

## Adaptive Assistance for Crisis Response

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Computer systems are becoming extremely powerful as well as more pervasive. In order to maximize their benefits, we want to provide adaptive interface layers between these systems and their users. Specifically, we expect the interface layer to adapt to unique characteristics of a particular user. Ultimately, we hope to uncover general principles of adaptive user interface design, which include techniques for modeling user habits, gathering information and feedback to drive those models, and a methodology for quantifying the value embodied in a particular adaptive user interface.

Toward these ends, we have explored several problem domains and several modeling techniques. We have tested some of the combinations on users and are in the process of designing methods to test the others. Our strategy has been to first focus on the hardest problems with the assumption that we could learn the most from these. Thus, we have focused primarily on the crisis response domain, a domain where the user (responder) must cope with threat, uncertainty, and urgency. In this short abstract, we sketch our research with respect to crisis response, and then close with a summary of our efforts to generalize our methods and results.

### Crisis response

It might be fair to say that crisis response is the most difficult of problem domains. Organizations and individuals can find themselves in crisis in situations that can be characterized by three elements: threat, uncertainty, and urgency. First, something of value to an entity is at risk; unless actions are taken to change the course of events, the entity expects the threat to occur. Second, the entity has considerable uncertainty about the details of the situation and the outcomes of possible actions. Finally, the entity in crisis perceives that if something is not done *soon*, that the threat will occur; that is, a sense of urgency or time pressure also characterizes a crisis response situation. Therefore, the crisis response task is to quickly select a course of action, or response, that minimizes the expected damage to the value at risk weighted by the uncertainty in the situa-

tion and the need to act before complete information can be collected.

Naturally, a user interface to a crisis response assistant should help the user sort through uncertainty, prioritize actions, and help meet deadlines so as to protect the threatened value. An *adaptive* user interface should modify its assistance so as to accommodate and anticipate a particular user's strategy, values, and habits. Toward these ends, we have developed INCA, an *IN*teractive *C*risis *A*ssistant, that addresses these concerns.

To test INCA, we also developed HAZMAT, a synthetic crisis response domain and simulator. The HAZMAT world models spills and fires of hazardous materials. In this domain, there are 4,000 unique incidents varying in the type of material involved and the magnitude of the spill and fire. The responder has a total of 49 primitive actions that may be used to contain and control the incident. However, not every action is appropriate (or allowable) in every incident. Finally, the user has 25 types of resources available.

Responding to a HAZMAT incident involves choosing a subset of the actions and scheduling them on the available resources without violating any of the resource's constraints. The effectiveness of such a response is measured by HAZMAT's simulator, which compares the consequences of the scheduled actions to the outcome when no actions are applied.

### Response assistance

One of our primary concerns is to provide *useful* assistance to the crisis responder. Others have utilized computational planning and scheduling to provide user assistance. We have focused on attending to the user and providing only the levels and types of assistance that she finds useful. Our results have shown that in some cases, the computational approach is much worse than providing less, but "user guided" assistance.

Our INCA system builds three types of knowledge about the user. First, it learns about the types of complete solutions that a user generates. These are stored in cases and are used through a case-based retrieval mechanism to initialize future responses. However these initialized responses are typically incomplete due to minor differences between the situation from the

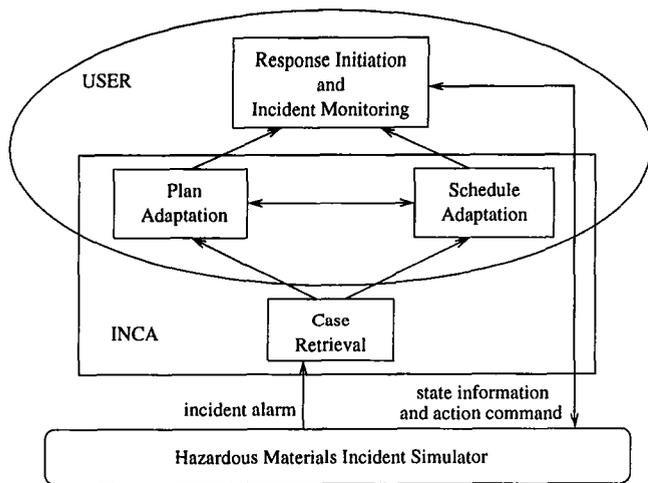


Figure 1: Mixed-initiative response to HAZMAT crises involving INCA and a human user.

stored case and the new incident. Therefore, the user will typically work from the seeded response and make various modifications or repairs. This corresponds to INCA's second type of user modeling.

INCA also learns about the specific types of repairs to a response that a user will implement. Internally to INCA, a selected repair action is represented by the current state of the response (which actions are scheduled and resources allocated) and the features describing the incident itself. Based on experience with a user over numerous HAZMAT incidents, INCA forms situation-action rules that predict what repair action a given user will initiate in a particular situation.

Finally, INCA forms a model of the user's value function to help guide the search for a satisfactory response. Responding to a HAZMAT incident is inherently a multi-valued tradeoff. Resources expended to contain and control a spill or fire cost money, the material spilling and possible structures burning have economic value, and the introduction of hazardous materials into the ground water or the air through combustion also has a particular (negative) value. In such domains, there generally is not an agreed upon value function and hence, different users will respond to the same situation in different manners. To form this type of model, INCA presents an ordered set of candidate responses to the user. The user's choice of which candidate to implement or improve serves as feedback on the model's ordering – either positive when the first candidate is selected, or negative feedback when another is. Through repeated observations of a user's behavior while responding to incidents, INCA forms a model of the user's value function and uses this model to guide the search for a solution.

Figure 1 shows the organization of INCA and how it relates to the user and domain. Note that plan and schedule adaptation are done collaboratively by the system and the user, whereas case retrieval and situation

assessment are performed independently. This structure capitalizes on the respective strengths of the user and the system, and their synthesis leads to better responses than either could achieve on their own.

## Results summary

In numerous experiments involving both human and synthetic users we have established several findings with respect to INCA's utility. First, we have found that case-based seeding significantly reduces the time required by a user to generate a response at a particular level of effectiveness. In the crisis context where urgency is a critical concern, this benefit is especially significant. Furthermore, we found that a fully automated approach that generated a response and presented it to the user required more time than providing no assistance at all! It turned out that the solutions generated by the automated system, though equally effective to user generated responses, were incomprehensible and unsatisfactory to the users.

We also found that INCA correctly predicted repair actions that were selected by the user. Although we have not quantified the time savings resulting from this type of assistance, we adopt the premise that recognition is faster and cognitively less taxing than retrieval. In this case, assenting to the desired repair action when presented as the default, should be faster than selecting the repair action to implement.

In both modeling the preferred repair actions and response seeding, we found user-specific patterns. That is, users tended to benefit more from their personalized assistant than from a generic assistant that modeled all users. An exception to this finding occurred where the user was a novice; in this case, we found the novice benefited from the models formed from expert users.

Finally, we demonstrated INCA's ability to converge on users' relative value functions over the various outcome dimensions of a HAZMAT incident. This was established with a number of synthetic users operating with a variety of value functions. Interestingly, INCA converged on highly accurate evaluation functions even in cases where the user value function could not be represented in the model space (linear combinations of dimensions).

## Ongoing work

We are currently extending our work with INCA in a number of directions. Specific extensions to INCA include user-guided plan monitoring during execution, information gathering actions to address uncertainty, and distributed response tasks requiring coordination and cooperation among multiple users.

Driven by the desire for general principles of adaptive user interfaces, we have implemented INCA in a second domain and are exploring two other potential domains. This exercise has identified aspects that were more domain dependent than we anticipated and has pointed in several directions where we expect to find generally transferable principles and mechanisms.