Critique and Visualization as Decision Support for Mass-Casualty Emergency Management

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ABSTRACT

Emergency management in highly dynamic situations consists of exploring options to solve a planning problem. This task can be supported through the use of visual cues that are based on domain knowledge of the current domain. We present an approach to use visualization of critical constraints in timelines and hierarchical views as decision support in mass-casualty emergency situations.

Keywords

Decision support, emergency management, expert systems, critique.

INTRODUCTION

Emergency management and response in the case of a mass-casualty incident is a very demanding task and involves numerous individuals and teams working together to save lives and property. The outcome of a rescue mission depends to a large extent on the responding units' ability to co-operate and the overall co-ordination of their efforts. This in turn makes it important to investigate how to support the decision makers in emergency situations.

When managing large-scale, time-critical incidents it is not possible to initially make detailed plans. Instead, decision makers rely on matching early observations from the scene with previous experiences to generate prototype plans. They continually refine their plans as they receive more information of the situation. They test approaches with the help of mental models of the characteristics of the situation including what constraints they must fulfill. Our hypothesis is that good support for collaboration in such dynamic situations is to provide the decision makers with different views on the same plan that allows for instant or near-instant intelligent feedback based on known constraints on when, where and how they are supposed to handle the situation. For example, if it is known that they have a limited timeframe for a rescue operation, any allocation of resources that violates this timeframe should be signaled (given as critique) to the user.

In the following, we describe critiquing in a command and control context and characterize a mass-casualty situation. We illustrate the use of a critiquing system and describe implications for the design of a decision support system. Last, we point out future directions.

DECISION SUPPORT IN COMMAND AND CONTROL

Previous research on decision support systems has put much effort on developing tools and methods to improve the conditions for decision makers. In the case of supporting multiple decision-makers, computer support for collaborative work has explored how to best support common work procedures, coordinate office tasks and communicate synchronously and asynchronously within the group (Kraemer and King, 1988; Schmidt and Bannon, 1992). However, few attempts have been reported in the literature on combining this with knowledge-based expert systems (Giarratano and Wiley, 1998).

Knowledge-based system have been used both to generate prototype solutions to problem, or to act as moderators and only react to a human user's own suggested solution. The former kind of system is called an Expert System, while the latter would be a Critiquing System. From a user's point of view, a critiquing system is less ambitious since it only gives advice if the proposed solution from the user differs enough from what the system would consider a valid solution. This criticism is provided to users based on their current work situation and what type of error the system believes the user has committed (Silverman, 1992).

As an example of the difference between an expert system and a critiquing system, the expert system would present us with a proposed plan on how to best use our resources to handle patients in an emergency incident in the shortest time possible. A critiquing system on the other hand could be used to react on a plan that a human operator constructs to point out potential problems or limitations.

The knowledge base that the critiquing system uses in order to give advice does not necessarily have to be pre-defined expert knowledge on how to solve well-defined problems in a given domain if we deal with multi-user scenarios. Instead, we can imagine that the knowledge is provided by other users of the system while the system is in use, and that the role of the system is not so much to make inferences but to mediate information in an intelligent manner, depending on the preferred modality and current domain (Leifler and Eriksson, 2004). According to this idea, we present a design for a decision-support system that can be useful even without highly accurate world models.

MANAGING MEDICAL EVACUATION IN MASS-CASUALTY SITUATIONS

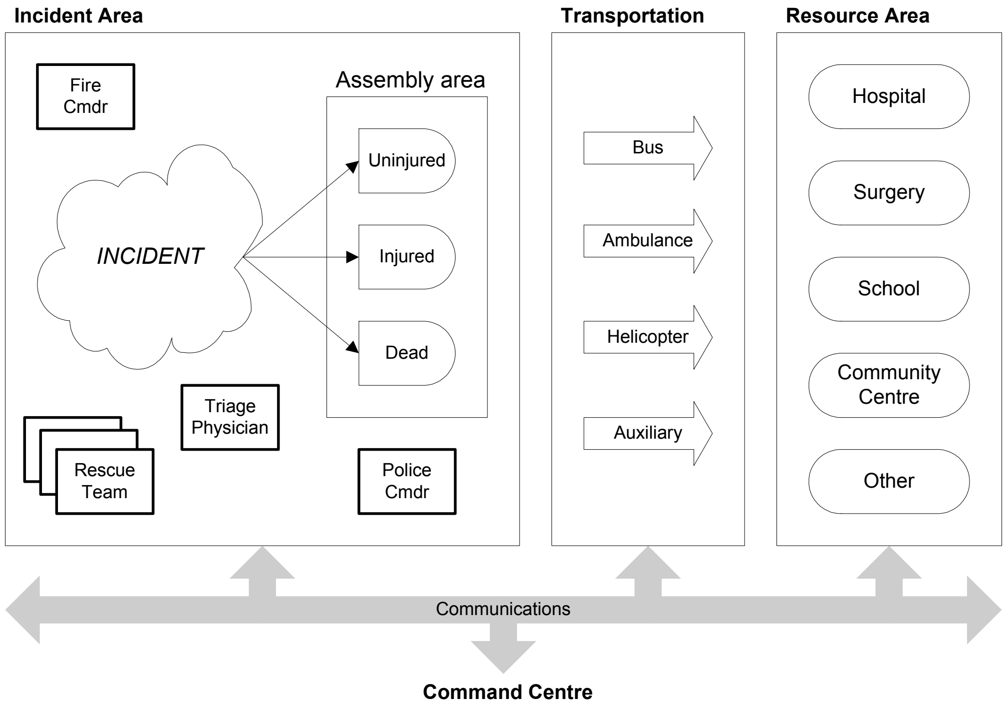

Figure 1: Schematic overview of a rescue operation in response to a mass-casualty incident. Adapted from Morin, Jenvald and Thorstensson (2000).

In a mass-casualty incident the rescue effort is concentrated on the recovery and treatment of casualties. This process is made up of several parallel activities at different geographical locations. Figure 1 gives a schematic overview of a sample rescue operation by outlining its principal activities with an emphasis on the flow of casualties.

The activity in an *incident area* is concentrated on recovery of casualties and triage. Casualties are assembled at an assembly area, receive first aid and are classified according to the severity of their injuries. The decision concerning what rescue teams to allocate and direct to an incident area is crucial to the outcome of the operation.

Different means of *transportation* can be used to move people out of the incident area for further treatment and care. The state of the roads, the weather in the area and the type of incident may restrict the types of transportation that are feasible. Furthermore, availability of transportation resources may impose further restrictions. Also, some victims require advanced treatment during transportation, whereas others do not. The management of transportation resources is critical to the success of an emergency response operation.

A collection of *resources* is available for providing medical care, shelters, and other types of help and assistance needed. Many resources have a limited capacity.

The personnel at the Command Centre make their decisions based on the information available about the situation in the incident areas and at the resource locations.

If we consider the description above of the type of situations where we would like to add decision-support tools, we can see that there are several questions a decision maker may ask himself before making decisions, such as:

- Are there transportation units available in or near the emergency area?
- What types of patients do we have to take care of, and how?
- How much time do we have for each patient?
- Can I use Ambulance X for this emergency, or is it currently in use?

With this in mind, we have begun constructing a tool that will help the user experiment with new approaches to solving a problem and continually get visual critique based on the problem formulation.

The current research prototype aims at supporting the planning, monitoring and replanning of transportation of patients during a mass-casualty emergency. This prototype is currently based in part on the SHOP2 automatic planner, which is developed on the principles of a hierarchical task network (Nau, Au, Ilghami, Kuter, Murdock, Wu and Yaman, 2003). Although we intend to evolve our tool into being user-driven where the user initiates all plan generation, we are currently using the automated SHOP2 planner to generate plans to test various visualization methods. The generated plans are visualized in different, but connected, views. Our use of such views is inspired by the work of Morin who has presented several applications for multiple coordinated views in command and control operations, both for training and analysis purposes (Morin, 2002; Morin, Jenvald, and Thorstensson, 2000).

Hierarchical view

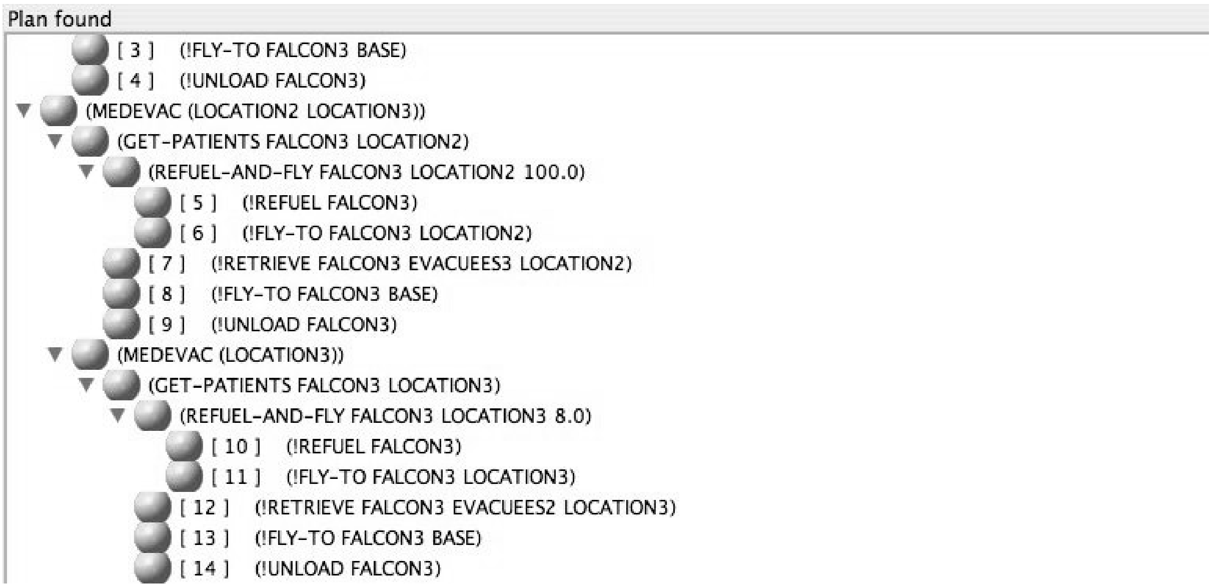

Figure 2. A hierarchically structured plan of a rescue mission using helicopters, as presented in the graphical planning interface that accompanies the SHOP2 planner (Nau et al, 2003).

When planning for how to handle an emergency, the emergency dispatcher may use a hierarchical view of how to decompose tasks into smaller parts. The reason for having this kind of view would be that standard procedures for handling emergency operations can be stated in this way. In the case of military planning, hierarchical task networks have been used to structure the work of a human decision-maker in this manner as well as for automated plan generation (Muñoz-Avila, Aha, Beslow and Nau, 1999). As illustrated in by the example in Figure 2, to retrieve patients from an area by helicopter (`GET-PATIENTS`), we need to

1. fly to the location after we have refueled our helicopter, if necessary (`REFUEL-AND-FLY`)
2. load the evacuees onboard the helicopter (`RETRIEVE`)
3. fly them back to our base (`FLY-TO`)
4. and unload the evacuees (`UNLOAD`).

This hierarchical view of how to structure a task may be suitable to someone who wants to have an overview of how to achieve the overall mission goal and how available resources are used.

Temporal view

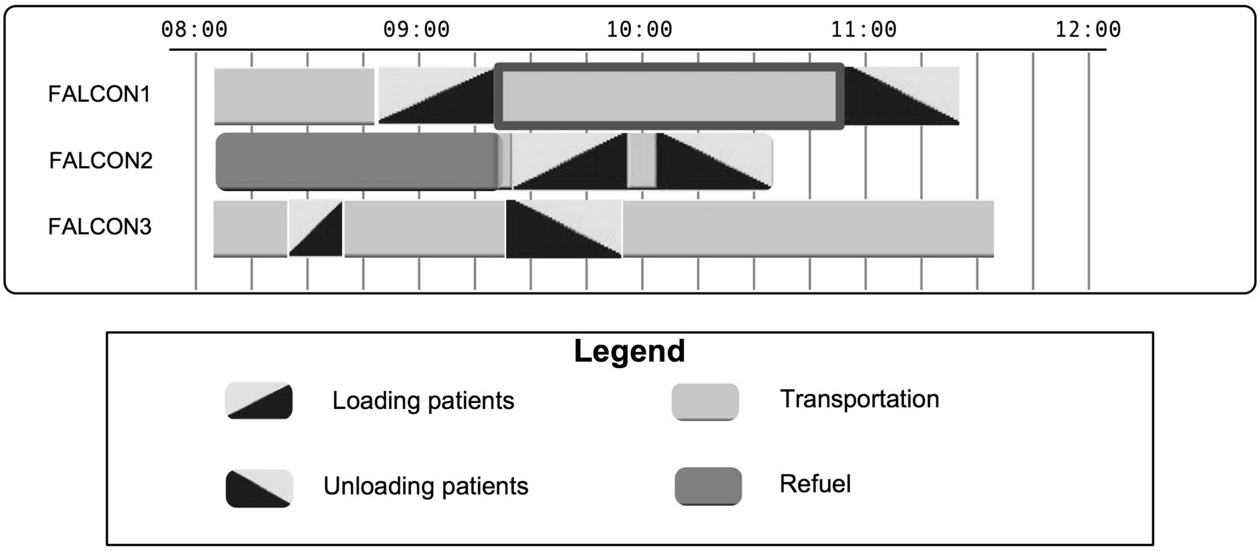

Figure 3. Timeline describing the actions that are part of a plan that uses helicopters to evacuate people from an emergency area. This view can be used to illustrate when we have conflicting use of transportation resources, if we are on time or when hospitals are overfull. In this view, a part of the timeline for helicopter FALCON1 is highlighted since it violates the time constraint on how long patients may be transported by helicopter to medical facilities.

Another view of the same operation is represented by the timeline in Figure 3. In this view, the decision maker can more directly appreciate the amount of time that the entire planned rescue operation will take, as well as how resources are used during the operation.

IMPLICATIONS FOR DECISION SUPPORT SYSTEMS

We believe that since planning mass-casualty scenarios involves continually refining a plan, with exploration as an important part of this process, visualization of limitations could be a good avenue for providing decision support. These limitations should be known through the mission goals, common knowledge about medical conditions and procedures, physical constraints on transportation and other resources. Since the system should have knowledge on what limitations are in effect, the user should immediately get information on how temporal, spatial and formal limitations affect his suggested plans. Preferably, this should be shown as discrete but obvious visual cues during the planning process.

Temporal limitations could refer to how well on time units are, which could be denoted by drawing lines in the timeline view from predicted arrival times according to the plan to latest allowed times as stated by overall mission goals. In the timeline view, one could also color-code the timeline according to how much slack there is in the plan compared to the latest times allowed by medical conditions. In Figure 2, we can see an example of visualizing a time constraint regarding how long patients may be in a helicopter.

Spatial limitations could refer to how the action radii of transportation units affect the possibilities of recovering patients from the emergency area on time. If we plan to use three ambulances to solve the mission, all of which are located at the nearby hospital, it might happen that they will not reach all parts of the emergency area within the time needed to provide first aid. Those parts of the scene could be colored differently to reflect this.

Formal limitations have to do with how, according to doctrine and common routines, missions can be broken down (that is, how a certain mission can be accomplished by performing simpler, smaller tasks), what units' capacities are and so on. If we have not assigned resources to all tasks that we need to complete, empty slots in our tree-based view could indicate this deficiency in the plan.

When designing a decision support system that is based on the concept of providing critique, there are several challenges. In particular, there has to be a sufficient amount of domain knowledge in the system. In the case of a dynamic decision situation such as the one described above, it is hard to express the amount of information that is sufficient and necessary to make a “good” solution since decision makers tend to revise the problems that they are facing as constraints are brought to bear on suggested solutions. If the solution space seems to large, additional constraints are imposed. If there are too few options, they relax their initial formulation of the problem. This calls for a new form of decision support where we do not require that the user of the system has the same goals and methods to solve the problem during the whole process (Beynon, Rasmequan and Russ, 2002). We want to be able to support *incremental refinement* of the knowledge, both so that the system is useable with only very little knowledge, but also so that it can be modified as new circumstances arise.

We believe that many commonly existing constraints that decision makers need to be aware of can be displayed visually using the views described above. Visualizations of constraints during the construction and refinement of plans can be seen as immediate intelligent feedback from the system, based on domain knowledge of the problem.

We argue that the most important aspect of collaboration in dynamic situations is to explore and develop a common understanding of the problem at hand. If decision makers have the possibility to test and communicate their own suggested plans to other members of the team, this could be of great value.

CONCLUSION

We have presented an approach to use visualization of critical constraints in timelines and hierarchical views as support for emergency management. For collaboration, we anticipate that communication of plans and visualization of plan alternatives can be a powerful support for the decision makers. In the future we plan to further develop our research prototype based on these ideas and conduct trials to estimate the user acceptance and operational efficiency.

ACKNOWLEDGEMENTS

We would like to thank Pär-Anders Albinsson and Mirko Thorstensson for their model on how to visualize time constraints and facilitate replanning by using timelines.

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