The Role of Middle-Agents in Electronic Commerce

Itai Yarom and Jeffrey S. Rosenschein, *Hebrew University*

Claudia V. Goldman, *University of Massachusetts*

How does the existence of intermediaries affect the efficiency of electronic markets? The authors look at several strategies for middle-agents, comparing how they—and the markets—did in each case.

As electronic marketplaces proliferated in recent years, many observers predicted the disappearance of middlemen. With consumers reaching producers directly, there would be little need for old-fashioned intermediaries, and the Internet-oiled wheels of commerce would roll along more efficiently than ever.[1]

Things didn't quite work out that way. Although it's true that in some industries, processes of so-called *disintermediation* occurred (one example being the increased sale of tickets by airline Web sites, sometimes removing ticket agents from the distribution channel), in other industries new types of intermediaries arose, providing their own style of added value to electronic commercial interactions. In fact, sometimes this process occurred in parallel with disintermediation within the same industry (for example, Expedia, Orbitz, and others establishing themselves as intermediaries for the sale of airline tickets). Another prominent example is eBay, which established itself as an intermediary through which end users could buy and sell commodities. eBay's success and rapid rise provided a case study on new ways in which an intermediary can provide value to a diverse community on the Web.

Although the sociology of these new intermediaries is fascinating in its own right, we wanted to explore theoretical questions related to the presence of these middlemen in electronic markets. How does the intermediaries' existence affect electronic markets' efficiency? What role is played by the various strategies that these intermediaries might adopt? What happens if they can sign long-term contracts with their suppliers? What if they can pursue more sophisticated pricing strategies?

We developed an electronic marketplace simulation—specifically, a marketplace of information—to explore these questions. Automated agents, which we designed to act as information suppliers, information consumers, or information middlemen (whom we dubbed *InfoCenters*), played all the roles in these simulations. We ran the simulations to test how InfoCenter intermediaries affected the market's efficiency and price behavior. We looked at several different middle-agent strategies, comparing how they—and the market—performed in each case. The bottom line: InfoCenters significantly enhanced the efficiency of our information marketplaces. And more sophisticated InfoCenters did the best of all.

Information marketplaces

Information is particularly well-suited to electronic marketplaces (e-markets), since purchasing information might be time critical and cumbersome using nonelectronic methods. In addition, e-markets have the potential to increase the ways we trade commodities. This would be particularly beneficial for information products—for example, by enabling the buying and selling of pieces of information. Users might be interested in purchasing articles without being obliged to buy an entire journal, or might want to obtain news that's crafted to their personal interests without needing to buy a newspaper subscription.

Information markets pose challenging questions: how should information be "packaged" for sale and how should it be priced? Information is different from other commodities in that it doesn't need to have a single physical existence; it can be presented in various digital formats. For example, we can represent printed information in PDF, PostScript, e-book or e-paper formats, audio information in WAV or

1094-7167/03/$17.00 © 2003 IEEE
Published by the IEEE Computer Society

MP3 formats, and video information in DVD, streaming video, or AVI formats.

Several market mechanisms have achieved popularity in existing e-markets, including auctions, continuous double auctions, and negotiation mechanisms. For our purposes, none of these were suitable, given some specific assumptions about information marketplaces. Auctions take time; a buyer of information might need to wait too long before the auction finishes and the price is set. The original request for information might become irrelevant. In time-critical situations, more straightforward pricing techniques are often preferred. Furthermore, the following pricing method is widely used both in the physical and e-commerce worlds. Dynamic post pricing, proposed by the Information Economies research team at IBM Research Labs,[2,3] is the most common method applied for information commodities: Sellers post their prices and buyers can either buy the commodity at that price or not. Sellers can change prices at any time. We believe this approach offers significant advantages in information marketplaces, and it is the overall technique we adopted in our e-market simulations.

The middle-agent, an InfoCenter

Humans and autonomous agents can play the roles of buyers or sellers in e-markets. It isn't self-evident which of these will perform better in a given market. Autonomous agents can generally exploit more information sources when making decisions (and they never get tired). Yet humans bring levels of intelligence that we have yet to duplicate in software. Will an agent, for example, perform better as a stockbroker than a human? Different e-market scenarios might give different results, but according to Rajarshi Das and his colleagues,[4] software agents can outperform humans in some markets composed of both trading agents and humans. Agents can perform various roles in e-markets, such as pricing agents, price comparison agents that help buyers find the seller with the lowest price, auction bidding agents, recommendation agents, and broker agents. Another contribution to this proliferation of agents is the automated middle-agent, who helps buyers and sellers in e-markets. Middle-agents help with information flow in e-markets by dealing with requests and enhancing other agents' capabilities.[5] These middlemen are neither seller nor buyer agents. While some intermediaries' roles are obsolete in the electronic world, new roles for electronic intermediaries might emerge, including aggregator and disaggregator of information (for example, aggregating several magazines into one information product, or disaggregating magazines into separate articles), provider of trust, and provider of interorganizational market information.

InfoCenter interactions in an e-market

Our research studies a specific kind of broker agent, namely middle-agents that we refer to as InfoCenters. InfoCenters are software agents acting as information intermediaries, and can reside, for example, in a library, at a portal Web site, or at a site that answers user questions. These agents buy information from information suppliers (sellers), sell information to information consumers (buyers), and can obtain manipulated information from information service providers (InfoSPs) which can be automated agents or humans. InfoSPs might, for example, change the format of visual information from JPEG to GIF, adapt the presentation of information for different computing platforms, or combine separate information pieces into one new product.

An InfoCenter can respond to market demand for an information commodity and plan a way to make it available, approaching information sources and InfoSP services.

An InfoCenter can respond to market demand for an information commodity and plan a way to make it available, approaching information sources and InfoSP services. InfoCenters can also provide buyers with new information products that are otherwise unavailable in the market. Moreover, InfoCenters can replace information commodities with more profitable ones, although figuring out what increases profit is not usually a simple task. Approaching InfoSPs with different information commodity requests in different orders might lead to different resulting products, and can lead to a decrease in InfoCenter profit. Choosing the best set of information commodities and InfoSP services might be a complicated task that requires planning, and InfoCenters must consider a variety of possibilities. For example, a new, more expensive, information commodity might decrease profits—even if buyers prefer it—if they are unwilling to pay more for it.

How can e-markets benefit from InfoCenters?

Information e-markets don't have the barriers that exist in physical markets. So why do we need InfoCenters at all in e-markets? Wouldn't it be better to have consumers buy information directly from the source, thereby shortening the supply chain? Although this might sound ideal, it doesn't always work out that way. First, as in physical markets, InfoCenter-like agents already exist in some situations. For example, eBay doesn't produce the items that it sells, and digital libraries offer collected information that one can peruse or buy. Publishers of electronic magazines or journals, such as *IEEE Intelligent Systems*, might sell articles that they have packaged together.

Do these InfoCenter-like intermediaries benefit e-markets' other agents? Or would the other agents be better off in a market without intermediaries? It turns out that InfoCenters can benefit both sellers and buyers in a variety of ways, which explains their having naturally arisen in certain markets. Sellers sometimes prefer to outsource the task of handling customers to a third party. One example is when an InfoCenter acts as a matchmaker, bringing together experts and buyers who are interested in the experts' knowledge (for example, Kamoon).

Although the results of our market simulations depend on the specific models and assumptions that we tested, they shed light on possible e-market behavior, including that of middle-agents such as the InfoCenters. Other researchers have tested e-market behavior (without assuming InfoCenters, but with similar models and assumptions).[4] InfoCenters, it turns out, can occupy an interesting niche in the e-market ecosystem.

The simulation setting

We simulated an information e-market based on the information economies model of the research team at IBM Research Labs.[2,6] We extended it by adding InfoCenters as mediators between information suppliers and

consumers. In our simulations, the marketplace included two basic information products, 100 buyers, three sellers, and one to five InfoCenters. (We looked at different market configurations composed of a single InfoCenter, three homogeneous InfoCenters, or five heterogeneous InfoCenters, and two InfoSP services. The homogeneous InfoCenters had the same capabilities and applied the same pricing and payment algorithms. In the heterogeneous case, we tested combinations of one InfoCenter with certain characteristics, another four that were different from the first InfoCenter but similar to one another.) Each buyer-agent chose whether to purchase some information, and each seller-agent chose whether to set a different price for the commodities it was supplying.

There was no cost associated with producing either of the two basic information products, and the buyers' maximal utility value for obtaining the requested information product was 1. Producing new information products by approaching InfoSPs incurred a positive cost. A buyer chose a seller that sold the requested item at the lowest price—but the buyer was not necessarily aware of all possible sellers. We implemented various types of buyers: 70 percent of buyers found the cheapest seller after comparing all the sellers' prices, 20 percent of buyers compared only two sellers' prices, and the remaining 10 percent picked one seller at random.

We implemented different pricing algorithms for sellers and InfoCenters to set prices for the information they offered. One of these algorithms was the myoptimal (MY) pricing algorithm, where the seller or InfoCenter sets the price of the commodity in the market to maximize its short-term profit (that is, it assumes that current market conditions don't change—a reasonable assumption in the short term). This method requires knowledge about the buyer population, the number of competing sellers, and all sellers' prices. Other algorithms were deviate follower (DF) and game theory (GT). The DF pricing algorithm doesn't require any knowledge of the market's other parties. Sellers or InfoCenters that use this pricing algorithm increase their price as long as profit remains above a certain level. When profit drops below that level, they start to decrease their price, and so on. In the GT pricing algorithm, sellers and InfoCenters choose prices that are part of a mixed Nash equilibrium. This method requires knowledge of the sellers' and InfoCenters' prices. More details are available elsewhere.[2,7]

Table 1. The sellers' average profit in different market configurations.

	Sellers' algorithm		
Market configuration	Myoptimal pricing	Deviate follower	Game theory
No InfoCenter	0.47	0.49	0.09
Single InfoCenter	0.47	0.50	0.10
Homogeneous InfoCenters	0.46	0.49	0.10
Heterogeneous InfoCenters	0.47	0.49	0.10

Table 2. The InfoCenters' average profit in different market configurations (the sellers used the DF pricing algorithm).

	InfoCenters' algorithm		
Market configuration	Myoptimal pricing	Deviate follower	Game theory
Single InfoCenter	1.22	0.62	1.43
Homogeneous InfoCenters	0.70	0.34	0.69
Five heterogeneous InfoCenters (1, 4)	(0.83, 0.68)	(0.27, 0.34)	(0.68, 0.84)

InfoCenters can benefit both sellers and buyers

Using InfoCenters often creates a win-win situation for both InfoCenters and sellers. At first glance, you might expect that the InfoCenters' profit comes at the sellers' expense. In our simulations, however, we found that not only did the sellers' profit not drop; it actually increased (because of an increase in the number of transactions). Sellers gained because InfoCenters reduced the cost of handling customers and generated more transactions. The latter benefit was particularly important. By offering the same information in several information bundles, InfoCenters increased the number of buyers who were interested in that information. (As a real-world example, an InfoCenter might translate information to several languages and thus make it available to non-English speakers. By doing so, the InfoCenter also profits from reselling the same information.)

In results obtained from averaging our simulations over 100 runs per configuration (2,000 settings tested in total), the number of transactions performed when InfoCenters assisted sellers was double the number when sellers worked alone in the same marketplace. (The results we present are representative of the 2,000 simulations tested, although values might vary between configurations. The differences were insignificant.) In both cases, the sellers' average profit remained the same (see Table 1, where the values are normalized). When InfoCenters were active in the marketplace, their average profit was positive (see Table 2). (An InfoCenter can create new information. The information with the highest value of 4.5 is the combination of the two basic information elements and their translations. The minimum cost of producing it is 0.5, and therefore the highest possible average profit is 4.)

InfoCenters can help sellers resolve problems that the e-market creates. Sellers, for example, could have a greater incentive to differentiate themselves by price, since physical location counts for less in online e-commerce, while comparison mechanisms make pricing differentiation more readily accessible. However, multiple requests for price quotes, by comparison agents and between sellers themselves, might create additional load on sellers' servers.

The InfoCenter helps sellers differentiate themselves in the digital world. InfoCenters customize information using InfoSPs' services, and thus become the unique agent that offers some specific information. In addition, InfoCenters can handle customer interaction, and therefore (for example) aggregate requests for price quotes directed at a seller. Unmediated requests for price quotes can increase the need (and therefore the associated cost) for servers and additional bandwidth, because their number increases linearly with the number of buyers' transactions.

In the marketplace simulations of 100 buyers, each seller received around 100 price quote requests every five turns. Only a third of these cases ended in a transaction. Assuming that a seller handling price quotes incurs a cost to supply the quote, the seller's average profit can be affected. For example, our simulations

Table 3. The average profits in a marketplace with a single InfoCenter.

		InfoCenter payment		
Seller algorithm	IC algorithm	Full price	Subscription price	Wholesale price
Myoptimal pricing	Myoptimal pricing	1.22	0.68	0.67
Myoptimal pricing	Game theory	1.69	1.21	1.22
Myoptimal pricing	Deviate follower	0.97	0.64	0.68
Game theory	Myoptimal pricing	1.43	0.63	0.75
Game theory	Game theory	1.64	1.09	1.16
Game theory	Deviate follower	1.45	0.71	0.75
Deviate follower	Myoptimal pricing	0.62	0.40	0.35
Deviate follower	Game theory	0.67	0.34	0.48
Deviate follower	Deviate follower	0.52	0.32	0.28

results showed that the sellers' average profit decreased from 0.47 to 0.27 when the cost of handling a price quote was set to 0.01. Sellers that transfer price quote handling to InfoCenters can reduce a significant part of the price quotes produced by the buyers—yet they still need to handle the price quotes created by the other sellers and the InfoCenters. Sellers that delegate customer handling to InfoCenters increased their average profit to 0.46. The InfoCenters, at the same time, can remain profitable because they also sell other information and the prices are set adequately (in our example, a single InfoCenter average profit is 1.01, and when three InfoCenters are in the marketplace, their average profit is 0.49).

InfoCenters also offer services that can benefit consumers, such as extending market services. For example, an InfoCenter agent can help buyers by aggregating or decomposing information residing at different sources, answering specific requests submitted by those buyers. InfoCenters might then need to interact with other software agents to understand the questions submitted, manipulating various information elements to prepare the answer. InfoCenters could also handle subscriptions to information suppliers, and provide buyers with only the information that is relevant to their requests. In general, InfoCenters should benefit both buyers and sellers to maximize success. If the middle-agent benefits just one party, it appears less likely that it will succeed. For example, a marketplace comparison agent might offer more than just price comparison. The agent can examine other characteristics, such as information quality, service quality, and special offers. In that way, the agent is less likely to be blocked by sellers, leading to its greater overall success.

Are seller-InfoCenter communities possible?

We can expect to see InfoCenters playing several roles within e-markets. Since sellers can benefit from InfoCenters, we might expect that several sellers and InfoCenters will create communities that take advantage of InfoCenters to handle customer issues. In that way, sellers can focus on producing information, while InfoCenters can focus on delivering information in the best way to customers.

InfoCenters generally have a high volume of transactions because they can operate as autonomous middle-agents—buying information from sellers and selling it to buyers. Because sellers benefit from signing distribution contracts with InfoCenters, they can offer discounts to attract InfoCenters into signing contracts. For example, a seller might offer a 10 percent discount if the InfoCenter buys 1,000 information commodities. (The discount level can be set using negotiation techniques.) In this case, the InfoCenter is committed to selling 1,000 information commodities. If the InfoCenter sells less than 1,000 units, it loses money. Based on the InfoCenters' risk attitude, they might prefer to sign less-risky contracts.

Another alternative is for InfoCenters to buy the right to sell 1,000 information commodities and get a discount, but without paying all the money at once. The InfoCenter pays part of the money for the right to sell the information, and a royalty fee for each information commodity that it sells. If the InfoCenter sells all 1,000 units, then it pays a discounted price for them (as before). But if it doesn't sell all 1,000 units, it loses less than it would have with the original contract. The seller, by selling the right to buy 1,000 units of information at a discount, achieves a certain level of guaranty that the InfoCenter will prefer to buy from it in the future. In that way, the seller increases the probability of selling the next 1,000 units. Results from our simulations show that InfoCenters often declined the discount offered by sellers. In many cases, an InfoCenter benefited more from a price war between sellers, rather than from the discount that sellers offered. Sellers eventually raised their prices, whether or not they had a contract with InfoCenters. The contract defined the discount level (for example, 50 percent of the list price), but this didn't actually set the final price to be paid. Therefore, after some time passed, another seller would sell the same information with a price lower than the original discounted price.

In addition, if the InfoCenter agrees to accept the discount price and buys the whole amount of information all at once, it remains uncertain as to whether it will be able to sell it all. Therefore, it might be more beneficial for the InfoCenter to decline a discount offer and buy information at the price set at that moment in the marketplace. Price wars between sellers over market share will thus offer lower prices to the InfoCenter, compared to the prices it would have gotten after accepting the discount. For example, the average profit of a single InfoCenter increased from 0.67–0.68 to 1.22 when it gave up the discount offer (as Table 3 shows). *Full price* denotes InfoCenters that did not use a discount. *Wholesale price* denotes those that buy large amounts of information at a discounted price, and *Subscription price* denotes InfoCenters that buy the right to get a discount in their future purchases. In a marketplace with three InfoCenters, average profit increased from 0.43–0.47 to 0.66 (as Table 4 shows), although by a smaller amount, since these agents also compete over prices.

This behavior is reminiscent of some stores' behavior. When a store opens, it might offer low prices to attract buyers. The store offers special discounts to buyers who pay a membership fee to join its customer club. After the store has increased the number of customer club members, it could start raising its prices. Buyers will continue to buy from that store, until prices get too high. The store, on the other hand, might then decrease its prices to stop buyers' abandonment. Raising and lowering of prices might oscillate. Buyers, of course, can take advantage of this price behavior. They might resist the cus-

tomer club and its discount, and look for the store with the current lowest price. On one hand, they don't take advantage of a membership-based discount, but on the other hand, they aren't encouraged to buy from this store even when prices are too high. According to our experiments, the InfoCenters acting as information buyers often gain more from price competition than from discounts (as the results in Tables 3 and 4 indicate).

The profitability of InfoCenters

So far, we've seen that middle-agents can assist both sellers and buyers who trade in electronic markets. Are the InfoCenters, themselves, profitable? InfoCenters can gain profit in several ways. For example, they can offer bundles of information, such as a theme journal, where a collection of papers on the same subject from different sources provides additional value. They can also offer new information that didn't exist in the market—for example, a translation of an article, a summary of a report, or a stream of news to be transferred to your cell phone. An InfoCenter's profit generally increases when it exclusively supplies this type of information.

In our simulation setting, InfoSP agents can bundle information and change their presentation format. InfoCenters were the only entities allowed to approach these InfoSPs and thus offer new information products to the market. Experiments done with a single InfoCenter and with a market comprising three InfoCenters have shown that the average profit of InfoCenters was indeed positive (see Table 2). In the three-InfoCenter case, the profit was lower because the agents competed with one another over the price of this new and exclusive information. Not only are InfoCenters profitable; in principle they might also have a significant effect on e-market price behavior. For example, an InfoCenter can buy all sellers' information and offer it to buyers. Buyers will then be able to buy information only from this InfoCenter. In that case, a competitive market is turned into a monopolistic one. This e-market is unstable, because additional InfoCenters will likely appear in the market, thus creating price wars. However, in our simulation the existence of autonomous InfoCenters didn't affect the price behavior because InfoCenters bought information offered by sellers and sold new information. Therefore, sellers had additional buyers (that is, the InfoCenters), and InfoCenters were the sellers of the new information.

Table 4. The InfoCenters' average profits in a marketplace with three homogeneous InfoCenters.

		InfoCenter payment		
Seller algorithm	IC algorithm	Full price	Subscription price	Wholesale price
Myoptimal pricing	Myoptimal pricing	0.66	0.47	0.43
Myoptimal pricing	Game theory	0.59	0.31	0.37
Myoptimal pricing	Deviate follower	0.43	0.32	0.27
Game theory	Myoptimal pricing	0.97	0.80	0.75
Game theory	Game theory	0.95	0.69	0.66
Game theory	Deviate follower	0.56	0.38	0.39
Deviate follower	Myoptimal pricing	0.70	0.57	0.50
Deviate follower	Game theory	0.69	0.45	0.35
Deviate follower	Deviate follower	0.34	0.22	0.15

Table 5. Alice's and Bob's average profit in different configurations.

Configuration	Alice	Bob
Alice sells A, Bob sells B	0.99	0.99
Alice sells A and B, Bob sells B	0.74	0.47
Alice and Bob sell A and B	0.47	0.47
Alice and Bob cooperate	0.99	0.99

Intelligent agents are better agents

Middle-agents must decide what price to charge for each information commodity, what information to offer, and what new information might interest buyers. This isn't a simple task. Deciding what information to offer and how to obtain it is an optimization problem that depends on the cost associated with the operators that might be applied to the information and on the InfoSPs' structure and availability that will apply to these operators.

For example, let's assume a uniform cost is associated with each information manipulation operator. To produce a collection of translated information, an InfoCenter can approach an InfoSP that will translate each piece of information and then apply a collector operator (offered by the same or another InfoSP), or it can collect the information pieces first and then translate the whole collection (by approaching the corresponding InfoSPs). The second approach might be preferable, because it uses the translation services only once instead of translating each piece of information separately. But, obviously, different operators' cost models can lead to different choices. Therefore, InfoCenters can increase their utilities by implementing planning algorithms that will choose the right combination of services when each one can be considered as an operator.

InfoCenters can also reduce their profit by offering information in an unwise manner. For example, assume that InfoCenter Alice sells information A, InfoCenter Bob sells information B, and buyers want to buy both A and B. Alice can buy B from Bob and offer the combined information to buyers. Buyers prefer the combined information, which will lead Bob to offer it too. However, now both Alice and Bob compete over the new product's price, and they are no longer agents that exclusively offer this new information. The average price and the total profit will decrease. If Alice and Bob cooperated, they could increase their profit. For example, Alice and Bob could agree that only Alice will sell information A and only Bob will sell information B. When a customer approaches Alice and asks for information A and B, then Alice will sell A and B. To obtain information B, Alice acts as a mediator and sells Bob's information for a retailer's fee. The same applies to Bob. In this way, Alice and Bob avoid price wars while offering A and B. This will lead to higher profits for each of them. This situation is similar to the Prisoner's Dilemma, where higher profits are achieved when prisoners cooperate (rather than both defecting). Table 5 offers a summary of our simulation results.

However, cooperation between Alice and Bob might be fragile, as we have found in

our market simulations. If, for example, the profit that Bob gets from selling B is higher than the profit Alice gets from selling A, Alice will not refrain from competing with Bob. Alice will eventually start selling information B, which will reduce both Alice's and Bob's profits in the long run.

To safeguard cooperation among InfoCenters, we let InfoCenters change which information they offer. For example, Alice might switch and offer B instead of A. That will create competition on B's prices. Then Bob, realizing that B is less profitable, might offer A instead. The subsequent change of information can balance the different members of the cooperation group, and enable InfoCenters to offer whatever information they like. In our simulations, it creates a stable cooperative relationship, and leads to the highest profits achieved compared to cases of simple cooperation or of no cooperation at all.

In our simulations, the three cooperative InfoCenters increase their average profits (from 0.45 when they don't cooperate to 0.62 when they do). The average profit over the three InfoCenters is 0.62. One obtained 0.99 and the other two obtained an average profit of 0.45. Nevertheless, cooperation is unstable (as seen in the values that each one obtains in the example). All InfoCenters attained an average profit after letting the agents switch among commodities.

InfoCenters must also address what type of information they should offer. One option is trial and error; that is, they try to sell products and, based on buyers' reactions, they keep selling this information or produce a new product. The variety of possible combinations of information is exponential in the number of unique InfoSP services. This can make the trial-and-error approach expensive. For example, results from our simulations show that the single InfoCenter loses profit (−0.1) while trying to figure out what information to offer (this happened when buyers value a certain new information product very highly, 5, relative to any other commodity, which was valued at 0.5). The three-InfoCenter case resulted in InfoCenters attaining a positive average profit (0.79), because their chances of finding a profitable piece of information were higher due to their number.

InfoCenters, therefore, might deliberately approach buyers to understand their needs. InfoCenters use this data to decide what information they want to offer.

Simulation results in this case led to a single InfoCenter obtaining an average profit of 4.24 instead of −0.1. The three InfoCenters attained an average profit of 2.34 when approaching buyers, due to competition over the price of the profitable information (instead of 0.79).

InfoCenters and buyers can use different protocols to communicate with one another. For example, organizations such as the Foundation for Intelligent Physical Agents (www.FIPA.org) and the Object Management Group (www.OMG.org) offer communication languages, protocols, and infrastructures. Although there isn't a "best way" to communicate with buyers, enabling communication can increase the effectiveness of the information offered. The need for this capability increases as long as buyers are selective and the market has many sellers. Then, finding the most profitable information niche is a challenging task.

E-markets open up an exciting world for agents and middle-agents—a marketplace where automated agents can represent humans and sometimes even outperform them.

Electronic markets offer new opportunities for trade, and at the same time change the rules of the game of commerce. Some barriers that were present in the physical world do not exist in digital markets. These changes affect the roles that a middle-agent, and in particular the InfoCenter, fulfills in information e-markets. Roles change, but the middle-agent's usefulness remains.

E-markets open up an exciting world for agents and middle-agents—a marketplace where automated agents can represent humans and sometimes even outperform them. However, agents have their own unique characteristics, which can lead to different market behavior. For example, agents can rapidly adjust prices and never get tired of doing so. Therefore, they can create price wars that last forever. Humans might decide that a minor price change doesn't justify the effort, and in that way reach more stable prices.

Our study showed that both buyers and sellers can benefit from a middle-agent such as the InfoCenter. Moreover, we demonstrated that these mediator agents could be profitable in such markets. Sellers benefit by outsourcing tasks such as customer handling (for example, processing price quotes, managing subscriptions), and by increasing the number of transactions (because of InfoCenters' added capabilities) that increase sellers' average profits. Buyers benefit by obtaining richer and personalized services directed at their specific needs (for example, new information products offered by InfoCenters that aggregate or disaggregate information available from Internet sources).

In the model we used in our simulations, InfoCenters didn't affect the market's price behavior. In addition, InfoCenters benefited more from price wars among sellers than from accepting a fixed discount for a larger amount of information offered by any particular seller (since the InfoCenter remains uncertain about being able to sell it all).

We are only starting to understand these types of market behavior, but this understanding is necessary before agents can properly represent humans and take greater charge of commercial transactions. This transition, where agents gradually assume more e-commerce roles, is driven by the advantages that such agent-based systems can provide. Simulations can help us know how to get there. ■

References

1. J.P. Bailey and Y. Bakos, "An Exploratory Study of the Emerging Role of Electronic Intermediaries," *Int'l J. Electronic Commerce*, vol. 1, no. 3, Mar. 1997, pp. 7–20.
2. J.O. Kephart, J.E. Hanson, and A.R. Greenwald, "Dynamic Pricing by Software Agents," *Int'l J. Computer Networks*, vol. 32, no. 6, May 2000, pp. 731–752.
3. J. Sairamesh and J.O. Kephart, "Price Dynamics and Quality in Information Markets," *Decision Support Systems*, vol. 28, nos. 1–2, Mar. 2000, pp. 37–47.
4. R. Das et al., "Agent-Human Interactions in the Continuous Double Auction," *Proc. Int'l*

Joint Conf. Artificial Intelligence (IJCAI 01), Morgan Kaufmann, 2001.

5. K. Decker, K. Sycara, and M. Williamson, "Middle-Agents for the Internet," *Proc. 15th Int'l Joint Conf. on Artificial Intelligence* (IJCAI 97), Morgan Kaufmann, 1997, pp. 578–583.
6. J.O. Kephart and A. Greenwald, "Shopbot Economics," *Proc. 5th European Conf. Symbolic and Quantitative Approaches to Reasoning with Uncertainty*, Springer-Verlag, 1999, pp. 378–379.
7. I. Yarom, C.V. Goldman, and J.S. Rosenschein, "The Impact of InfoCenters on E-Marketplaces," *Proc. 1st Int'l Joint Conf. Autonomous Agents and MultiAgent Systems*, ACM Press, 2002, pp. 1290–1291.

The Authors

Itai Yarom is a researcher in the School of Engineering and Computer Science at the Hebrew University. His research interests focus on the relationship and the influence of economic theory and game theory on multiagent systems. He received his MSc in computer science from the Hebrew University. Contact him at the Ross Bldg., School of Engineering and Computer Science, the Hebrew Univ., Givat Ram, Jerusalem, Israel; jarom@cs.huji.ac.il.

Claudia V. Goldman is a senior post-doctoral researcher at the University of Massachusetts Amherst. Her research interests are in decentralized control, resource-bounded reasoning, decision theory, and multiagent learning systems. She received her PhD in computer science from the Hebrew University. She is a member of the American Association for Artificial Intelligence. Contact her at the Dept. of Computer Science, 140 Governors Dr., Univ. of Massachusetts, Amherst MA 01003-4610; clag@cs.umass.edu.

Jeffrey S. Rosenschein is an associate professor in the School of Engineering and Computer Science at the Hebrew University. His research focuses on issues of cooperation and competition among agents and the use of economic theory, voting theory, and game theory to establish appropriate foundations for the field of multiagent systems. He has a PhD in computer science from Stanford University. Contact him at the Ross Bldg., School of Engineering and Computer Science, the Hebrew Univ., Givat Ram, Jerusalem, Israel; jeff@cs.huji.ac.il.