Electronic Catalogs and Negotiations

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Abstract

This paper presents an overview of negotiation processes within electronic commerce. Section 2 outlines a vision of electronic commerce which fits automated negotiation processes into the commerce cycle, and Section 3 presents a conceptual road map of negotiation processes, dividing them into categories along two dimensions. The first dimension classifies the type of problem as either cooperative or non-cooperative, and the second dimension classifies the different types of approaches to the problems as either a human factors approach, an economics / game theoretic approach, or a computer science approach. Section 4 provides a literature review. Section 5 synthesizes business requirements for automated negotiation processes within electronic commerce, drawing upon our knowledge of both electronic commerce and of negotiation processes.

1. Introduction

With the spread of the Internet, electronic commerce has been the subject of much research lately. Graphical World Wide Web browsers such as Netscape have made it possible to navigate the Internet using simple, point-and-click interfaces, and business-to-business procurement processes can rely on accurate, up-to-date inventory and financial information from trading partners. Progress is rapidly being made in the areas of payment systems and security. In short, 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 in order to support current business practices as well as new ones on the Internet, electronic commerce systems need the ability to negotiate. The purpose of this paper is to outline a vision of electronic commerce which supports negotiation. Section 2 outlines a vision of electronic commerce which fits automated negotiation processes into
the commerce cycle, and Section 3 presents a conceptual road map of negotiation processes. Section 4 provides a literature review, and Section 5 synthesizes business requirements for automated negotiation processes within electronic commerce. Section 6 summarizes conclusions and areas for future research.

2. A Vision of Electronic Commerce

Electronic commerce is a major new business paradigm. According to [Sok89], “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.” 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\(^1\) has continued to quicken the pace.

The top half of Figure 1 shows Nissen’s Integrated Commerce Model [Nis96], a high-level functional diagram of commerce. The bottom half of Figure 1 shows the various current electronic commerce technologies currently in use which support each function. Although many of the activities in the model have moved into the world of electronic commerce, the negotiation part is still mainly done by hand.

**ID Need / Arrange to Provide**. Electronic catalogs can help a potential buyer identify a business need. Electronic catalogs are Web pages used to

\(^1\) http://www.commerce.net
display and sell a company’s goods and services to members of the Internet community, via a graphical user interface. In their October 1995 paper, Segev et. al. [Seg95.1] reported that most electronic catalogs were direct translations of their paper-based predecessors and were used mainly for marketing purposes. While at that time the authors found electronic catalogs were directly involved in very few sales, many catalog owners felt they were effective in establishing brand name recognition and providing a new marketing channel, both of which contribute to identifying buyer needs.

Find Source / Find Customer. Several tools of electronic commerce can be quite helpful in this area too. Electronic catalogs can alert customers to additional products and services which are now available. The “smart” and “virtual” electronic catalogs outlined by Keller [Kel95], which bring together heterogeneous product databases into a searchable, annotated listing of product announcements, represent a leap in the ability to intelligently find a source or a customer. Electronic mail and newsgroups can contain product announcements, and search engines such as Yahoo\(^2\) and intelligent agent comparison shoppers such as Andersen Consulting’s BargainFinder\(^3\) provide greater flexibility and functionality for the search. Moreover, electronic RFP’s are often used in government contracting work, and some EDI messages can also contain this type of information. Collaborative filtering\(^4\) is an emerging field in which expert systems can currently recommend restaurants and movies, but could conceivably move to recommending business partners. In short, one of the strengths of the Information Age, and the Information Superhighway, is the ability to quickly, inexpensively, and easily disseminate and locate information.

\(^2\) http://www.yahoo.com

\(^3\) http://bf.cstar.ac.com/bf/

\(^4\) For more information on collaborative filtering, see http://sims.berkeley.edu/resources/collab.
regarding products and services, and this is shown by the strong coverage in this portion of the commerce process.

**Figure 1: The Commerce Model and Its Technologies**

<table>
<thead>
<tr>
<th>Buyer</th>
<th>ID Need</th>
<th>Find Source</th>
<th>Arrange Terms</th>
<th>Purchase</th>
<th>Use, maintain, and dispose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange</td>
<td>Information</td>
<td>Influence</td>
<td>Money and goods</td>
<td>Information</td>
<td></td>
</tr>
<tr>
<td>Seller</td>
<td>Arrange to Provide</td>
<td>Find Customer</td>
<td>Arrange Terms</td>
<td>Fulfill Order</td>
<td>Support Customer</td>
</tr>
</tbody>
</table>

**Technologies Currently In Use**

| Electronic Catalogs | X | X | X | X | X |
| Electronic Mail | X | X | X | |
| Search Engines | X | |
| Electronic RFP’s | X | |
| EDI and FEDI | X | X | X | X |

Note: The top half of the above figure is thanks to the Integrated Commerce Model in [Nis96].

**Arrange Terms**. At the moment, very little technology is present to electronically support the middle process, that of arranging terms. Many
current electronic catalogs, such as FlowerStop’s\(^5\), employ basic “supermarket” techniques, in which an item (in this case, a dozen roses) is offered at a given price, and the customer can take it or leave it. Hewlett-Packard\(^6\) displays product specifications for its bar code scanners on its electronic catalog, but refers the customer to a distribution outlet for actual pricing information and any price negotiation. For relatively standard items, a consumer can use search engines to iteratively hunt for the best price or terms on the item, but the sellers cannot change their offers based upon the consumer's inquiry, and no counteroffers are possible. Some negotiation and term arrangement doubtless occurs over email, but most negotiation is still done manually. The remainder of this paper will look in depth at different ways negotiation is conducted and the different outcomes.

**Purchase / Fulfill Order.** The tools of electronic commerce are being more widely used here as well. Electronic Data Interchange (EDI), a form of electronic commerce developed over 20 years ago, is widely used in such diverse settings as automobile manufacturing by General Motors and food processing by Frito-Lay, and Internet-based Financial EDI is used in the banking industry by BankAmerica [Seg95.2],[Beam96]. EFT, or electronic funds transfer, is becoming more and more common in the world of banking, and payment systems are becoming more secure and more widespread. When the product itself is information-based, such as computer software, it can be delivered over the Internet, either downloaded from electronic catalogs or sent directly via email.

\(^5\) [http://www.flowerstop.com](http://www.flowerstop.com)  
\(^6\) [http://www.hp.com](http://www.hp.com)
Use, Maintain and Dispose / Support Customer. Electronic Catalogs are able to support some of this functionality [Seg95.2], and electronic mail can be used as an effective means of communicating with the customer.

To summarize, then, the commerce process shown in Figure 1 has generally taken well to the new paradigm of electronic commerce, particularly with respect to electronic catalogs. However, the negotiation step in the middle has been for the most part left behind. Current electronic commerce tools and technology do not even begin to approach the complexity of negotiated business deals. Future electronic catalogs should provide full support for negotiation technology. This technology would allow a potential buyer to specify the object and desired attributes (such as a pair of black shoes, leather, size 10, under $70) to a software agent. Based upon the buyer’s exact preferences, the agent would negotiate with one or more electronic catalogs and return deals to the customer which most closely match the specified preferences. If the object can be split into subcomponents, such as a computer and a keyboard, the agent should return deals from retailers which would sell the components together and separately. Moreover, the negotiation should apply to small-scale consumer goods and, more importantly, to larger-scale, business-to-business procurement. General Motors could specify its needs for brake pads, and intelligent agents could negotiate with different suppliers, returning with several smaller deals which would incorporate delivery terms, quantity discounts, and sufficient diversity of suppliers to satisfy the automaker.

In a world of electronic commerce, many such negotiations could take place every second, in a global, asynchronous, distributed manner. This paper
seeks to place negotiation within a framework which can be automated and similarly integrated into electronic commerce.

3. Negotiation: A Conceptual Road Map

Section 2 outlined the commerce process, highlighted current technology being used, and recognized that negotiation is a process with relatively little automation to date. This section explores the issue of negotiation in more detail. In this section, we fit negotiation into the overall business cycle; in subsequent sections, we concentrate on the negotiation process alone.

Negotiation is as old as business, and humans were negotiating in order to strike a more favorable deal long before the rise of electronic commerce. 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.

The larger and more complex a good or service is, the more likely negotiation will be involved. Additionally, in business-to-business negotiation, the future relationship between the companies may overshadow any single current negotiation. Current human-based negotiation is relatively slow, does not always uncover the best solution, and is furthermore constrained by issues of culture, ego, and pride [Fis91, Rai82]. Automating negotiation will ensure speed, consistency, and freedom from human errors; however, it is a complex
The process of negotiation, in the words of Jim Oliver, can be viewed as "negotiators jointly searching a multi-dimensional space and then agreeing to a single point in the space." [Oli96] Figure 2 shows a conceptual road map of past and current work in the field. The road map analyzes negotiation along two
major dimensions: 1) the types of problems, and 2) the types of approaches to the problems. We propose placing electronic catalog negotiation in the shaded box in the lower right corner of this diagram.

Using Oliver’s view of negotiation as a search, then, the different types of problems characterize the different spaces in which to look; the different types of approaches characterize the different ways in which to look. Section 3.1 outlines the types of problems in more detail, and Section 3.2 covers the types of approaches. Both sections identify which areas are the most applicable to electronic catalogs within electronic commerce.

3.1 The First Dimension: Different Types of Problems

There are two main types of problems covered in this paper, the cooperative and the non-cooperative, which represent two extremes on a continuum of possibilities. The degree of cooperation is a factor which determines optimal strategy for each player. We have placed electronic catalog negotiation, between a buyer and seller as envisioned above, within the non-cooperative domain, largely because the interests of both the buyer and seller can be most securely protected by assuming a non-cooperative domain. If one player assumes a cooperative approach, and the other assumes a non-cooperative one, the side which assumed the non-cooperative approach will come out with a very favorable deal at the other party’s expense. The way to protect one’s own interests against such asymmetry is to assume a non-cooperative type of problem.
3.1.1 Cooperative Problems

Cooperative negotiation takes different forms in the different problem domains, and will be covered in more detail in later sections of this paper. Cooperative negotiation assumes, for the most part, that all parties are working towards fundamentally the same goal. These situations are commonly found when different profit centers of the same corporation negotiate internally; while each branch tries to maximize its internal profits, it will accept a less favorable situation locally to ensure a better situation companywide. Another example of cooperative negotiation occurs within coordination problems such as those which occur during software engineering. Each member of the team has the same goal, a good software program, but will negotiate to coordinate who does which parts of the task and when. Because all parties are working towards the same goal, it is in the interests of all to disclose confidential information such as reservation prices\(^7\), actual cost figures, and deadlines. Such disclosure gives the parties the most possible degrees of freedom when cobbling together a negotiated solution such as a schedule or a price chart.

While widely used in some business processes, we do not think that cooperative negotiation should be used to model electronic catalog negotiations within electronic commerce. A party which erroneously assumes a cooperative negotiation situation when one does not exist leaves itself open to potentially costly mistakes. Disclosing one party’s reservation price to a non-cooperative other side will usually mean that the first party will receive zero surplus from

\(^7\) A reservation price for a buyer is the absolute highest price the buyer would pay for an item; a reservation price for a seller is the absolute lowest price a seller would be willing to sell an item for. If the buyer’s reservation price is greater than the seller’s reservation price, a deal is feasible, and negotiation will help place the exact price. If the buyer’s reservation price is lower than the seller’s reservation price, no deal can be made.
the deal; the non-cooperative party will receive it all. For this reason, we do not recommend cooperative negotiation as a good candidate for negotiation in electronic commerce.

### 3.1.2 Non-cooperative and/or Competitive Problems

Non-cooperative and/or competitive negotiation assumes there is at least some conflict of interest. The degree of goal incongruency, and the methods for managing the conflict which arises, determine the best strategies for players to adopt in the different circumstances. When both parties have assumed non-cooperation, neither side discloses its reservation price. Rather, a series of offers and counteroffers would be made, each nudging towards a possible deal. If the deal is made, each side counts the distance between the agreed-upon price and its reservation price as its surplus.

At least as envisioned above in the outline of electronic commerce, the negotiations will primarily take place between a buyer and a seller. In the matter of price, with all other attributes the same, the two parties have directly incongruent goals: the buyer wishes to lower price, while the seller wishes to raise it. Moreover, neither would disclose its reservation price to the other side. This suggests that non-cooperative negotiation is a better model for electronic catalog negotiations, and in Figure 2, places electronic catalog negotiation in the non-cooperative part of the chart.

### 3.2 The Second Dimension: Different Types of Approaches

In addition to the two types of problems, cooperative and non-cooperative, there are three major types of approaches to negotiation covered in this paper.
They are the human factors approach, the economics/game theory approach, and the computer science/intelligent agents approach. The human factors approach does not present much which is directly applicable to electronic negotiation at this time. While the field of economics yields some valuable insights into the problem, we feel the approach taken by computer science is the most applicable to electronic catalogs and negotiations within electronic commerce. Reasons for this recommendation can be found in each of the following subsections.

3.2.1 Human Factors Approach

This school of thought assumes the negotiation is done by humans, and concentrates on methods, techniques, and strategies to negotiate successfully. The focus here is to how to best manage the human factors, such as pride, ego, and culture. While this school of thought is important for understanding user preferences and human negotiation, it is not very applicable to electronic commerce and electronic negotiations. Electronic commerce removes, to a large degree, the human factors and allows us to focus on the pure process of commerce and negotiation.

3.2.2 Economics, Game Theory, and Bargaining Approach

The disciplines of economics, game theory, and bargaining treat negotiation from a more mathematical perspective. The economic approach to negotiation covers mechanisms and methods to negotiate the price of a good, and concentrates mainly upon price determination. Game theory recommends a course of action to a participant while taking into account the opponent's strategies and payoffs, and allows formulation of moves beyond pure price determination. The axiomatic, or Nash, school of game theory assumes the set of possible outcomes to a game purely determines the players' moves and
equilibrium states, while the process-oriented school of thought, associated with Rubinstein, holds that the actual bargaining process itself can affect the outcome of the negotiation.

Game theory, however, does not adequately address many issues in electronic catalogs and electronic commerce. It often assumes perfect information, identically perceived, on all sides of the bargaining table, when real-life bargaining situations often deal with imperfect information which is perceived differently by the different parties. Furthermore, game theory often assumes perfect rationality of all players, when in reality players are either at times not wholly rational or must work under constraints of time and/or bounded computational ability. However, despite these shortcomings, it offers theoretical insights and bargaining strategies which provide a solid background for beginning work on negotiation for electronic catalogs in electronic commerce.

3.2.3 Computer Science and Intelligent Agents Approach

The discipline of computer science, and particularly the subfield of artificial intelligence and software agents, takes a more “hands-on” approach to negotiation processes. A research project will typically create one or more types of intelligent agents, each with its own agenda, and have the agents electronically negotiate with each other within a predefined set of rules.

While this approach is currently primitive, it offers perhaps the most hope for electronic catalogs and negotiations. It is relatively free from human issues such as pride, culture, and ego, and also is not constrained by game-
theoretic assumptions such as perfect information or superrationality. Additionally, the intelligent agent approach already involves software programs, and hence may be more easily incorporated into computer applications such as EDI or Web search engines. Moreover, the agent approach can electronically simulate the process as it happens already between humans, and hence human negotiating strategies and approaches may be easier to translate into software agents than into any of the other approaches considered here.

4. Review of Non-cooperative Computer Science Literature

Section 3 presented the road map of negotiation in Figure 2, and identified the non-cooperative computer science approach to be a relatively promising means of looking at negotiation processes within electronic commerce. While the other five boxes in Figure 2 are parts of the rich and diverse literature on negotiation processes, they are not as applicable to negotiation in electronic commerce and hence are reviewed in the Appendix, which can be found in Section 7. This section concentrates on non-cooperative problems which use the computer science approach.

Within the field of computer science and intelligent agents, non-cooperative negotiations occur when each agent has differing, not necessarily congruent, goals. The agents are not necessarily interested in either helping or hurting the other agents; rather, they are self-interested, and will help another agent exactly to the extent it helps themselves. The degree to which the agents are in direct conflict depends on the agents’ goals and the rules of the game. It would be unusual for agents in this type of situation to share more information or resources than minimally necessary.
Negotiation is a complex activity, and computer programs which must negotiate require extensive instruction. But how does the agent acquire the instruction it needs? There are two major schools of thought which answer this question. 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.

4.1 No agent learning allowed

In [Syc96], Sycara and Zeng outline a meta-framework for coordinating and structuring a collection of intelligent software agents. They classify agents into three categories: 1) interface agents, which interact with the user; 2) task agents, which actually carry out the user’s tasks, and 3) information agents, which provide access to diverse, possibly heterogeneous information sources. While the main thrust of this paper is on the agent framework and organization, they touch on possible applications to negotiation within electronic commerce. They briefly summarize a negotiation process consisting of expectation levels and utility functions for each agent which are iteratively relaxed during negotiation. 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 [Sand93] extends the Contract Net Protocol for decentralized task allocation in a distributed artificial intelligence network first presented in [Smith80]. The simulation is TRACONET, a vehicle routing problem in which
geographically dispersed dispatch centers are responsible for routing a fixed number of vehicles to make deliveries for different factories. Each dispatch center may negotiate with other dispatch centers to try to minimize its transaction costs, subject to remaining feasible (in this case, ensuring that all packages are always delivered at all times). 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. Each agent accepts deals which are profitable to it, based on the marginal cost of adding or subtracting that particular delivery from its current routing schedule\textsuperscript{8}. This is a basic automated negotiation situation, in that the strategy of each agent is preprogrammed, relatively simple, and does not learn. It is significant because of its multi-agent, distributed nature. However, 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 in [Sand95.2], which assigns costs to commitment and to breaking a contract, and analyzes the implications of bounded rationality. This paper also outlines the “tragedy of the commons,” in which low-fee transmission costs (such as on the Internet) lead to congestion of negotiation offers and counteroffers.

Sandholm and Lesser [Sand95.1] analyze coalitions among self-interested agents which need to solve combinatorial optimization problems to operate efficiently in the world, and does not allow agents to learn. By colluding, or acting jointly, rather than acting individually, the agents can sometimes save

\textsuperscript{8} Depending on the number of vehicles and the current routing schedules, the marginal cost of the same delivery may differ substantially between two different routing centers, so trading off deliveries may benefit all parties.
costs, and this paper looks into the theory of this issue. This is a mathematical, technical paper. While the field of game theory would define this as a cooperative problem, in the field of computer science this paper counts as a competitive one because the agents are self-interested, and will form coalitions if and only if it is in their own self-interest to do so. The agents are constrained by bounded rationality, because the agents and coalitions of agents are asked to solve NP-hard problems.

Chavez and Maes [Cha96] 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. Users must approve a negotiated deal before the agents can close it. Once created by a user, each buying agent can negotiate with many selling agents simultaneously, and vice versa. The agents here use the satisficing protocol, under which the first agent found which is willing to buy/sell at their current asking price is offered the deal, subject to user approval.

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. Additionally, they report that the participants felt the
Kasbah agents should require less user supervision and be more proactive and capable of reasoning.

### 4.2 Agents can learn to bargain and negotiate

The previous papers have reviewed situations in which the agents could not learn. Rather than attempting to exhaustively translate bargaining strategies from humans to software agents, the field of machine learning allows the software agents themselves to learn how to negotiate.

In [Zeng96], Zeng and Sycara present Bazaar, an experimental system for updating negotiation offers between two intelligent agents during bilateral negotiations. This paper contains a formal analysis of the negotiation state space, which is capable of tracking a rich set of issues and tradeoffs, necessary for multi-issue negotiation. It explicitly models negotiation as a sequential decision making task, and uses Bayesian probability as the underlying learning mechanism. Each agent takes into account the universe, which includes the states of other agents, when it updates its own probabilities; hence, the authors claim this is an open model of negotiation. 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 holds 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 [Oli96] to upwards of 4000 generations [Dwo95], 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.

In [Oli96], Oliver 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. This paper evaluates the performance of the
software agents in terms of distance from the Pareto frontier and difference
from the solutions found by human negotiators faced with the same problem. It
presents results from several different negotiation games, with different
payoffs along more dimensions than merely price. He finds that artificial
agents using genetic programming can perform favorably when compared to humans negotiating the same tasks, and outlines a possible system for electronic commerce using these results. The electronic commerce system would include eliciting user preferences, formulating bargaining strategy (with, of course, the help of genetically programmed algorithms), and control of and communication with the electronic marketplace.

[Dwo95] Dworman, Kimbrough, and Laing continue the approach into genetic programming and algorithms. They report on a series of experiments in which they used genetic programming to discover high-quality negotiation strategies. The game was composed of three agents, each trying to negotiate a coalition composed of exactly two of the three. The two agents inside the coalition received payoffs, while the third agent received zero. The amount of the payoff depended on which two agents formed the coalition. This paper outlines the model representation, including the strategy syntax, and then runs and evaluates the genetic algorithm. 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 [Dwo96]. In that paper, Dworman, Kimbrough and Laing argue that under current theory it is nearly impossible to explicitly encode human bargaining processes satisfactorily into a software agent. Rather, they contend that teaching the agent to bargain on its own is a more effective way to proceed. They describe a series of experiments aimed at producing artificial agents which can negotiate effectively in mixed-motive bargaining contexts. This expands on [Dwo95] in its analysis of the stability
and opportunity costs of the different negotiated solutions reached, and increased the state space, already on the order of at least $10^{10}$, by a factor of $10^6$, with satisfactory results. They note that while the evolved bargaining strategies do not always take full advantage of the strategies of their opponents, the results here can be applied to electronic commerce, particularly in the areas already supported by EDI protocol.

5. Requirements For Negotiation in Electronic Commerce

So far, Section 2 of this paper has outlined the commerce process, and shown how the negotiation part of it currently has little electronic support. Section 3 outlined a road map of negotiation processes and broke the work down along two dimensions – the type of problem and the type of approach to the problem. Section 4 provided a literature review of research which appears to be the most applicable, and directed the reader to the Appendix for more literature on the other areas outlined in the road map.

This section uses contributions from the various fields covered in the literature review to help synthesize the requirements for automated negotiation processes in electronic commerce. It divides the issues into four major categories of consideration: phrasing the negotiation properly, system architecture, the actual negotiation process, and macroscopic considerations. While we are not irrevocably committed to each of these requirements, we feel that they are worth strong consideration.

5.1 How to Formulate the Negotiation

This issue covers the difficulty of translating human preferences and issues into terms which can be meaningfully analyzed, communicated, and bargained with in an electronic medium. This is especially difficult because
human negotiators do not often have clear, well-defined value functions and utilities for the different aspects of a deal, and furthermore may change their minds as the negotiation continues onwards. Factors such as culture, pride, and ego, as well as communication barriers make it quite difficult to separate the “hard facts” of a negotiation from the rest of the deal.

In order to make the transition to electronic commerce, a clear, unambiguous ontology for the items under negotiation is needed. Real-world items, from athletic shoes to fighter planes, do not easily lend themselves to clear, detailed specifications, and when negotiating, such specifications are indispensable. The ontology must capture all important attributes of an object – i.e., price, color, delivery terms, etc. Each possible variable which matters must be specified to a degree which will allow the software agent to make a valid “apples to apples” comparison. Some rudimentary categorizations of consumer goods currently exist, such as the Universal Product Code (UPC) system of bar codes on grocery products, but a comprehensive, integrated ontology is needed. Much work on ontologies has been done already in computer science, and rather than re-invent the wheel, a brief overview of the tools and literature is presented here. Two items are KIF\(^9\) (Knowledge Interchange Format) and Ontolingua\(^{10}\), both of which are products of Stanford University, and several papers have been written on the subject [Wied92], [Gru93], [Wied94], [Gen95]. Negotiation processes in electronic commerce require an ontology which carries enough specificity in its definitions of the items that both the buyer and the seller regard the item as substantially the same. The ontology must carry enough knowledge with it to allow for intelligent bargaining on both sides of the table, must allow the parties to move up and down a hierarchy of

\(^9\) http://logic.stanford.edu/kif/kif.html.
detail, and must have the ability to integrate into the back end of a “smart
catalog” such as the types described in [Kel95].

In addition to the ontology, there must be an easy-to-use front end for
data input. This can be accomplished by means of a World Wide Web form or
similar item. The form should use the data given and prompt the user for more
specific explanations of what is desired. Such a form should provide adequate
security for negotiations; ideally, it would be standardized across industries
and negotiation items so users would be familiar with the form.

Next, the ability to map buyer and seller preferences, as input by the
front-end form, into coherent utility functions is necessary. While preferences
are human, and therefore not completely logical, conflicts within the requests
for each side must be detected and resolved before electronic negotiation can
occur. The representation of the preferences must be consistent: one cannot
prefer A over B, B over C, and yet C over A. The representation must be
monotonically nondecreasing: if speed is a desired attribute, more speed cannot
make the item less desirable. The representation must support both cardinal
and ordinal measures of value, and must allow set preferences such as A over
both B and C, indifference between B and C, and both B and C over D. Taken as a
whole, the set of preferences forms a utility map which can be used during
electronic negotiation. Ideally, the preferences would be additive and
independent, but interactive preferences may also be accommodated.\footnote{Additive, independent preferences work as follows: If issue A is worth $2 alone and issue B is worth
$3 alone, then both issues A and B together are worth $2 + $3 = $5. If A and B were interactive
preferences, together they may be worth $7. This may arise in business negotiations, for example, if A
is a parcel of land, and B is a permit to build. Alone, they are each worth something, but together the
owner can build on the parcel of land, making the worth of the whole much more than the sum of the
parts.}
To summarize, then, an ontology, an easy-to-use front-end to the system, and the ability to map user preferences are required to phrase the negotiation properly.

5.2 System Architecture

The system architecture for negotiation within electronic commerce must fit well into the existing electronic commerce infrastructure.

First, it must have the ability to use the Internet as a backbone for transmitting data to and from the different negotiating parties. The reasons to use the Internet are overwhelming, and include near-ubiquitous connection, a rapidly growing user base, and low data transmission costs. The lone major reason against using the Internet as a backbone would be the data security; however, encryption and secure payment systems have advanced rapidly and are paving the way for secure data transmission. The reasons to use the Internet for electronic negotiation are very similar to those to use the Internet for FEDI data transmission; more information on the use of the Internet for sensitive data can be found in the case study contained within [Seg95.2].

Additionally, an automatic negotiation system must have the ability to integrate into the back ends of electronic catalog databases and existing EDI systems. This integration will likely require firewalls for data security. It is the information contained within these heterogeneous databases which makes electronic commerce so desirable, and which makes automated negotiation such a powerful concept. The ability to “talk to” the back ends of these databases will expand the quantity and quality of information available to the negotiating parties, and perhaps allow the automated negotiation system to leverage its
ability to manage large quantities of data to find negotiated solutions humans could not.

Moreover, the architecture must be distributed. While centralized solutions, especially for situations such as mediated negotiation, are tempting, they do not scale well; the scalability inherent in a distributed solution is required. The architecture must be capable of supporting both real-time and asynchronous negotiations. Small items, such as consumer goods, may have an impatient consumer waiting for a response, while larger items, such as long-term supply agreements, may have more delays built into the process.

For now, tentatively we also recommend an intelligent agent architecture. This appears to be the best way to clearly, fairly, and confidentially represent the interests and information contained within each party’s bargaining platform. This architecture will also allow expansion to a larger market, in which a party could create several bargaining agents with essentially the same bargaining agenda in order to bargain with several other parties simultaneously. The agent will not require constant supervision from the user, freeing the user to do other tasks. With the intelligent agent architecture comes the need for an agent protocol; more research must be done into this area.

5.3 The Negotiation Process

The actual negotiation process is quite important. By focusing on the process, rather than the outcomes, for now we are taking the bargaining process-oriented (Rubinstein) approach, rather than the axiomatic approach found in much of game theory.

First and foremost, the negotiation process must be contained within the tools and techniques of electronic commerce. It must be capable of taking direction and input from either a human user or another software program, and
from there, with minimal guidance, negotiating a solution with other similar negotiation tools. To reiterate an example used earlier in this paper, this effectively rules out two executives using electronic mail to negotiate an agreement, because the email does not provide a self-contained bargaining unit.

The negotiation process for the automated electronic commerce negotiations must support the ability to negotiate along more dimensions than merely price. While price is an important issue, it is by no means the only issue, and often price is counterbalanced against concessions in other areas such as delivery time, financing terms, and service contracts. The ability to support negotiation along dimensions other than price depends heavily on the ontology chosen, and the selection of the ontology must reflect this requirement.

The negotiation process must support the ability for all parties, should they so choose, to propose and counter-propose solutions, as well as walk away from the bargaining if a negotiated solution cannot be found. This eliminates simple search engines and many more rudimentary negotiation algorithms which do not all grant parties the ability to counter-propose and/or to determine when to terminate negotiations.

The negotiation process must be able to cope with bounded rationality on all sides. Because real business deals at times can be murky and convoluted, it is not realistic to assume that all sides of the bargaining process will have complete information and perfect rationality. Rationality may be bounded by, among other things, limited computational resources and/or limited time to decide.

While we are not ready to specify whether the process should be considered cooperative or non-cooperative at this time, it must be able to
respond well to other parties who are using strictly non-cooperative bargaining strategies. This means that the bargaining process must not be vulnerable to being repeatedly in the “cooperate” side of the prisoners’ dilemma when the opposing party is choosing to “defect.”

It would be nice if the negotiation process could learn from its prior mistakes and experiences, as shown in the literature reviewed in Section 4.2 regarding agent learning. We are not ready at this time to unequivocally require that learning be an integral part of the bargaining protocol, but it seems to be the reasonable approach to take. Some advantages of this approach are that different strategies can be “trained” against simulated opponents before bargaining “for real,” and furthermore it allows strategy improvement “on the fly.” It may be possible that further into the future, bargaining strategy modules could be developed and sold, much as additional hard disk storage space is today. Additionally, exhaustively encoding bargaining strategies into computer programs is a difficult task for many reasons, including that often humans themselves cannot articulate in advance what the desired response to a given situation would be, and for complex negotiations, the state space becomes prohibitively large distressingly quickly.

5.4 Macroscopic Considerations

The three previous sections have covered requirements for negotiation on a microscopic level, looking mainly at the requirements for a single negotiation between several parties. However, such automated electronic negotiation will become an integral part of electronic commerce, and the macroscopic implications must be considered.

The performance requirements will be different for large and small negotiations. Finding the best deal on a pair of athletic shoes is quite different
from brokering the best deal for General Motors’ brake pads over the next few years, and yet the underlying negotiation techniques may be the same. The way in which the differences in scale are taken into account is important.

Additionally, companies must formulate bargaining strategy with buyers in terms of an overall corporate policy. For example, the shoe manufacturer must realize that each individual sale adds up to an overall corporate pricing policy. If it wants to sell no more than 20% of its shoes below a certain price, it must make sure that no more than 20% of its negotiations end up in that price range. This raises the additional question of price discrimination. How can the company determine which customers receive the lowest price offer? While all customers would prefer the lowest price, each customer has a different willingness to pay, and the company may want to gauge its bargaining mechanisms appropriately.

There is also the issue of customer privacy. After a buyer has negotiated several purchases from the same seller, each party can analyze the negotiation history and try to piece together the strategy and private preferences of the other party. This can yield a bargaining advantage to the party which is the most successful. Additionally, if there are leaks in the negotiation data stream, a household’s negotiation patterns and purchasing preferences can be determined by an electronic eavesdropper; this offers a whole new arena for electronic “junk mail” and solicitation and raises correspondingly new areas of concern regarding consumer privacy.

6. Conclusions and Areas for Further Research

This paper has presented an overview of negotiation processes within electronic commerce. Section 2 outlined a vision of electronic commerce which fit automated negotiation processes into the integrated commerce diagram, and
Section 3 presented a conceptual road map of negotiation processes, dividing them into categories along two dimensions. The first dimension, the type of problem, was either cooperative or non-cooperative, and the second dimension, the different types of approaches to the problems, encompassed human factors, economics / game theory, and computer science approaches. Section 4 provided a brief review of the literature in some applicable areas of negotiation. Section 5 synthesized business requirements for automated negotiation processes within electronic commerce, drawing upon our knowledge of both electronic commerce and of negotiation processes.

There are some areas in which we cannot currently make recommendations or outline requirements, and they are covered here. These include an incentive for truthfulness in negotiations: to what degree should each party be bound to tell the truth regarding its pricing policies or willingness to pay? Behavior that one party regards as completely fair and within the rules can be regarded as cheating or grossly immoral by another. Moving negotiation to electronic media deprives the negotiation process of many small hints and signals human negotiators give out; rather than hints, these signals must be explicitly codified. What was acceptable when only hinted at may be completely unacceptable when brashly, explicitly stated.

Another area in which we cannot currently make a recommendation is the degree of offer integrity: in other words, to what degree is a party bound to a deal it has proposed? What are the penalties incurred for breaking a proposal? If a party has a single item to sell, is it permissible to negotiate with two potential buyers at the same time, knowing it can only sell to at most one of them? Must the bargaining parties remain strictly within the bounds of
feasibility at all times, or are digressions in an attempt to discover additional solutions permitted?

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. Another possibility is that parties will send out decoy agents to “test the waters,” without actually intending to do business in any deal brokered by the decoy agent.

While negotiation is a complex, difficult area, progress is being made in moving it from the realm of human interaction to one of machine automation. Electronic commerce is growing at an increasing rate, and while many tools and techniques exist to support pre- and post-sale activities, the actual process of negotiation still remains largely a manual endeavor. This paper has outlined the field of negotiation, summarized current literature in the area, and drawn on knowledge of both electronic commerce and negotiation to pull together guidelines for developing negotiation systems to support electronic commerce.
7. Appendix

This appendix contains a more in-depth look at some problem-type/approach pairs which were not selected as the most promising ones for negotiation within electronic commerce. This section is intended to give the interested reader a brief review of some additional literature available in the field; it is not intended to be a comprehensive review of any of the fields.

7.1 Cooperative Human Factors

In the realm of human factors negotiation, the cooperative approach concentrates on finding alternative, at times creative, solutions which bring benefits (or at least do no harm) to all players. Goal congruency is a strong underlying assumption. Often a skilled human mediator or negotiator will be brought into the situation to help the different sides see the issues and discuss them more clearly; frequently, one major task of the human negotiator is to identify congruent, or at least non-conflicting, goals of the differing parties. This is often called the “win/win” school of thinking, because it seeks to find a winning solution for all sides.

Fisher and Ury [Fis91] present a comprehensive manual on how to conduct interpersonal negotiations, a product of the authors' research at the Harvard Law School Program on Negotiation.\(^\text{12}\) It outlines rules of conduct and methods of thinking to identify negotiation issues and to resolve conflicts, concentrating mainly on the cultural and interpersonal issues. This book assists all parties to identify goals which are congruent for all sides, and in viewing other conflicts in terms of possible congruencies.

\(^{12}\) http://www.law.harvard.edu/groups/pon/
Raiffa [Rai82] presents a research-oriented perspective on dispute resolution using techniques of negotiation. He integrates the perspectives of mathematics and game theory into a book which focuses on human factors negotiation, and upon the behavior of human negotiators given different incentives and conditions. He outlines a taxonomy of negotiation which includes the number of parties bargaining, the degree of repetition in the negotiation, the number of issues, types of mediation and arbitration, and whether the bargaining is integrative or distributive. A central tenet of this book is that different parties tend to have different perceptions of reality -- specifically, each party tends to view uncertain future events with a probability distribution more favorable to its side -- and that these differences in perspective can often present opportunities for negotiated solutions which are more favorable to all parties. Sprinkled throughout this book are recommendations for human negotiators faced with bargaining situations of all types, with emphasis on integrative bargaining.

7.2 Non-cooperative Human Factors

"Business is a form of human competition greatly resembling war." This quote from Colonel F. N. Maude neatly summarizes the non-cooperative human factors school of thought. In human factors thinking, non-cooperative and/or competitive negotiation, also called “hostile” negotiation, takes place when both sides believe the only possible negotiated solutions are those which give one player an advantage at the expense of others. Such negotiations are often accompanied with deep distrust and/or dislike, and are often called “win/lose” negotiations. A classic example of these types of negotiations, outlined in

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13 Distributive bargaining assumes there is a fixed pie and the parties are bargaining over who gets how much; in this case, one party’s gain is clearly the other party’s loss. Integrative bargaining looks for
[Fis91], is the United States - Soviet Union negotiations during the Cold War and particularly during the Cuban Missile Crisis, in which distrust, miscommunication, and misperception colored every interaction. Another classic example would be the long-running friction between the United Auto Workers and the management of General Motors, in which strikes and heated, hostile discussions have been the norm for nearly 60 years and continue; in 1995, 6 different UAW locals struck General Motors[Cim94],[Sorge95].

Porter [Por80] recommends non-cooperative strategies when looking at the bargaining power of buyers and suppliers in an industry. Porter suggests that a buyer with enough power play off different suppliers against each other in order to negotiate the best deal possible, and recommends similar tactics for a powerful supplier. Similarly, Porter treats market signals, intelligence collection, and strategy formulation as bargaining chips in the larger game of business, to be judiciously held or played as competitive strategy requires. This is a cultural attitude, and an American one; in Japan, for example, many businesses will choose to aim towards a single supplier in the interests of reducing variability, and so playing off suppliers against each other would not be such a successful business tactic.

### 7.3 Cooperative Game Theory

Game theory is a field of study which, given a game and rules to play by, determines a player’s best strategy by taking into account the incentives and reasoning of the player’s opponents in addition to each player’s own incentives. These games may contain one move or many moves, may be a one-time game or a repeated one; may require both players to move simultaneously or may require ways to expand the pie size before dividing it up, and hence may be able to increase shares all around.
sequential moves, and may have different amounts of information known to different players at different times in the game. The strategies for playing these games may be pure, in which case the same situation would always receive the same move, or mixed-strategy, in which the same situation would receive different moves according to a probability distribution. These characteristics are the same for cooperative and non-cooperative games.

In cooperative game theory terminology, the goal congruency of human factors is replaced by a different rule. Cooperative problems in game theory assume the parties involved can make irrevocable agreements with each other, such as “If and only if you do A, I’ll do B,” before the actual game begins. A cooperative situation will often focus on coalitions of players rather than on individual ones, and negotiation in this situation focuses on the terms of the binding agreements the players all sign. Coalitions are often identified by characteristic functions which describe the total payoff to the coalition formed by certain members, and sometimes use the Shapley value to allocate a coalition’s total payoff between its members. Additionally, whether side payments from one player to another are allowed will influence the shape of a coalition.

Players with completely opposite goals, and yet the ability to make binding pre-game agreements and hence form coalitions, are still considered to be playing a cooperative game. It should be stressed again that in game theory, it is the capability to make binding agreements, not the similarities or differences in the players’ goals, that makes a bargaining situation a cooperative one.
Nash [Nash50, Nash53] laid the groundwork when he outlined mathematical solutions to bargaining problems and 2-person cooperative games, showing equilibria under perfect information and rationality.

Osborne and Rubinstein [Osb94] present a mathematical treatment of cooperative game theory in this textbook\(^\text{14}\). It covers strategic and extensive form games, and looks at games with both perfect and imperfect information. It describes coalition formation, in which players must decide whether and which coalition of other players to join. Transferable payoffs, in which a player’s value is transferred to the coalition to be divided up any way the coalition wishes, are modeled, and conditions under which a coalition is stable are outlined.

Ponssard [Pon81] covers cooperative game theory\(^\text{15}\), with an emphasis on the implications for business strategy. It touches on economic issues surrounding sharing an economic good between two players, particularly on the issues of efficiency and equity. It also presents in some detail a multi-issue, 2-player negotiation game and analyzes results from 15 human negotiation teams with respect to the Pareto frontier\(^\text{16}\) and each other.

The volume Roth edited contains several research papers by many authors on the subject of bargaining within the context of game theory [Roth85]. It looks at mechanisms for cooperative bargaining between parties, including a paper by Binsmore on bargaining within the context of coalition formation and a paper on axiomatic approaches to coalitional bargaining by Hart.

\(^{14}\) This book also covers non-cooperative game theory.

\(^{15}\) This book also covers non-cooperative game theory.

\(^{16}\) The Pareto frontier is the set of points from which no party can be made better off without making some other party worse off.
7.4 Non-cooperative Game Theory

Non-cooperative games retain many of the characteristics outlined above: they may have one or many moves; they may require simultaneous or sequential moves; they may have information imperfection or asymmetry, and may yield pure or mixed-strategy results.

The characteristic which separates non-cooperative games from cooperative ones is the assumption that no pre-game agreements are allowed, and hence the rules of the game completely define the players’ moves and payoffs. No coalitions are allowed; rather, strategy is formulated by and for individual players. Again, the absence of pre-game agreements (and therefore absence of coalitions), not the presence or absence of goal congruency, defines a non-cooperative game. The rules of the game and the accompanying payoffs determine a self-interested player’s best course of action, and players will not necessarily hurt each others’ interests. A competitive negotiation situation is more extreme than a non-cooperative one. A competitive negotiation situation is one in which the players perceive there to be a zero-sum dynamic, in which any gain by one player is a corresponding loss by another.

One classic example of a non-cooperative, one-shot, simultaneous game is the prisoners’ dilemma, in which two prisoners are jailed for an alleged crime and interrogated separately. If they each cooperate, they each receive a payoff of 6. If they each defect (by implicating the other prisoner), they each receive a payoff of 1. However, if the first prisoner cooperates while the second one defects, the first one receives a payoff of 0, while the second receives a payoff of 10. They are both better off, with a total social payoff of 6 + 6 = 12, if they both cooperate; however, given that the other is cooperating, they each have an
incentive to defect. Game theory extensively analyzes this situation in many different variations, including repeated play of the game and different strategies for the situations.

Osborne and Rubinstein [Osb94] cover non-cooperative game theory. They present pure and mixed-strategy Nash equilibria and strictly competitive games. They also outline extensive and sequential games with perfect and imperfect information. It covers the Rubinstein model of bargaining when no coalitions can be formed, in which two players alternate making offers and deciding whether to accept or reject the proffered deal. They characterize the subgame perfect equilibria and derive the conditions under which a subgame perfect equilibrium will exist for the alternating offer bargaining game. This idea draws connections between a player’s strategy and the game outcome for both the one-time and the repeated games.

Ponssard [Pon81] contains analyses of non-cooperative games, highlighting strategy for each player, stability of the game, and the likely outcome of the resulting game. Games of multiple time periods are also considered. The theoretical outcomes are applied to business situations such as marketing, competitive bidding, and the use and value of information.

VanDamme [Van91] presents an analysis of the bargaining and fair division problem, traditionally a cooperative problem, using non-cooperative methods. He looks at the surplus sharing problem, in which two players need to decide non-cooperatively how to divide the surplus which results from their cooperation. He considers a side payment situation in which the party which values an indivisible item the most receives it, and must pay the other a fair compensation. He outlines the divide and choose method, in which both players
ante up money, and one player creates two packages, one containing the indivisible item and some money, and the other consisting purely of money. The other player gets to choose which package he wants. VanDamme also looks at auction methods to determine fair, efficient pricing and compensation for the object. He finishes with descriptions of bargaining strategies and outlines future research in the area.

Varian [Var95] presents an overview of economic mechanism design and outlines some applications to electronic commerce in this paper. It provides explanations of some basic mechanisms such as Vickrey auctions and places them in the context of electronic commerce, and contains a brief introduction to the literature.

7.5 Cooperative Computer Science

In the area of computer science, cooperative negotiation is defined as negotiation in which the different parties have goal congruency. This definition is similar to that used in the human factors negotiation and different from the one in economics and game theory. Computer science is a relatively new field compared to human factors and economics, but offers promise for electronic commerce and electronic negotiations. The computer science approach most often uses software agents, defined as independent, autonomous pieces of computer code which attempt to fulfill goals using resources available to them. A typical negotiation project in this field will create several independent software agents, endow them each with one or more goals and a protocol for interacting with each other, and then observe the interaction between the agents. The agents will, with varying degrees of interaction from human users, typically reach a negotiated agreement which can then be analyzed. Cooperative
negotiation takes place among agents which are defined to have the same larger goal, but different methods, pieces of knowledge, and/or sub-goals.

The collaborative computer science approach to negotiations within electronic catalogs suffers from the same prisoners’ dilemma-type weaknesses that most cooperative negotiation does; if the other side is not playing cooperatively, the cooperative player stands to lose a large amount on any deals made.

Chu-Carroll and Carberry [Chu95] define collaborative (in our terms, cooperative) negotiation as a negotiation in which “the agents are not trying to enforce their views on one another or to maximize their own benefits, but rather are trying to share their individual knowledge and beliefs in order to determine what really is best.” An example of this situation, outlined in their paper, is an aircraft control tower, in which independent agents representing the airplanes negotiate to come up with an acceptable landing plan. The overriding goal, to land all aircraft safely, is the same for all the agents; however, they may have different preferences or pieces of information with which they negotiate. Agents in this situation share information and resources with other agents, and implicitly trust that the information and resources will be used for the greater good, not as competitive weapons against the source. Collaborative negotiation, while perhaps not immediately suited to the types of negotiations outlined in the beginning of this paper, can offer its techniques of domain management, conflict detection, dialogue analysis, and user preference mapping to the more competitive negotiation described later on.

Lander and Lesser [Lan92] outline negotiated search, a paradigm for cooperative search and conflict resolution among heterogeneous, reusable,
expert agents. This is cooperative negotiation by definition, because, in their words, “agents are willing to contribute both knowledge and solutions to other agents as appropriate and to accept solutions that are not locally optimal in order to find a mutually-acceptable solution.” They outline a negotiation algorithm which, when a conflict is detected, first extends the search to a larger subsection of the state space in hopes of finding a mutually acceptable solution, and then, if no solution can be found in that manner, relaxes solution criteria, thereby expanding the solution space. Another strategy outlined here, albeit a limited one, is the linear compromise, in which two agents with intersecting linear utility functions over the same variable agree to use the intersection point, which can be quickly algebraically calculated. They outline an architecture and implementation of the negotiated search paradigm called TEAM, and report on preliminary data. This is a cooperative negotiation paradigm at work, using distributed intelligent software agents.

Jennings et. al. [Jen96] wrote a paper on ADEPT, a project which uses intelligent agents to manage business processes within a large corporation. While this would fall closer towards the cooperative end of the spectrum, it is not a purely cooperative model; the individual business process may have conflicts and are required to resolve them through agent-to-agent negotiation. This paper outlines how the ADEPT agent architecture specifics a negotiation protocol and a bargaining process model which attempts to model the actual reasoning which takes place during human negotiation. The bargaining process model includes generating initial offers, evaluating offers, and counterproposing. While the paper is still phrased in general, relatively abstract terms, it includes an example for the customer quote business of BT. This approach takes on the larger, more ambitious task of explicitly modeling
the human negotiation process in a software agent, and currently has few concrete results. A more general overview of the ADEPT system can be found in [Alty94].
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Also at http://www.cs.cmu.edu/~zeng/publications/ijcis-pleiades.ps.gz.


