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A Decision Support System for Generalized Negotiations*

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Abstract

This paper reports on the development of a Decision Support System GENIE that aids participants in crisis negotiation simulations. GENIE is an instance of a general DSS which can be used to support a large class of decision problems. The major function of GENIE is to provide the user with on-line information about a complex decision scenario. To this end, GENIE utilizes a combination of graphic and textual information presentation formats to create an environment in which a user can develop a mental picture of the decision problem facing him/her and then dynamically formulate an effective negotiating strategy. The design and development of GENIE are described along with an explanation of the major features of the system.

Experimental results from user evaluations and system log files are also discussed. These results allowed us to gain insight into the decision processes of the users and rate the effectiveness of our DSS design strategy. Experimental results indicate that simulation participants who had access to the system performed on average better than participants without access to the system.

Introduction

Decision makers today are frequently overwhelmed by the vast amounts of information which they must consider. Often, they are forced to make partially informed decisions which ignore critical issues because of the complexity of the situation being analyzed. Decision support systems (DSS) can play a crucial role in the decision making process by allowing the decision maker to navigate large amounts of information and to explore interrelationships between factors that may influence his/her decision. A DSS can also facilitate the simultaneous evaluation of multiple negotiating positions. This can play a decisive role in real time negotiations by allowing the supported parties to rapidly formulate dynamic strategies and quickly evaluate opponent proposals. DSS systems, when used in the context of negotiation support, are called negotiation support systems (NSS).

This paper describes the design and implementation of GENIE, a specific NSS/DSS developed jointly by the University of Maryland Institute for Advanced Computer Studies and Project ICONS of the Department of Government and Politics. GENIE is an instance of a general NSS/DSS which can be used to support a large class of decision problems. The problem domain corresponding to the GENIE class of DSS/NSS is formally described in section 2. GENIE is specifically customized to support a subset of this domain, namely n-player time variant negotiations with full information. See [S. Kraus and J. Wilkenfeld, 1990b, S. Kraus and J. Wilkenfeld, 1991b, S. Kraus and J. Wilkenfeld, 1991a] .

Several systems have previously been developed to aid decision makers in negotiation scenarios. Some examples of these systems are NEGO [Kersten, 1985], MEDIATOR [M. Jarke *et al.*, 1987], and NEGOPLAN [S. Matwin *et al.*, 1989] [1] Of the three systems mentioned, GENIE is most similar to NEGOPLAN in that it allows a user to explore various negotiation positions without making "judgments" about the utility of the positions.

When describing GENIE, major emphasis will be placed on GENIE's model visualization capabilities, user interface, and negotiation support tools. We will also discuss the simulation experiments which tested the effectiveness of GENIE.

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[1] The following work is also relevant: [B. Shneiderman, 1987, Andriole, 1989, Heymann and Bloom, 1988, Tufte, 1983, Bui, 1987, Mittra, 1986].

GENIE: (A Simulation Environment)

GENIE was developed as part of a simulation environment of a real world situation in which negotiators can be trained and where experiments can be conducted.[2] GENIE is designed to be used as an aid to players in a hostage crisis simulation. This simulation is a hypothetical model of an international crisis [S. Kraus and J. Wilkenfeld, 1990b, S. Kraus and J. Wilkenfeld, 1990a, S. Kraus and J. Wilkenfeld, 1990c]. Each party has a list of objectives with associated payoffs. An objective of one party may or may not conflict with the objectives of either of the other two parties. Each party knows the objectives and associated payoffs of the other players (i.e., the model assumes full information.) During the simulation players have access to information about their situation. This information changes over time. Based on this information, players are able to negotiate with other players or take actions which they believe will result in their own payoff maximization. A successful player must consider information about his/her own objectives as well as those of the other players. There are 35 possible outcomes to the simulation in each of 50 time periods (1,750 total possible outcomes). If a player were to consider each of these outcomes from his own point of view and from those of the other two players he would have to consider 5,250 different point values. Clearly, this is an overwhelming amount of information. We hope to show that our NSS/DSS both helps simulation participants to develop clear mental pictures of the situation facing them as well as helping them to create logical and well-informed plans of action.

By studying the actions of undergraduate political science students at the University of Maryland using the DSS, we were able to gain insight into the decision processes of the students and rate the effectiveness of the DSS design strategy. Preliminary experimental results are from a group of simulation runs of a hostage crisis scenario involving, Israel, Egypt, and hijackers. Testing of the interface is underway using an India, Pakistan, Sikh scenario.

After each simulation, participants are given a questionnaire asking them to rank the relative importance of each of the features of the system. The DSS keeps log files on each player to determine the frequency and duration of use of each of the DSS features.

Although GENIE was customized to work with the hostage crisis model, it can be easily modified to support many other types of models. The following section describes the general class of models which can be handled by a GENIE-type system.

[2] Another aspect of the project is the creation of a prototype automated negotiator that will take roles in such simulations [S. Kraus and J. Wilkenfeld, 1990c].

Model Description

Formally, we describe the class of situations or problems that can be handled by GENIE as follows: Let $\mathcal{P} = \{P_1, ..., P_N\}$ be the set of agents involved in the situation. Let $W_j = < f_1, f_2, ..., f_m >$ define a state of the world, where f_i is the i^{th} factor that influences this state. We assume that there is a finite number of factors and that each of these factors can range over a finite set of values. Therefore we assume a finite number of world states W_i. We denote the set of world states by $\mathcal{W}$. Note, as the complexity of the model increases, $\mathcal{W}$ can become very large. Let A_i be the set of possible actions available to agent i. Also if X is a state, then let $Pr(X)$ be the probability that state X will occur. If $a \in A_i$ then let $g(a, W_j) = W_j \circ a$ where $\circ$ is an operator that has the effect of applying action a to the state of the world W_j to produce a lottery $((W_k, Pr(W_k)), (W_l, Pr(W_l)), (W_m, Pr(W_m)), \ldots)$ where $Pr(W_k) + Pr(W_l) + Pr(W_m) + \ldots = 1$. In the simplest case $g(a, W_j) = ((W_k, 1))$, i.e., application of action a to the state W_j produces the state W_k.

The class of models that can be handled by GENIE assumes that each agent i places a numerical payoff value on each world state W_j. Let $V_i(W_j)$ be the payoff value that agent i places on the world state W_j.

These payoffs can be ordered to represent the preferences over world states of player i. Then without loss of generality we can assume that for a fixed agent i we have the ordering: $V_i(W_1) \geq V_i(W_2) \ldots \geq V_i(W_P)$. In a model with full information, it is assumed that an arbitrary agent i knows the preference orderings of all of the agents $i = 1 \ldots N$. [3]

Even though we are assuming that an agent has full information about the other agents' preferences over different states, we cannot assume that the agent knows the other agents' preferences over the set of possible actions given an arbitrary state W_k. It is often the case that while the world is in some state W_k agent i wants to predict the actions of agent j by studying the set of possible outcomes $g(a, W_k)$ for all $a \in A_j$. For example, suppose that $\{a_1, a_2\} \subseteq A_j$ and that there exist world states W_l, W_m, W_n such that $g(a_1, W_k) = ((W_l, Pr(W_l)), (W_m, Pr(W_m)))$ and that $g(a_2, W_k) = ((W_n, 1))$. Also assume that $V_j(W_l) > V_j(W_n)$ and that $V_j(W_m) < V_j(W_n)$ and $Pr(W_l) + Pr(W_m) = 1$.

Now agent i wants to decide which action agent j will take. The problem is that agent i doesn't know agent j's attitude towards risk. [4] Later in this paper

[3] Note, we cannot assume that if $V_i(W_k) \geq V_j(W_k)$ then world state W_k is more preferable to agent i than it is to agent j.

[4] To clarify the idea of risk attitude, consider the following short example. Consider the CEOs of two competing tire manufacturing companies trying to formulate production strategies for the next fiscal year. Assume that CEO_1 is trying to predict the production plan of CEO_2. Assume further that CEO_1 knows that Y units of rubber are worth Z dollars on the open market. However, CEO_1 does not

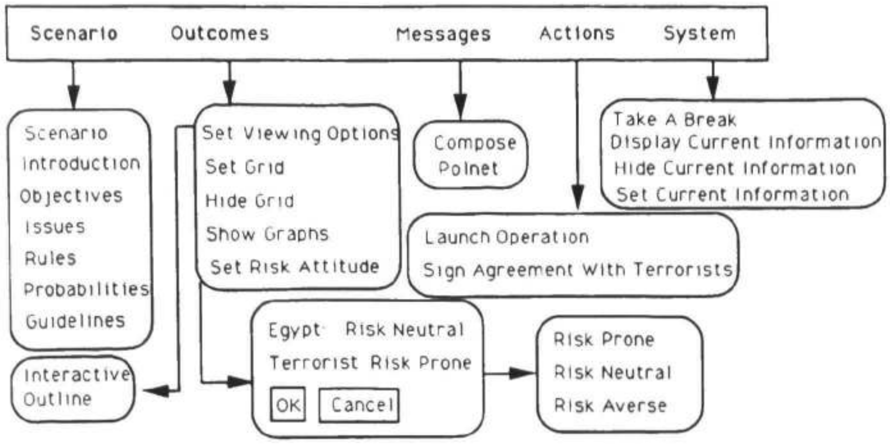

Figure 1: Schematic of the GENIE Menu System

we discuss a method to assist the user in forming a model of his/her opponents' preferences over actions.

GENIE: (A Functional Description)

GENIE is composed of three main components: the interface, the knowledge base, and support tools. The interface and tools platform provide an environment for the decision maker to access, view, manipulate, and act based on information contained in the knowledge base. The knowledge base consists of information which models the decision problem scenario. Detailed information about the specific model used in GENIE can be found in [S. Kraus and J. Wilkenfeld, 1990b]. Figure 1 is a schematic of GENIE's menu system.

Fumás [Fumas, 1987] states that future DSSs should have the following characteristics: modularity, interfaces, graphics, ease of use, and availability on mini-computers. From the discussion below it can be shown that GENIE meets all of these criteria.

Ghiaseddin [Ghiaseddin, 1987] gives an in depth description of the characteristics of a successful DSS. He states that a successful DSS should have the following functional capabilities: modeling, data management, and support of all decision making activities. In addition he states that a DSS implementation should provide personalized support, security and integrity, transferability, and evolving capabilities for the support of increasingly complex demands. [5] Within this framework we will describe the major features of GENIE.

know whether CEO_2 would rather have the Y units of rubber and risk going into production or play it safe and keep the Z dollars.

[5] Ghiaseddin also includes ability to learn as a non-essential feature. Currently, our system does not have this capability.

Modeling and Data Management

GENIE is designed to provide the user with a clear mental picture of the model contained in the knowledge base. This is a difficult task since often the model of the scenario being analyzed is complex with numerous interdependencies among data objects. The task is further complicated when the model contains large amounts of numeric information. As stated in [Pracht, 1990] research has shown that images and symbolic representations are much more easily assimilated by humans as compared with textual information. This would suggest representing the structure and content of the model in some symbolic form. The problem is then transformed to finding a concise symbolic representation for the model. [6]

GENIE combines its data management and modeling capability in one mouse-supported screen which enables a user to quickly set parameters for information viewing. This screen not only provides quick access to information items in the knowledge base, but also allows the user to form a mental picture of the entire simulation. This screen serves to organize the complex details of the scenario into one easy-to-digest outline. With this outline, the user can than brainstorm and play "what if" to form a personalized strategy for outcome maximization.

One data management feature of GENIE which is critical to any successful DSS is the ability of the user to control the complexity of the queries and responses

[6] A previous approach to this problem is taken by Pracht [Pracht, 1990] who uses a frame based knowledge representation. This scheme partitions knowledge into discrete structures called frames. Each frame has a set of slots for holding clusters of related knowledge. Hierarchical relationships among frames are expressed as arcs between nodes in a tree. Our approach differs from that of Pracht in that we are exclusively concerned with aiding the decision maker in model visualization. Pract's system devotes substantial resources to assisting the model developer.

from the DSS. Novice users who ask the DSS simple questions should not be flooded with screens of complex charts and graphs. At the same time, advanced users should have the facilities to develop sophisticated strategic models. GENIE's interface allows a user to define one or more hypothetical state(s) of the world and then investigate possible future actions based on these states. The user can explore outcomes resulting from his/her own actions as well as those of his/her opponents. Also, a user can switch viewpoints to see things from the point of view of one or more of his/her opponents. This is possible, since the model assumes full information. A simultaneous display of these viewpoints allows the user to formulate a strategy which takes into account possible opponent actions.

The system employs a model specific interactive outline with information categories which a user can select to see graphic information about the scenario. This outline gives the user access to the major model visualization and data management features of the system which include: multiple frames of reference, time variant outcome projections, and multiple world state definitions. The following section gives a detailed description of the interactive outline.

The Interactive Outline The interactive outline is organized into three main categories: viewpoints, decisions, and world states. By selecting items and defining parameters in each of these categories, a user is able to view the pieces of the model that are directly relevant to formulation of his/her negotiation strategies. [7] The outline not only allows users to define choices and parameters, but also uses heuristics to determine whether the choices are reasonable in terms of the complexity of the graphic output produced. A powerful feature of the system is that a user can select to view multiple frames of reference, decisions, and world states simultaneously. This allows a user to compare numerous negotiating positions concurrently. [8]

The viewpoints section of the outline gives the user a list of the parties[9] involved in the negotiations. The user can interactively select one or more of these parties to define a set of viewpoints. Once selected, these viewpoint(s) become the frame(s) of reference for all subsequent queries to the knowledge base. When more than one viewpoint is selected, information corresponding to each viewpoint is displayed simultaneously. This facilitates the development of strategies which incorporate the goals of all involved parties. Having fixed the viewpoint(s), the user can then move to the decisions section of the outline.

The decisions section lists all possible types of decisions that a player can make during the course of the negotiations. The user selects the types of decisions to investigate by moving the mouse cursor to the appropriate position on the outline and clicking on the desired choices. Obviously, the system must provide a method for the user to specify parameters that will uniquely identify the exact decision(s) to be investigated. Note that since the model contains information about decisions that can be made by any of the parties, each party that is supported by the system should be able to ask for information about all decisions, not just those that he/she can personally make. Once the frame(s) of reference and decision(s) are fixed, the user can then move to the world states section.

In the world states section a user fills in parameters that define the hypothesized state of the world at the time the decision(s) in the previous section take effect. This organization of the outline reveals the main structure of the model by emphasizing the dependence of the decision(s) on the state of the world at the time they are made. Parameters of the world state may be positions held by other negotiating parties, economic conditions, time, etc.

One of the powerful features of this system is that it allows a user to project the outcomes resulting from one or more decisions over a range of time periods. Using this feature, users are given information that helps them to decide not only what decision to make, but when to make it.

Another feature which is helpful for developing negotiating strategy is that of varying world state parameters. Often decision makers have some influence over the state of the world (i.e., they have influence over some of the parameters in the world state definition). During strategy formulation, a decision maker may want to find out whether it is worth it for him/her to expend energy to change the world state. [10] GENIE lets a user select multiple values for a given parameter and then simultaneously view the selected decision outcomes based on the different world states.

Figure 2 shows the outline developed for the Israel-Egypt-hijacker hostage crisis model. Here the user has fixed the frames of reference to be Israel and Egypt. The decisions to be investigated are set to Israeli operation, terrorists giving up, a deal which involves the exchange of 400 prisoners in Israeli jails for the release by the terrorists of all hostages, and a deal which involves the exchange of 500 prisoners.

Here under the Egyptian behavior section of the outline the user has defined a state of the world that assumes that Egypt has not given the press access to

[7] Interactive outlines also have application to scenarios outside the realm of negotiation support.

[8] The reader can refer to figure 2 for a concrete example of the concepts explained in the following discussion.

[9] Or stakeholders in the language of management decision support.

[10] For example, in the hostage crisis scenario, the hijackers could decide that they will blow up the plane and kill all of the hostages. In this case they should try to influence the state of the world so that at the time of the action, they (or their cause) receive maximum benefit. Influencing the state of the world could mean waiting a certain amount of time or convincing Egypt to allow press coverage.

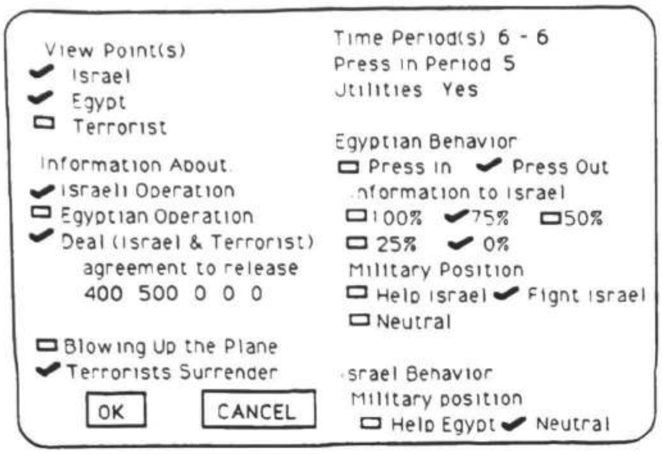

Figure 2: Interactive Outline: Middle East Scenario

the terrorists' and that Egypt will fight Israel in the event of an Israeli operation. Two options have been selected under the "Information to Israel" category, 0% and 75%. These numbers correspond to percentage of information provided by Egypt to Israel that might aid in an Israeli operation. Two world states are defined by the specified parameters, one that assumes that Egypt provides no information and one that assumes that Egypt provides 75% information. Figure 3 shows the system output from the point of view of Egypt. [11]

Attitude Towards Risk Attitude towards risk becomes an important consideration when a player is trying to predict the actions of an opponent. Seeing an opponent's payoff for the outcome of a given decision or action does not give the user any idea about how the opponent views or interprets these point values. GENIE has a feature which helps the user form an approximation of an opponent's view of the world. It allows a user to fix an attitude towards risk for each opponent in the negotiations. The values for risk attitude are: risk neutral, risk averse, and risk prone. A player is **risk averse** if he always prefers payoffs equal to the expected payoff value of a lottery. He is **risk prone** if he always prefers entering a lottery to receiving a payoff equal to the expected payoff value of the lottery. He is **risk neutral** if he is indifferent between entering a lottery and receiving a payoff equivalent to the expected payoff of the lottery.

When an opponent's risk attitude is set to risk prone, we apply a convex function to his payoffs, to generate appropriate preferences. When an opponent risk attitude is set to risk averse, we apply a concave function on his payoffs [French, 1986].

[11] Numbers on the bars correspond to payoff values to Egypt for various outcomes. From the figure it is apparent that for the options considered it is most advantageous for Egypt to try to encourage some type of deal between the Israel and the hijackers.

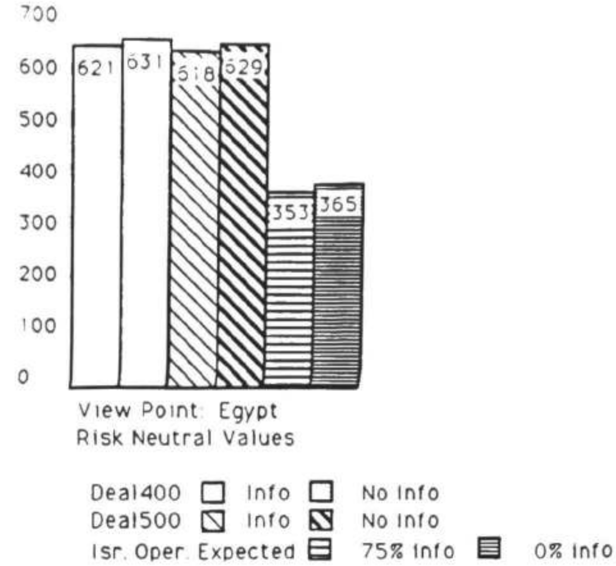

Figure 3: Genie output from the viewpoint of Egypt.

Graphic Output After the user has selected the frame(s) of reference, decision(s), and world state(s), the system sends the request to the evaluation and display routines. These routines determine the format, content, and emphasis of the graphic output of the system. Point values are displayed in graphic form. Histograms are used to display values that are not projected over multiple time periods. When values are projected, piecewise linear graphs are used.

If the result of a decision is a lottery of world states, then the user must be informed both of the payoff of each of these states and the probability that each state will occur.

When the outcomes are not projected over time, these probabilities are simply presented in numeric form next to the associated label in the display key. The user also has the option of seeing expected payoffs. These values are calculated by taking the product of the probability that a given state will occur with the payoff value from this state.

When objectives are projected over time, the probability values can no longer be easily presented to the user. In this case we decided to factor the probabilities into the payoff values to give the user a display of the expected payoffs from an outcome.

Figure 3 is an example of output from a typical query to the knowledge base.

Experimental Results

The simulation experiments were run with undergraduate students in the political science department. Many of the students had little or no experience using computers.

Our preliminary results are from eight simulation runs, each involving three students. Two of these runs involved players who were participating in the simulations for a second time.

In the six runs involving new students, we gave a thirty to forty five minute oral introduction to the system. The students were then allowed about fifteen minutes to experiment before the simulations began.

The results of the simulation runs indicated that multiple frames of reference, projection into the future, and multiple world state definition are the most important features of our system.

Currently, we are running more extensive and controlled experiments which involve comparing the outcomes from simulations run on participants who have access to GENIE versus simulations where participants do not have such access. [12] Among the controls that we have introduced are a modification in setting from the Middle East to India/Pakistan, and a comparison of participants with access to the interface with students with no access. This second round of experiments involves two sets of runs with approximately 13 simulations per set. Preliminary analysis of total payoffs earned by system users versus total payoffs earned by users without access to the system indicate that the system users had on average higher payoffs. From further analysis of these results we hope to be able to draw conclusions not only about the success of our design strategy, but also gain insight into the decision processes of the simulation participants.

Future Work

In the future we plan to add a feature that will allow the user to view multiple outcomes in a tree structure. The leaves of the tree will contain numeric values that represent the payoff to the user from a certain outcome. Interior nodes will represent parameters in the world state on which these payoffs depend. In this way, a user will have access to a symbolic representation that summarizes all of the dependencies of a specified outcome or group of outcomes.

References

[Andriole, 1989] S. J. Andriole. *Handbook of Decision Support Systems.* Tab Books Inc., 1989.

[B. Shneiderman, 1987] B. Shneiderman. *Designing the User Interface: Strategies for Effective Human-Computer Interaction.* Addison-Wesley Publishing Company, 1987.

[Bui, 1987] T. X. Bui. *Co-oP, A Group Decision Support System for Cooperative Multiple Criteria Group Decision Making.* Springer-Verlag, 1987.

[French, 1986] S. French. *Decision Theory: An Introduction to the Mathematics of Rationality.* Ellis Horwood Limited, 1986.

[Fumas, 1987] V.S. Fumas. Strategy planning: Implications for the design of dss. In C.W. Holsapple and A.B. Whiston, editors, *Decision Support Systems: Theory and Application*, pages 429–449, 1987.

[Ghiaseddin, 1987] N. Ghiaseddin. Characteristics of a successful dss user's needs vs. builder's needs. In C.W. Holsapple and A.B. Whiston, editors, *Decision Support Systems: Theory and Application*, pages 159–184, 1987.

[Heymann and Bloom, 1988] H. G. Heymann and Robert Bloom. *Decision Support Systems in Finance and Accounting.* Quorum Books, 1988.

[Kersten, 1985] G. Kersten. Nego: Group decision support system. *Information and Management*, 8:237–246, 1985.

[M. Jarke *et al.*, 1987] M. Jarke, M. Jelassi, and M. Shakun. Mediator: Towards a negotiation support system. *European Journal of Opreational Research*, 31:314–334, 1987.

[Mittra, 1986] S. S. Mittra. *Decision Support Systems, Tools and Techniques.* John Wiley and Sons, 1986.

[Pracht, 1990] W. Pracht. Model visualization : Graphical support for dss problem structuring and knowledge organization. *Decision Support Systems*, 6:13–27, 1990.

[S. Kraus and J. Wilkenfeld, 1990a] S. Kraus and J. Wilkenfeld. An automated strategic model of negotiation. In *AAAI-90 Workshop on Reasoning in Adversarial Domains*, Boston, 1990.

[S. Kraus and J. Wilkenfeld, 1990b] S. Kraus and J. Wilkenfeld. Modeling a hostage crisis: Formalizing the negotiation process. Technical Report UMIACS TR 90-19 CS TR 2406, Institute for Advanced Computer Studies, University of Maryland, 1990.

[S. Kraus and J. Wilkenfeld, 1990c] S. Kraus and J. Wilkenfeld. A strategic negotiations model with applications to an international crisis. Technical Report UMIACS TR 90-20 CS TR 2407, Institute for Advanced Computer Studies, University of Maryland, 1990.

[S. Kraus and J. Wilkenfeld, 1991a] S. Kraus and J. Wilkenfeld. Negotiations over time in a multi agent environment: Preliminary report. In *Proc. of IJCAI-91*, Australia, 1991. To appear.

[S. Kraus and J. Wilkenfeld, 1991b] S. Kraus and J. Wilkenfeld. The function of time in cooperative negotiations. In *Proc. of AAAI-91*, California, 1991. To appear.

[S. Matwin *et al.*, 1989] S. Matwin, S. Szpakowicz, Z. Koperczak, G. E. Kersten, and W. Michalowski. Negoplan: An expert system shell for negotiation support. *IEEE Expert*, 4(4):50–62, 1989.

[Tufte, 1983] E. Tufte. *The Visual Display of Quantitative Information.* Graphics Press, 1983.

[12] The authors wish to thank J. Hewitt and M. Lebrun for helping to conduct the simulation experiments.