Rapid Identification of Toxic Chemicals during Emergencies: Integrating Search with Visual Analytics

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Abstract

First responders have a critical need for rapidly identifying toxic chemicals during emergencies. However, current first-responder systems require a large number of inputs before a chemical can be identified. Here we demonstrate a novel system which significantly reduces the number of inputs required to identify a toxic chemical, and provides a visualization of the identification process to help first responders make sense of complex information during stressful situations. The system has been evaluated, and demonstrated to first responders in the field. Current development efforts are focused on refining the prototype for deployment, and generalization to other datasets.

Introduction

The rapid and accurate identification of toxic chemicals is critical for saving lives in emergency situations ranging from terrorist attacks to chemical plant incidents. Unfortunately, current systems such as WISER (developed by the National Library of Medicine) require a large number of inputs before a chemical can be identified[1]. This is because chemicals tend to have a high overlap of symptoms (e.g., irregular breathing) resulting in few that are discriminating. Furthermore, existing systems use *Boolean Search* to access databases, and provide little assistance for determining which symptoms are the most discriminating.

Design

To address the above problem, we collaborated with experienced first responders from a local county hazardous materials response team to iteratively design an algorithm and interface that addressed the high overlap of symptoms across chemicals. We then used guidelines (e.g., provide system feedback) from the *heuristic evaluation* method to implement and refine the design, which was subsequently evaluated in context inside a fire truck by first responders.

Figure 1 shows the resulting prototype which is developed in *Flash*, and called *Mining And Interpretation of Diagnostic Networks* (MAIDN). The prototype integrates search and visual analytics in a flat interface (requiring few menu selections), which was accepted by first responders as appropriate for use in stressful and time critical situations. The top left pane provides a dynamically generated list of symptoms ranked by their ability to eliminate close to half of the remaining chemicals. For example, the top-ranked symptom (*Dizziness*) in the figure will eliminate 47% of the chemicals (as shown by the pop-up box) if it's yes option ("Y") is selected, and about the same if the ("N") option is chosen. In the middle pane, the visualization provides "at-a-glance" the chemical that are eliminated (white dots), and candidate chemicals (black dots with labels) which progressively move into smaller rings towards the inner red circle. When no more symptoms are available to distinguish between chemicals, the final candidate chemicals move into the inner red circle (the "bulls eye"). The system therefore guides the user towards considering symptoms that eliminate many chemicals, and simultaneously provides visual feedback on the effects of different inputs to help make a rapid decision.

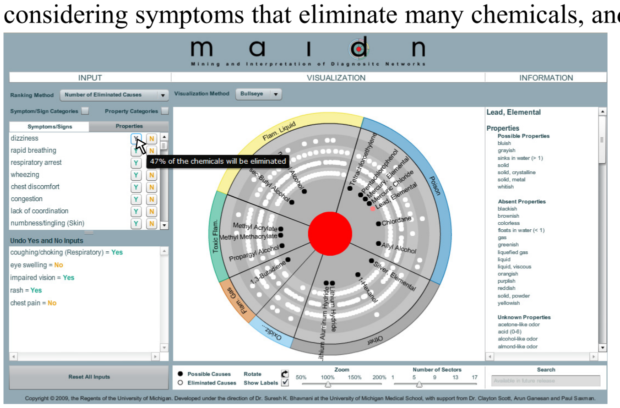

Figure 1. The MAIDN prototype integrates an algorithm which guides users to consider the most discriminating symptoms (upper left pane), and a visualization (center) that provides "at-a-glance" how the symptom selections reduce the candidate chemicals (black dots moving to the center), which are categorized by their chemical properties (sectors).

System performance was evaluated by 2000 simulations of a user diagnosing a chemical exposure using either WISER or our prototype. Significantly fewer symptoms were needed to uniquely identify a chemical using our prototype (mean=8.33, SD=0.7) compared to WISER (mean=25.69, SD=12.79, $p<.01$ two-tailed t-test). The design therefore should be effective in rapid identification of toxic chemical during emergencies.

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References

1. Bhavnani, S.K., et al. Network Analysis of Toxic Chemicals and Symptoms: Implications for Designing First-Responder Systems. *Proc. of AMIA'07* (2007).