Automated Negotiations:
A Survey of the State of the Art

Carrie Beam and Arie Segev
Fisher Center for Information Technology & Management
Walter A. Haas School of Business
University of California, Berkeley
Berkeley, CA 94720

Abstract

This paper provides a definition of automated negotiation within electronic commerce. It outlines two barriers to automated negotiation, the ontology issue and the strategy problem. State of the art overviews are given of automated negotiation, specifically Negotiation Support Systems, intelligent agents, the auction mechanism, and online marketspaces. Both academic research and currently functional systems are covered, and several World Wide Web addresses are given for readers who wish to investigate further on their own. [1]

[1] While every attempt is made to provide current URL locations, the Web changes more quickly than print media can ever capture. Hence, some of the URLs may not be current or correct by the time this article appears. We will try to keep our Negotiation Project web site, http://haas.berkeley.edu/~citm/nego-proj.html, current with respect to these addresses.

1. Introduction

> "Leo Baekeland sold the rights to his invention, Velox photographic printing paper, to Eastman Kodak in 1899. It was the first commercially successful photographic paper and he sold it to Eastman Kodak for $1 million. Baekeland had planned to ask $50,000 and to go down to $25,000 if necessary, but fortunately for him, Eastman spoke first." (Asimov, 1982)

It's been nearly a century since Baekeland's negotiation with Eastman Kodak, and the business world has changed substantially. The Internet is rapidly connecting businesses across the globe, and electronic commerce technologies and processes have introduced new ways of doing business. The infrastructure for a completely new business paradigm, that of electronic commerce, is being laid. However, the infrastructure is not yet complete. Negotiation is an important part of the procurement process, and yet most corporate negotiation today is conducted in much the same manner as Baekeland's was nearly a century ago. In order to support current business practices as well as new ones on the Internet, electronic commerce systems need the ability to negotiate.

Electronic commerce is a major new business paradigm. According to Sokol, "Electronic Commerce is the sharing of information using a wide variety of different electronic technologies, between organizations doing business with one another... . [It includes] also procedures, policies, and strategies to support incorporation of these electronic messages into the business environment." (Sokol, 1989) Electronic commerce has exploded in the past five years with the blossoming of the Internet and the World Wide Web, and research from consortia such as CommerceNet has continued to quicken the pace.

Nissen's Integrated Commerce Model (Nissen, 1996), a high-level functional diagram of commerce, distiguishes five phases of commerce:

Seen by the buyer	Seen by the seller
Identify Business Needs	Arrange to Provide Offers
Find Source	Find Customer
Arrange Terms (Negotiation)	
Purchase Goods	Fulfill Order
Use, Maintain, and Dispose of Goods	Support Customer

Although many of the activities in the model have moved into the world of electronic commerce (using e.g. electronic mail, search engines, electronic RFP's, EDI, or electronic catalogs), the negotiation part is still mainly done by hand.

We define negotiation in electronic commerce as the process by which two or more parties multilaterally bargain resources for mutual intended gain, using the tools and techniques of electronic commerce. Under this definition, a process in which two executives use email to exchange negotiation offers would not be considered negotiation in electronic commerce, but a process in which two intelligent software agents negotiate a solution electronically and then present it to the executives would be.

Automated negotiations take place when the negotiating function is performed by (networked) computers. Despite the fact that current human-to-human negotiation appears to be an extremely complex process, each automated negotiating agent may not need to be similarly complex. Maes points out that one characteristic of a network of artificial intelligent agents is that even though individual agents may act simplistically, the entire environment can seem to act in a sophisticated, intelligent manner (Maes, 1994)

Real-world negotiations do not require the parties to reach a negotiated agreement; similarly, the automated negotiation covered here has the same option. An agent can choose “no deal” if it cannot negotiate a satisfactory agreement. Furthermore, we distinguish between “open” and “closed” marketplaces. A closed marketplace is based upon a predefined set of users, who “enroll” in the marketplace and agree to a certain set of rules. An open marketplace has no such agreement; agents are welcome to enter and exit at any time, and are required to agree to no rules.

In this paper, we focus on automated, rather than human factors, negotiation. Moreover, we focus on competitive, rather than cooperative negotiation; in other words, we assume the parties have some conflict of interest. While we recognize that automated trading in the stock is one example of automated negotiation, we focus rather on other domains of electronic negotiation. We assume the agents may always choose "no deal" as a valid option. And finally, we focus on open, rather than closed, marketplaces. Within these confines, the purpose of this paper is to provide a state of the art overview of automated competitive negotiation processes within electronic commerce.

Section 2 addresses the main problems of automated negotiations. Section 3 describes Negotiation Support Systems (NSS), an important stepping stone to fully automated negotiation. Section 4 focuses on intelligent software agents, distinguishing agents with machine learning from those without. Section 5 gives a brief overview of the online auction as a negotiation mechanism, and Section 6 presents some actual online marketspaces for case studies. Section 7 provides a conclusion and areas for further research.

2. The Need for Automated Negotiation

Why does current electronic commerce technology not support automated negotiation? The answer, briefly, is that negotiation is difficult, and automated negotiation is even more so. More information and more detailed explanations of these difficulties can be found in Beam, Segev, and Shanthikumar (1996) and at (CITM, 1997). To give only two of many examples highlighting this difficulty, the following issues are outlined here: the need for an ontology, and the need for a strategy.

An ontology is a way of categorizing objects such that they are semantically meaningful to a software agent. An ontology is required to ensure the agents are referring to exactly the same good. With a compact disc, it is relatively easy; but specifying an automobile, or a food product, or a delivery schedule can be very difficult. Moreover, with many give-and-take negotiations, attributes such as delivery time, delivery quantity, and batch quality, and financing terms are up for debate; it is crucial that an agent be able to evaluate the tradeoffs and implications of all the variables.

The second difficulty outlined here is that of negotiation strategy. If one agent's negotiation strategy is known to the other agent, the first agent may be at a significant disadvantage. Suppose the buyer knows that the seller's strategy is to accept all offers above a certain (unknown) threshold value. The buyer can begin at $0.00, and repeatedly offer the seller a penny more each time, until the seller's threshold value is reached, at which point the (worst possible, for the seller) deal is made. This is but one example of mechanism design; Varian (1995) outlines many more issues with economic mechanism design for computerized agents, including some ways to ensure against losses due to strategy inference.

3. Negotiation Support Systems

This section will give an extremely brief overview of some current literature regarding Negotiation Support Systems (NSS) to give a basis of comparison for the fully automated negotiating systems also reviewed in this paper.

A NSS is a software program which is specially geared towards helping human negotiators make better decisions and negotiate more productively, and is a step towards automated negotiation. Jelassi and Foroughi (1989) present an overview of design issues and existing software. They place a fair emphasis on human factors issues such as behavioral characteristics, cognitive differences, and negotiation theories, issues which have also been brought up by human factors approaches taken by Raiffa (1982) and Fisher and Ury (1991). Nunamaker *et. al*. (1991) provide another literature review, and present results of laboratory and field experiments using negotiation support systems to solve cooperative negotiation problems. Foroughi (1995) presents a survey of current usage of NSS in business negotiations, and Perkins *et. al.* (1996) investigate practical implications of NSS for purchasing managers. While NSS are quite powerful tools, and can often support negotiations which are more productive than would be possible without them, they are far from able to support automated negotiation on their own. NSS require near-constant human input, and both the initial problem setup and all final decisions are left to the human negotiators.

There are some interactive Web-based negotiation support systems available for public use. Carleton University's INSPIRE (www.business.carleton.ca/inspire/) is an interactive system which helps two human users negotiate a solution to a predetermined problem. Users sign on to the system, and are typically given a case study and a position (seller or buyer, for example). The interactive system helps each user formulate and evaluate an offer, and then sends the offer to the counterpart. Each user can see all offers and counteroffers, and his own evaluation of the issues, but not the evaluation of his opponent. While this system is probably not robust enough to handle major negotiations, and currently functions as an NSS, rather than a fully automated system, it is worth further consideration because it runs over the Internet and is available to the general public. Carleton also offers INSS (www.business.carleton.ca/interneg/tools/inss/), a different Web-based tool which lets users experiment with negotiation protocol.

4. Intelligent Agents

This section of the paper will focus on competitive automated negotiation which involves intelligent software agents. More detail can be found in Beam and Segev (1996). A research project will typically create one or more intelligent agents, each with its own agenda, and have the agents electronically negotiate with each other in an environment which is governed by rules. Some negotiations focus more on the intelligent agents; these situations concentrate on teaching the agents effective strategies for negotiation (for example, genetic programming). Other negotiations focus more on the environment rules, requiring relatively little processing from the software agents; these situations generally require humans to delineate the environment rules, or mechanisms, and optimal agent strategies follow (see the section on electronic auctions for an example).

When the focus is on the software agent's programming, the agent requires extensive instruction. There are two major schools of thought regarding how an agent should acquire and execute its extensive instructions. The first school says that the agents should be initially created with their complete set of strategies in place; in other words, the agent should have a large memory containing detailed instructions for each possible situation. The second school of thought says that the agents should be able to learn; rather than having a large memory, they should have the ability to acquire experience from previous negotiations they've conducted. Both schools will be reviewed here.

4.1 Intelligent Agents: No Machine Learning

Sycara and Zeng (1996) outline a meta-framework for coordinating and structuring a collection of intelligent software, and they report they have designed a protocol for proposals and counter-proposals between agents. It is unclear whether the framework is intended to be used for cooperative or competitive problems, but the architecture setup makes it appear viable for non-cooperative situations. Sandholm (1993) extends the Contract Net Protocol for decentralized task allocation in a distributed artificial intelligence network in the context of vehicle routing. The negotiation follows an announce-bid-award cycle, and is real-time in that immediately upon award of a contract, the exchange of goods is made. Sandholm recognizes many opportunities for improvement here, including the inability to support counterproposals, the inability for an agent to break a commitment if a better deal comes along later, and the inability of agents to anticipate future announcements. This paper is extended by Sandholm and Lesser (1995), which assigns costs to commitment and to breaking a contract, and analyzes the implications of bounded rationality. Chavez and Maes (1996) have created Kasbah, a marketplace for negotiating the purchase and sale of goods using intelligent software agents. The agents are, in their words, “not tremendously smart,” nor do the agents use any machine learning or AI techniques, nor do the agents attempt to encompass abstractions such as user goals or preferences. Rather, the Kasbah software agents receive their complete strategies through a World Wide Web form from the users, who specify the way in which the acceptable price can change over time, and who retain final control over the agents at all times. The paper includes results from a live-user experiment, in which users bought and sold playing cards using Kasbah agents, trying to maximize the value of a poker hand. Chavez and Maes report the user feedback was generally positive, but the participants were disappointed when their agents did “clearly stupid things,” such as accepting the first feasible offer when a second, better one was available.

4.2 Intelligent Agents: Machine Learning

Zeng and Sycara (1996) present Bazaar, an experimental system for updating negotiation offers between two intelligent agents during bilateral negotiations. It explicitly models negotiation as a sequential decision making task, and uses Bayesian probability as the underlying learning mechanism. They present an example which uses price as the issue of the negotiation. Further work is aimed at empirically applying Bazaar to supply chain management.

The study of genetic algorithms and genetic programming may hold promise for competitive negotiation within the approach of computer science. Genetic programming is based upon Darwinian evolution, and in the context of negotiation in these papers, works as follows. Each of the software agents begins with a population of various, randomly generated (and not necessarily very good) negotiation strategies. It then employs its strategies against the other strategies of the other agents in a round of bargaining which takes place under specific predetermined rules and payoffs. At the end of a "generation," the agent evaluates the performance of each strategy in its current population, and crosses over strategies from the current "parent" population to create a "child" generation of bargaining strategies. The more successful strategies are chosen to be parents with a higher probability; also, mutations may be randomly introduced. The size of the initial population, the number of generations, the crossover rate, and the mutation rate are parameters of the algorithm.

The major apparent disadvantage of genetic programming is it requires many trials to achieve the good strategies in the end. This number varies from about 20 generations (Oliver, 1996) to upwards of 4000 generations (Dworman, Kimbrough, and Laing, 1995) and all runs must be made against opponent(s) which are as realistic as possible. Hence, it may be unrealistic to "teach" a genetic algorithm using a human opponent because of time constraints. However, it is feasible that two or more agents can "learn" by bargaining against each other, as shown in the following papers.

Oliver (1996) presents a fully competitive method of studying electronic negotiations which still respects the bounded rationality aspect of the problem. He uses genetic algorithms and genetic programming to teach self-interested software agents to negotiate with each other, and shows how after repeated training runs against each other, the software agents have learned more effective methods of negotiating with each other, even for relatively complex negotiations. Dworman, Kimbrough, and Laing (1995) report on a series of experiments in which they used genetic programming to discover high-quality negotiation strategies for a coalition game. After runs approaching 4000 generations, the agents converge to the quota solution, an external one proscribed by cooperative game theory. They conclude that "experimentation and selection ...(can) substitute for experimenter ingenuity," even in a relatively complex (three-agent) game with a relatively large (10^{10} response policies) state space. This research was extended in (Dworman, Kimbrough, and Laing, 1996).

5. Economic Mechanism Design: the Online Auction

This section will focus not on the software agent programming, but rather on the rules of the environment, the mechanism. The field of economic mechanism design is a broad, complicated one, and this paper can barely scratch the surface of it. Economic mechanism design looks at how to design the "rules of the game" so that each independent agent, acting only self-interestedly, will behave in a certain manner. The mechanism of interest here is the auction, in which the buyers bid for an item following a predetermined set of rules. While the outcome of the auction is unknown beforehand, the rules are well laid out, and both the buyer and seller can formulate optimal strategy and program it into a software agent ahead of time. The auction mechanism's biggest limitation is that it only allows negotiation for price, not for color, delivery schedule, or any other variable; however, despite this shortcoming, the auction mechanism has had success on the Internet and is well worth studying.

Auction theory is a complex economic subject, and space does not permit a treatment here. For more rigorous discussion, see the seminal paper by Vickrey (1961), introductions and overviews by McAfee and McMillan (1987) and Milgrom (1989), and a more theoretical treatment by Milgrom and Weber (1982). For a case study of auctions over the Internet, see Beam, Segev, and Shanthikumar (1996), and for more information on auctions of refurbished computer equipment, see Feldman (1997).

The Michigan Internet AuctionBot (auction.eecs.umich.edu/) allows users to create their own Internet-based auctions. It is a prototype available to the entire Internet community, and may become the starting place for more commercially successful auctions.

Cathay Pacific (www.cathaypacific.com) used an electronic sealed-bid auction to sell airline tickets. In September 1995, Cathay Pacific gave Internet users the chance to bid for 50 round trip from Los Angeles to Hong Kong. The tickets fetched an average of $2000, about half the going rate. The auction was successful enough that two more have been staged since, the most recent offering 387 tickets between Los Angeles or New York and Hong Kong. During the six weeks the auction was open, the airline received over 14,000 bids; proceeds are expected to total over $400,000. The auction of airline tickets is especially interesting because of the cost structure of the airline industry: once the decision to send a plane has been made, the marginal cost of adding an additional passenger is nearly zero (Laver, 1996).

Onsale (www.onsale.com) is a 24-hour-a-day auction house, founded by Silicon Valley entrepreneur Jerry Kaplan in June 1995. It sells refurbished and “end of life” computer and high-technology goods by auction, usually a hybrid English/sealed-bid auction of 1-10 identical items, over the Internet. The auctions close three times a week, and bidding is continuous. Onsale claims weekly revenues of $700,000, profit margins of 13-20%, and a growth rate of 15-20% per year (Mardesich, 1996).

JEM Computers (www.jemcomp.com) also operates in the refurbished computer market, but using slightly different mechanisms. Founded in 1992 in Cambridge, Massachusetts, JEM Computers specializes in direct sales of PC manufacturers' inventories. They offer both straight-sale discounted computer items and JEM’s Basement, a descending (Dutch) auction in which the price of an item is progressively lowered until all items are sold, negotiating the price by that type of auction mechanism.

Koll-Dove (www.koll-dove.com) was an established auction house long before the Internet began, and today on the Internet provides a wide variety of auction services. Of special interest are their sealed-bid auctions run over the Internet; a recent example was the sale of four multi-million dollar institutional quality real estate projects in Texas and Louisiana by sealed bid. Bidders could submit either paper or electronic mail bids.

Rust and Friedman (1993) cover the Santa Fe Double Auction, a programming contest in which 30 computer programs played both the role of buyer and seller in a series of double auction tournaments, vying for a cash price of $10,000. The agents were given tokens and traded them on the double auction market; the sole variable up for negotiation was price. The runaway winner was a very simple program. It used the strategy of waiting in the background until the bid/ask spread was within 10%, and then it jumped in to “steal the deal.”

6. Online Marketspaces

The marketspace is the online parallel to the physical marketplace. In an online marketspace, buyers and sellers exchange information about the goods and services, reaching agreements through information alone. Information-based goods and some services may be delivered through the marketspace; physical goods and some services may be delivered to the customer later on, outside of the marketspace. Some interactive marketspaces offer rudimentary negotiation, usually of the price for items which are relatively well-defined, such as credit cards

Figure 1: Current Online Marketspaces and Locations

Good or service offered	Company name	URL
Financial		
Credit Cards	Gromco's Credit Card Adviser	www.gromco.com/cca/
Securities	NASDAQ	http://www.nasdaq.com
Information		
Classified Ads	Buy & Sell Online	www.buysell.com/
Physical Goods		
Automobiles	DealerNet	www.dealernet.com/
Refurbished Computer Equipment	Onsale	www.onsale.com
	JEM Computers	www.jemcomp.com
Electronic parts and components	FAST Electronic Procurement System	info.broker.isi.edu/1/fast
Wide variety	Koll-Dove	www.koll-dove.com

Information courtesy of CITM's Negotiation Project, http://haas.berkeley.edu/~citm/nego-proj.html.

and cars. These items are ones for which the ontology problem is relatively simple, and can usually be solved by displaying either a few critical pieces of information or a picture of the item. Figure 1 shows a few basic online marketspaces, the types of goods or services they broker, and their URL locations.

7. Conclusions and Areas for Further Research

This paper has provided a brief state of the art overview of negotiation processes in electronic commerce. It outlined two major stumbling blocks, the ontology issue and the strategy issue. It reviewed NSS, intelligent agents with and without learning capability, online auctions, and online marketspaces.

More research is needed. On the individual transaction level. The field of economic mechanism design has a set of mechanisms for which truthtelling is the best strategy. Such mechanisms make programming a software agent relatively straightforward; the agent does not need to worry about deceptive strategies.

If an entire electronic economy negotiates electronically, additional macroscopic questions are raised. Will the advantage tilt towards sellers, who may be able to “pointcast” and hence sell to each customer at exactly the consumer’s willingness to pay? Or will the advantage tilt towards buyers, who will be able to comparison shop much more easily? It also raises the question of how to set buying and selling rules so that several smaller transactions add up to a coherent larger corporate procurement policy.

Negotiation is an important part of commerce today, and automated negotiation will be a vital part of electronic commerce in the future.

REFERENCES

(Asimov, 1982) Asimov, Isaac. Asimov's Biographical Encyclopedia of Science and Technology, 2nd rev. ed. Doubleday, Garden City, NY, 1982.

(Beam and Segev, 1996) Beam, Carrie, and Arie Segev. "Electronic Catalogs and Negotiations," CITM Working Paper 96-WP-1016, available at http://haas.berkeley.edu/~citm/wp-1016-summary.html.

(Beam, Segev, and Shanthikumar, 1996) Beam, Carrie, Arie Segev, and J. George Shanthikumar, "Electronic Negotiation Through Internet-based Auctions," CITM Working Paper 96-WP-1019, available at http://haas.berkeley.edu/ ~citm/wp-1019-summary.html.

(Chavez and Maes, 1996) Chavez, Anthony, and Pattie Maes, "Kasbah: An Agent Marketplace for Buying and Selling Goods," MIT Media Lab, http:// agents.www.media.mit.edu:80/ groups/ agents/ Publications/ kasbah_paam96.ps, July 1996.

(CITM, 1997) Fisher Center for Information Technology and Management, University of California, Berkeley, Negotiation in Electronic Commerce Project web pages, http://haas.berkeley.edu/ ~citm/nego-proj.html.

(Dworman, Kimbrough, and Laing, 1995) Dworman, Garett, Steven Kimbrough, and James Laing. "On Automated Discovery of Models Using Genetic Programming in Game-Theoretic Contexts," http://opim.wharton.upenn.edu/ ~dworman/my-papers/ HICSSGP6.ps, January 1995, forthcoming in Journal of Management Information Systems, vol. 12(3), Winter 1996.

(Dworman, Kimbrough, and Laing, 1996) Dworman, Garett, Steven Kimbrough, and James Laing. "Bargaining by Artificial Agents in Two Coalition Games: A Study in Genetic Programming for Electronic Commerce," forthcoming in Proceedings of the AAAI Genetic Programming Conference, Stanford, CA, August 1996. Also at http://opim.wharton.upenn.edu/~dworman/.

(Feldman 1997) Feldman, Saul. "Buying Used: A Guide to Buying Used Computers," Bay Area Computer Currents, February 18, 1997, pp. 45-67.

(Fisher and Ury, 1991) Fisher, Roger, and William Ury, with Bruce Patton, ed. Getting to Yes : Negotiating Agreement Without Giving In. 2nd ed. Boston , Houghton Mifflin, 1991.

(Foroughi, 1995) Foroughi, Abbas. "A Survey of the Use of Computer Support for Negotiation," Journal of Applied Business Research, Spring 1995, pp. 121-134.

(Jelassi and Foroughi, 1989) Jelassi, M. Tawfik, and Abbas Foroughi, "Negotiation Support Systems: An Overview of Design Issues and Existing Software," Decision Support Systems, June 1989.

(Laver, 1996) Laver, Ross. "Flight into Cyberspace," Maclean's, September 1996.

(Maes, 1994) Maes, Pattie. "Modeling Adaptive Autonomous Agents," Artificial Life Journal, edited by C.Langton, Vol. 1, No. 1 & 2, pp. 135-162, MIT Press, 1994.

(Mardesich, 1996) Mardesich, Jodi, "Onsale Takes Auction Gavel Electronic," Computer Reseller News, July 8, 1996.

(McAfee and McMillan, 1987) McAfee, R. Preston and John McMillan, "Auctions and Bidding," Journal of Economic Literature, June 1987, pp. 699-738.

(Milgrom, 1989) Milgrom, Paul, "Auctions and Bidding: A Primer," Journal of Economic Perspectives, Summer 1989, pp. 3-22.

(Milgrom and Weber, 1982) Milgrom, Paul, and Robert J. Weber, "A Theory of Auctions and Competitive Bidding," Econometrica, September 1982, pp. 1089-1122.

(Nissen, 1996) Nissen, Mark. "Knowledge-Based Reengineering: From Mysterious Art to Learnable Craft," CITM Working Paper 96-WP-1012, available at http://haas.berkeley.edu/~citm/research.html.

(Nunamaker, *et. al*. 1991) Nunamaker, J. F., Jr., Alan R. Dennis, Joseph S. Valacich, and Douglas R. Vogel, "Information Technology for Negotiating Groups: Generating Options for Mutual Gain," Management Science, October 1991.

(Oliver, 1996) Oliver, Jim R. "A Machine Learning Approach to Automated Negotiation and Prospects for Electronic Commerce," http://opim.wharton.upenn.edu/~oliver27/papers/jmis.ps, July 31, 1996.

(Perkins, *et. al.* 1996) Perkins, William C, James C. Hershauer, Abbas Foroughi, and Michael Delaney. "Can a Negotiation Support System Help a Purchasing Manager?" International Journal of Purchasing and Materials Management, Spring 1996, pp. 37-45.

(Raiffa, 1982) Raiffa, Howard. The Art and Science of Negotiation, Harvard University Press, Cambridge, MA, 1982.

(Rust and Friedman, 1993) Rust, John and Daniel Friedman, eds., The Double Auction Market : Institutions, Theories, and Evidence, Workshop on Double Auction Markets, Santa Fe, NM, 1991; Addison-Wesley, Reading, MA, 1993.

(Sandholm, 1993) Sandholm, Tuomas. "An Implementation of the Contract Net Protocol Based on Marginal Cost Calculations," Eleventh National Conference on Artificial Intelligence (AAAI-93), Washington DC, pp. 256-262, 1993.

(Sandholm and Lesser, 1995) Sandholm, Tuomas, and Victor Lesser, "Issues in Automated Negotiation and Electronic Commerce: Extending the Contract Net Framework," First International Conference on Multiagent Systems, San Francisco, 1995.

(Sokol, 1989) Sokol, Phyllis K. EDI : the Competitive Edge, McGraw-Hill, New York, 1989.

(Sycara and Zeng, 1996) Sycara, Katia, and Dajun Zeng. "Coordination of Multiple Intelligent Software Agents," to appear in the International Journal of Cooperative Information Systems, 1996. Also at http://www.cs.cmu.edu/ ~zeng/ publications/ ijcis-pleiades.ps.gz.

(Varian, 1995) Varian, Hal, "Economic Mechanism Design for Computerized Agents," presented at the USENIX Workshop on Electronic Commerce, July 11-12, 1995, New York, NY. Available at http://www.sims.berkeley.edu/~hal/people/.

(Vickrey, 1961) Vickrey, William, "Counterspeculation, Auctions, and Competitive Sealed Tenders," The Journal of Finance, March 1961, pp. 9-37.

(Zeng and Sycara, 1996) Zeng, Dajun, and Katia Sycara, "Bayesian Learning in Negotiation," Working Notes of the AAAI 1996 Stanford Spring Symposium Series on Adaptation, Co-evolution, and Learning in Multiagent Systems, also http://www.cs.cmu.edu/~zeng.