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NEW APPROACHES FOR REAL TIME DECISION SUPPORT SYSTEMS

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ABSTRACT

NCCOSC RDT&E Division (NRaD) is conducting research into ways of improving decision support systems (DSS) that are used in tactical Navy decision making situations. The research has focused on the incorporation of findings about naturalistic decision-making processes into the design of the DSS. As part of that research, two computer tools have been developed that model the two primary naturalistic decision-making strategies used by Navy experts in tactical settings. Current work is exploring how best to incorporate the information produced by those tools into an existing simulation of current Navy decision support systems. This work has implications for any applications involving the need to make decisions under time pressure, based on incomplete or ambiguous data.

BACKGROUND

Our research at NRaD is part of the TADMUS (TActical Decision Making Under Stress) project, funded by the Office of Naval Research. That project is generally involved with looking into new ways to enhance the decision making of Navy personnel in tactical command and control situations.

The particular focus of TADMUS is on the area of anti-air warfare (AAW), and involves situations in which shipboard commanders must make decisions about the nature and intent of aircraft that are in the vicinity of the ship. Because these situations can involve jet aircraft armed with missiles, decisions must sometimes be made in seconds even though the available information can be incomplete or ambiguous. The decisions are made by six person teams, where the ultimate responsibility for making decisions lies with the ship's commander (CO) who is closely aided by a tactical action officer (TAO).

The TADMUS research has taken two primary directions. Part of the work is involved with looking at new training approaches for the decision teams. The other primary effort involves the investigation of new approaches in the area of decision support systems. We are involved with the DSS area at NRaD.

A large part of the early DSS related work under TADMUS involved the investigation of the decision-making strategies used by experienced Navy personnel in actual tactical situations. That research took the approach of looking into naturalistic decision making. Naturalistic decision making emphasizes gathering data about how experienced decision makers make their decisions in real world settings. This approach is to be distinguished from the more artificial approaches often used in decision research, where inexperienced subjects are tested in doing unfamiliar tasks in artificial settings. One of the general ideas emerging from studies of naturalistic decision making is that it appears that experienced human decision makers are much better at making good decisions than is often suggested by more traditional research approaches.

The early TADMUS research identified two primary naturalistic decision-making strategies being used by experienced Navy personnel [5]. In most situations, those decision makers use a strategy referred to as recognition-primed decision making (RPD). This strategy relies on the use of prior experience to suggest how prototypical patterns of data may be sufficiently close to currently observed data to guide decisions about the current data [6]. When prior experience proves insufficient to guide current decisions, a second strategy comes into play using explanation-based decision making, or story generation. This strategy involves the construction of a few alternative explanations that account for the current data, followed by an evaluation of which explanation is the most plausible [8]. In both the RPD and story generation situations, selection of a course of action is expected to be automatically generated as a consequence of the situation assessment.

Two tools have been developed under TADMUS to model those strategies. An RPD template based tool takes the approach of matching current data items against a set of stored templates [7]. Those templates represent a set of typical scenarios that can be expected to occur in given tactical settings. The tool estimates the degree of fit between actual current data and the stored templates, and brings templates to the user's attention when there is a sufficiently good fit. A second tool called SABER (Situation Assessment By Explanation based Reasoning)

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constructs alternative explanations that suggest how all current data can be accounted for in reaching distinct different conclusions [2,3]. SABER makes use of a few heuristics to evaluate which of the alternatives is most plausible.

Also in connection with the TADMUS DSS work, a simulation facility has been set up that models existing Navy shipboard systems. A number of experiments have been run at that facility to develop empirical evidence about what kinds of problems arise [4]. A new set of experiments will begin shortly to compare performances with and without the use of the new tools. All experiments are done with experienced Navy personnel.

NEW IDEAS IN DECISION SUPPORT

New Information Products

One of the key hypotheses relied on in developing the two decision support tools is that the use of models of people's cognitive strategies will promote the ability of the tools to enhance people's performance with those strategies. At a general level, the idea is to match the internal models of the tools to the naturalistic decision-making strategies of the users, as a means of achieving a cognitive fit between the way both the tool and the user approach the problem. That fit is expected to lead to improved performance by facilitating a more rapid and accurate use of the strategies. The desirability of achieving a cognitive fit has been emphasized in recent work in the human-computer interface field dealing particularly with tools intended to enhance human performance [10].

Development of these tools has led to an ability to produce new kinds of information products for the decision makers. Some of the key new information products available from the RPD tool are: scenario events shown in a timeline, predicted events, and suggested responses. These products arise directly out of the tool's use of timeline based templates representing event scenarios.

The more important new products produced by the SABER tool are: an ability to group data according to the hypotheses each piece of data directly supports, the related ability to indicate where important pieces of data are missing, and a review of possible ways to account for contradictory pieces of data. This kind of information arises from the tool's ability to construct alternative explanatory structures to account for arbitrary sets of data.

Some of these new information products are illustrated in Figures 1 and 2, where virtually all of the parts of those figures represent either completely new kinds of information or a new way of presenting the information, as compared to existing Navy decision support systems. These figures show information related to a given aircraft track, where the tracks are typically shown as symbols on a geographic display. Figure 1 illustrates an early proposed interface for the new tools. There are nine separate windows illustrated which in counterclockwise order show the following: (1) a three dimensional display of the track history for a selected track; (2) a list of events of interest for the track, keyed into the 3D display; (3) a list of other information related to the track; (4) a bar graph indicating the most likely hypothesis as to the nature of the track; (5) a template presentation showing the key elements of the hostile intent hypothesis; (6) a geographical display showing various tracks, with the currently selected track highlighted; (8) a list of suggested responses with regard to the track; and, (9) a more general list of alerts, which bring items of possible interest to the user's attention.

Figure 2 illustrates a way of presenting some of the information available through the SABER tool. The window to the right shows the grouping of data items according to four high level possible conclusions. Also shown is the ability to indicate important pieces of data that may be missing, where in that window such items are greyed out. The bottom part of the window to the left shows where assumptions can be used to explain away some pieces of data. The upper portion of that window represents a way of indicating which of the four conclusions is the most plausible according to the SABER tool.

Building the Interface

A major goal in designing the interface is to try to satisfy the partially conflicting goals of providing new kinds of information, while at the same time minimizing the time required for users to assimilate the available information. The need for minimizing user interaction time results directly from the real time nature of the tactical situation. As a result of these goals, we are directing part of the design effort at determining what new information is most critical to the decision maker and at finding ways to compress the presentation of that information.

A related problem lies in presenting the information produced by the system in a way that does not suggest to the user that the actual decisions are being made by the system. It is important to note that since these tactical situations necessarily involve incomplete and ambiguous information, it is not possible for any computer tool to generate completely reliable conclusions. In that kind of situation it seems preferable to leave the ultimate decision up to the user, particularly where the decisions can have life or death consequences. One of the principal questions that needs to be resolved in this connection is whether or not the system should indicate to the user the system's own evaluation of the situation.

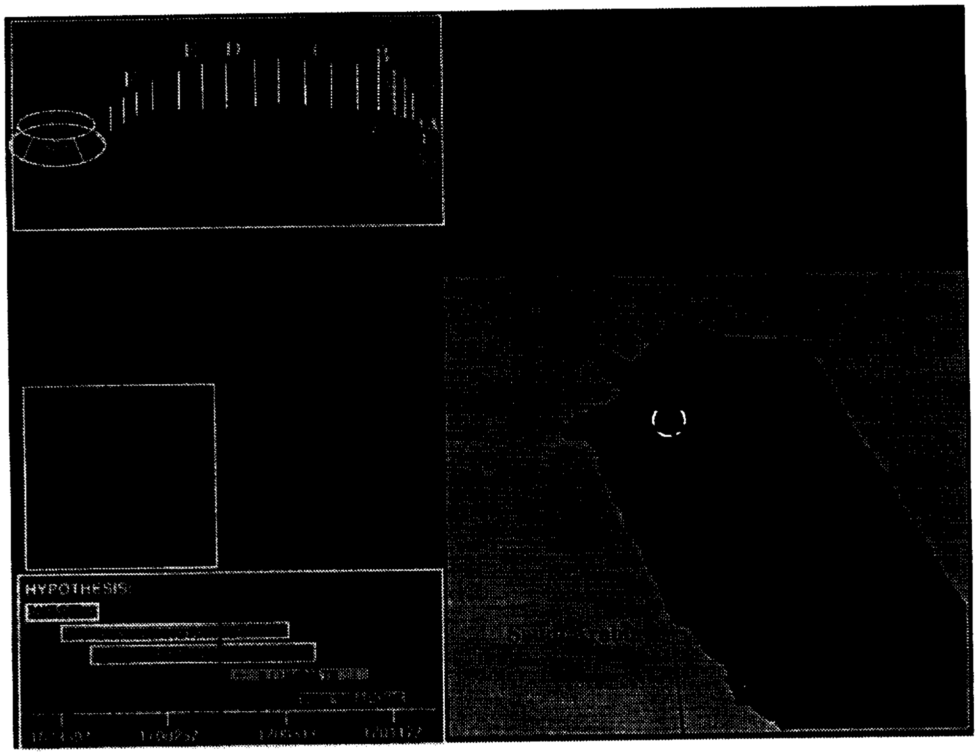

Figure 1. General decision support system interface.

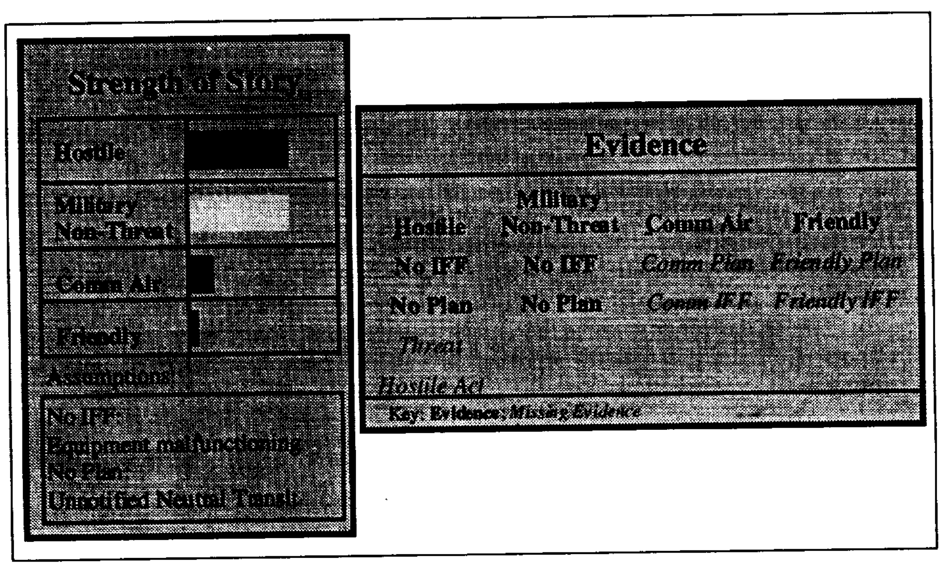

Figure 2. SABER related information products.

In arriving at some final design ideas, we have radically changed our approach to integrating the new information products into the existing DSS framework. The RPD and SABER tools were originally developed as highly interactive, standalone tools. At that time it was expected that the tools would be incorporated into the overall DSS system through separate CRT displays. However, it became clear from both the real time nature of the problem and the identity of the users that that approach was not viable. In fact, it appeared that if that approach were adhered to we would have reached the situation of needing to add a new person to the decision team who could mediate between the two tools and the other team members.

The real time constraint leads to a general need to avoid the need for user interactions with the system. In addition, as the TADMUS empirical work progressed, the decision was made to focus on the two members of the decision making team who have the ultimate decision making responsibility: the CO and TAO. Those individuals are officers who typically do not take a very active role in interacting directly with the DSS, making it even more desirable not to introduce new interactive features.

The net result was to decide on a single CRT display, that would combine the most critical information products of the RPD and SABER tools. The general idea of the intended product is illustrated in Figure 1. It should be noted that the actual display will be in color rather than the black and white shown in Figure 1. The main point here is that Figure 1 shows that a variety of information can be incorporated in a display on a single monitor.

Also of importance in Figure 1 is the point that the only kind of user interaction called for is to click on a track of interest in the geographical display window. Related information of interest is then automatically changed in the other windows. This action is one that is already required on existing DSS's. It should further be pointed out that the symbology used in the geographical display window shown in Figure 1 is unchanged from standard Navy usage, except that color has been added to our product.

In determining how best to fit together the RPD and SABER tools we have developed the view that the tools fit together in a two level approach. At the more specific level, the RPD tool is able to determine how well current data fits into one or more predefined template representations of typical scenarios. Where there is a good fit, the RPD tool can bring templates to the user's attention along with accompanying information products. The SABER tool is seen as performing a more general role that is useful when current data may not fit any of the predefined templates well. Viewed at this level, the role of SABER is seen as supplying tentative, alternative ways of explaining the data in terms of a limited number of high level possible conclusions.

Critics

In part, our interface design efforts are now being guided by principles related to the use of critics in user interfaces. Critics are devices that have received increasing interest in the user interface community in recent years [1,9]. Critics have been implemented in a number of forms, but the essential idea is to have a built-in mechanism for making suggestions to the user about how to proceed with a given task. This kind of mechanism is particularly useful where the computer and user are thought of as working together to cooperatively solve a problem of some sort. Critics have been most often used in cooperative design settings.

That approach fits in well with what we want to accomplish with the TADMUS DSS research. The goal is to achieve a situation in which decisions are made partly as a result of cooperative problem-solving. What is then needed is to identify which activities are done best by computers and which by people in this setting, with the view that by integrating those activities the overall cooperative performance will exceed what either the computer or the person could do alone.

One way of utilizing the critic concept would be to build a model of the user into the interface such that the system could calculate from the user's actions what the user was trying to do at any given time. Based on that kind of knowledge the critic could automatically supply new information as it reasoned that the user needed it. Although we believe that approach is worth further study, at the present time we are not pursuing it. The problems are that the approach does not appear to be appropriate for real time applications, and in our situations it is likely that users would object to having the system decide for them when to change displays and what to display.

Instead, we have adopted the approach of trying to critique the user's decision-making processes in a way that is purely passive and transparent to the user. Essentially, we try to emphasize through our display that there are always alternative ways of explaining a given set of data. While doing that we show some possible ways in which the existing data fits together, and indicate where the fact that some pieces of data are missing may be important. This approach is illustrated in Figure 2 where the user is shown how a current set of data relates to the top level conclusions about whether an aircraft may be friendly or not. That figure indicates that the interface can compactly show alternative ways of accounting for data as long as there are a limited number of top level conclusions.

POSSIBLE COMMERCIAL APPLICATIONS

There are applications for this research in any setting involving the need for real time decision making. Some examples are: some kinds of medical settings, weather forecasting, and possibly air traffic control. These are situations in which decisions must sometimes be made quickly, and may need to be based on incomplete or ambiguous data.

The specific RPD and SABER tools developed for the TADMUS project are not likely to be of value in other settings, since they have both been specially tailored for the AAW command and control setting. However, it is reasonable to assume that the decision-making strategies modeled through those tools are the same strategies used by other decision makers in stressful, real time decision making areas. Where those strategies are used, it should be straightforward to create tools that use the basic underlying approaches of the two tools. The part that would not be so easy, would be tailoring the interface to meet the needs of new domains.

There are a few key lessons learned in our project that should be kept in mind in developing new special purpose tools based on these strategies. The most important lesson is that there are essentially two approaches to making new tools like this available to users. One way is to build in a lot of functionality along with interactive features, with the assumption that either the user will spend a significant amount of time learning to use the tools or that a new human assistant will be used to mediate between the user and the tool. The other option is to try to simplify the interface as much as possible, and require as little interaction as possible. We have chosen the second approach at NRaD. A related lesson is that it is vitally important to identify the ultimate intended user as early as possible so that realistic approaches can be taken with regard to the use of features that require extensive interaction.

CONCLUSION

Initial research done under the TADMUS project has produced a theory about the strategies used by expert Navy decision makers in tactical command and control situations. Two computer tools have been developed that are tied into that theory: the SABER tool and an RPD tool. Work is now being done to determine how best to present the information produced by those tools to users. The expectation is that such information will lead to improved decision making.

The principles being developed through this work have application in any areas involving the need for real time decision support systems. The most obvious area of applicability is in medicine where emergency situations can raise problems with time constraints, incomplete data, and ambiguous data. Those are exactly the kind of problems that are the focus of the TADMUS efforts.

Our design process has suggested a few design principles of particular interest in these real time settings. At a general level it can be noted that simply using models of user cognitive strategies may not directly suggest good ways to construct the interface. We believe that the models do lead to producing the kind of information that is needed, but that determining how to present the information remains a hard problem. More specifically, we have found that although direct manipulation is normally viewed as a desirable approach for letting users manipulate data, in this real time setting it is desirable to minimize such manipulations in order to minimize the time the user must spend dealing with the interface. In addition, we are using graphical data presentations where possible, but not to the extent that users are required to learn an extensive new set of symbols.

At a general level we have focused our design efforts on the idea that the RPD and SABER tools fit naturally together through a two level model of the kinds of information that need to be presented to users. The RPD tool can supply information related to specific, detailed representations of scenarios, while the SABER tool relates data to more general possible conclusions. In addition, we are exploiting the idea that our overall interface can be viewed as a type of critic.

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KNOWLEDGE-BASED COMMODITY DISTRIBUTION PLANNING

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ABSTRACT

This paper presents an overview of a Decision Support System (**DSS**) that incorporates Knowledge-Based (KB) and commercial off the shelf (COTS) technology components. The Knowledge-Based Logistics Planning Shell (KBLPS) is a state-of-the-art DSS with an interactive map-oriented graphics user interface and powerful underlying planning algorithms. KBLPS has been designed and implemented to support skilled Army logisticians to prepare and evaluate logistics plans rapidly, in order to support corps-level battle scenarios. KBLPS represents a substantial advance in graphical interactive planning tools, with the inclusion of intelligent planning algorithms that provide a powerful adjunct to the planning skills of commodity distribution planners.

INTRODUCTION

The complexity and dynamics of commodity distribution planning - both in commercial and military domains - require decision support tools that provide much more than data base access and spreadsheet solutions. This paper presents an overview of a Decision Support System (DSS) that incorporates Knowledge-Based (KB) and commercial off the shelf (COTS) technology components.

The Knowledge-Based Logistics Planning Shell (KBLPS) is a state-of-the-art DSS with a rich map-oriented interactive graphics user interface and powerful planning algorithms that has been designed and implemented to support skilled Army logisticians to much more rapidly prepare and evaluate logistics plans to support corps-level battle scenarios than currently possible. These plans may be developed as contingencies against future possible scenarios or in direct support of troops on the ground. In either case, the ability to build, evaluate, and improve plans in a fraction of the time now possible has been a major objective which is in the process of being met.

KBLPS is an appropriate blend of Artificial Intelligence, Knowledge-Based, conventional, and commercial off the shelf technologies that, taken together, provide a logistician with a powerful tool to help define, analyze, and evaluate very complex planning problems quickly. The Logistician can configure the problem/scenario with a through-the-screen object-oriented approach, as well as give guidance to the algorithm by (optionally) setting a number of parameters; the DP algorithm constructs distribution plans, involving significant computational complexity on behalf of the logistician. As a consequence, the logistician can spend more time analyzing and assessing plans than in generating them.