Different Rules for Ending an Auction, Working paper, Harvard University.

Roth, A. E., and Ockenfels, A. 2002. Last-Minute Bidding and the Rules for Ending Second-Price Auctions: Evidence from eBay and Amazon Auctions on the Internet. *American Economic Review*. Forthcoming.

Roth, A. E., and Peranson, E. 1999. The Redesign of the Matching Market for American Physicians: Some Engineering Aspects of Economic Design. *American Economic Review* 89(4): 748–780.

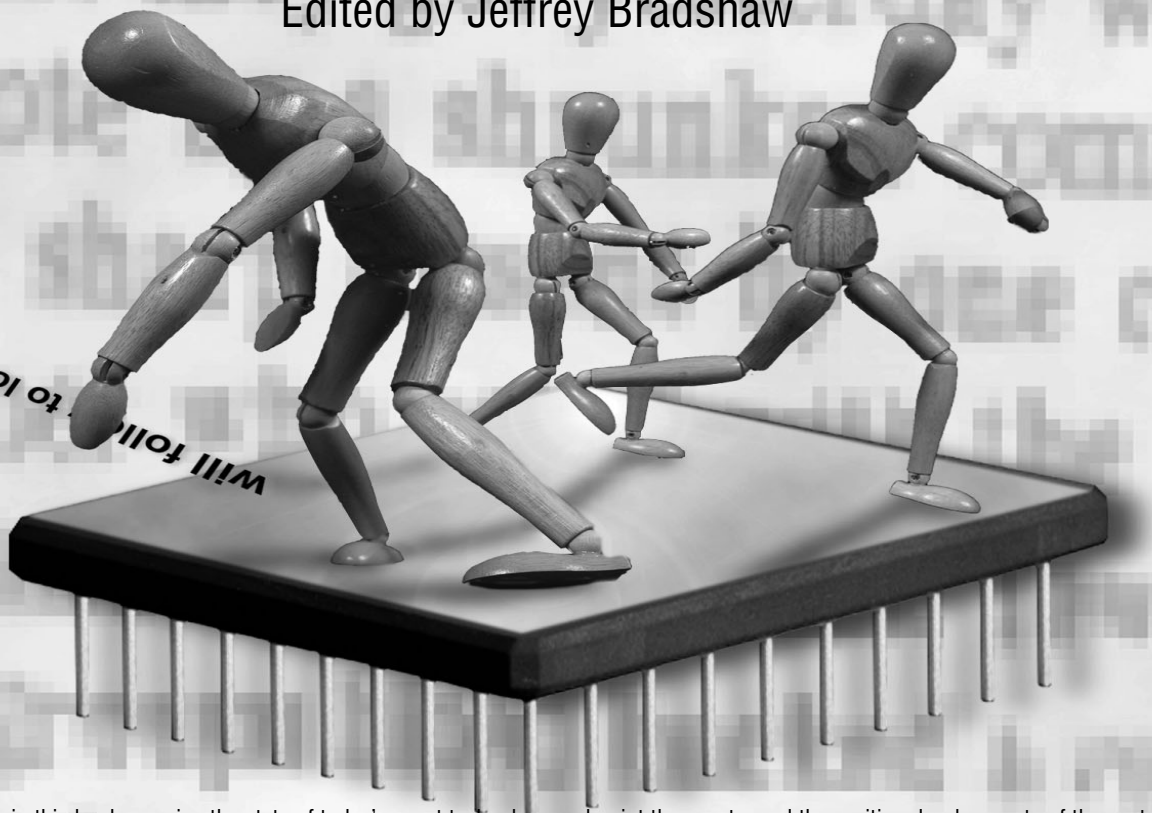
Vickrey, W. 1961. Counterspeculation and Competitive Sealed Tenders. *Journal of Finance* 16(1): 8–37.

Axel Ockenfels graduated from the Economics Department at the University of Bonn (Germany) in 1994 and received his Ph.D. in economics from the Faculty of Economics and Management at the University of Magdeburg (Germany) in 1998. After extended research stays at Pennsylvania State University and Harvard Business School, he is now working at the Max Planck Institute for Research into Economic Systems in Jena, Germany. He is also the head of a research group funded by the German Science Foundation that focuses on the economic design of online markets and the efficiency of online reputation mechanisms. Using game theoretical and experimental methods, he investigates questions such as the design of online auctions, fairness and the evolution of reciprocity in anonymous communities, and the impact of boundedly rational behavior on market outcomes. His e-mail address is ockenfels@mpicw-jena.mpg.de.

Al Roth teaches at Harvard University, where he divides his time between the Economics Department and the Harvard Business School. His work concerns market design, game theory, and experimental economics.

Software Agents

Edited by Jeffrey Bradshaw



The chapters in this book examine the state of today's agent technology and point the way toward the exciting developments of the next millennium. Contributors include Donald A. Norman, Nicholas Negroponte, Brenda Laurel, Thomas Erickson, Ben Shneiderman, Thomas W. Malone, Pattie Maes, David C. Smith, Gene Ball, Guy A. Boy, Doug Riecken, Yoav Shoham, Tim Finin, Michael R. Genesereth, Craig A. Knoblock, Philip R. Cohen, Hector J. Levesque, and James E. White, among others. 500 pp.,ISBN 0-262-52234-9

Published by the AAAI Press / The MIT Press
To order, call 800-405-1619 (http://mitpress.mit.edu)