Cognitive Systems Engineering and GIScience:
Lessons learned from a work domain analysis for the design of a collaborative, multimodal emergency management GIS

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This research presents an overview of the implementation strategies, results, and lessons learned from an onsite Work Domain Analysis for the design of a multimodal emergency management GIS for hurricane response. An overview of the onsite visits including details of the knowledge elicitation techniques used (e.g. critical incident analysis, concept mapping, and design storyboarding [19],[12]) will be presented. Feedback on the process itself will be discussed, along with an individual example of the use of the concept mapping technique in the creation of realistic scenarios for system design. Finally, recommendations for streamlining the techniques for use in other GIScience domains will be presented for consideration.

In emergency management situations, GIS have been used extensively to create both digital and paper maps to improve decision makers' situational awareness. Geospatial information is crucial to emergency decision-makers for developing planning and mitigation strategies or for real time response and recovery activities. Traditionally, GIS users are constrained to the functionality accessible through WIMP (windows, icons, menus, pointers) executable commands existing within a GIS or geovisualization application. A barrier exists that hinders the decision makers' (e.g. government officials, operations managers, etc) access to, and manipulation of, real time geospatial information stored in a GIS. Currently, decision-makers must rely on the hand delivery of large format, hard copy maps created by GIS specialists. One way to overcome this barrier is by placing the decision maker directly in control of the geospatial display through speech and gesture inputs. This research is focused on designing a system that supports real time display of geospatial information on large screen displays in command and control situations in the main Emergency Operations Center (EOC) and in adjacent briefing and planning rooms.

Research in transparent and multi-modal (sketch, pen, and gesture based) interfaces suggests that such interfaces are more efficient and more desirable than the traditional unimodal interaction [2],[11],[8],[14],[4]. Yet, the application of such interfaces to complex visualization tools and GIS remains elusive. An impediment to real time access to GIS products for decision makers in EOCs is that today's GIS are built for individual users interacting with the software on a personal computer, whereas most emergency response planning is done by groups of individuals interacting with datasets that include satellite imagery, real-time weather forecasts, and multiple GIS coverages printed as paper maps or displayed on personal computers. Moreover, GIS continually contain more complex toolsets, data storage methods, analysis features, and plug-in applications, ensuring that only the highly trained specialists with years of experience are able to make use of GIS functionality during time critical, emergency situations. Clearly, there is a

need to simplify basic GIS interaction, and tailor it for *multiple* users addressing complex problems simultaneously. Early efforts on the development of more natural interfaces such as unimodal natural language processing [5] in GIS represent the first research towards simplifying GIS interaction.

This research represents one portion of an interdisciplinary effort at Penn State University to develop a gesture and speech enabled, multimodal GIS for both public planning and emergency management. In order to better design this prototype system – a Cognitive Systems Engineering (CSE) approach to system design was adopted. An onsite Work Domain Analysis (WDA) was conducted with state and county level emergency managers and GIS professionals in South Carolina and Florida to map out the process of emergency management response to hurricanes, to design interface prototypes, and to aid in the creation of realistic emergency management scenarios that can be utilized for developing, designing and testing the multimodal GIS. (See [19], [12], [17] for overviews of CSE and WDA.)

In designing user interfaces, the field of Human Computer Interaction (HCI) is dominated primarily by two approaches, usability engineering and cognitive systems engineering. A usability engineering (UE) approach focuses on the design of the interface between human and computer interface itself (see [10], [15], [6], [7]). UE is concerned mostly with developing and testing an interface's ease of use, efficiency, error handling, and obtaining information about user satisfaction. CSE focuses more on the design of the interface between the decision maker or expert user and the deep relational structure of the work domain.

CSE is concerned with how expert knowledge can be transformed into blueprints that represent a hypothesis about how the system design influences cognition or collaboration. CSE methods aid analysts in the discovery of the cognitive processes that underlie the task for which a system was designed. Fundamentally, CSE couples human intelligence and cognition with machine power into integrated systems that maximize overall performance [18]. A critical distinction between CSE and UE is that CSE attempts to gain an in-depth understanding of the cognitive aspects of HCI, while UE is more concerned with testing the usability of the final product. One way to frame the difference between CSE and UE is to consider that a system designed with UE methods alone might have highly usable interfaces, but, because the design did not consider the complex social and organizational constraints of the collaborative work domain, could be the *wrong* system, designed correctly.

While researchers in GIScience have begun to adopt techniques from usability engineering [1],[3],[13],[16]; the integration of cognitive systems engineering approaches in GIScience represents a largely untapped, but potentially productive, approach to the design of geoinformation technologies. A problem with standard UE methods (e.g. questionnaires, interviews, and focus groups) is that there is no formalized method for representing the elicited information or for integrating the domain expert's knowledge into the interface design. CSE offers a suite of techniques for a) eliciting the knowledge

from domain experts, b) representing that information for analysis and c) integrating both the domain expert and the elicited knowledge into the final interface design.

This research integrates CSE techniques into GIScience research and development. Because many GIS users require the application and domain specific components to perform their required tasks, CSE design techniques could assist in the development such additional applications (plug-ins) by providing developers with a new toolkit for eliciting expert knowledge about the work process, domain application, and the integration of expert knowledge into the software interface design.

Of the techniques employed, concept mapping is reported on here. Concept mapping is a concept elicitation technique that uses a set of objects, elements, and parts in order to understand a domain. These techniques allow the analyst and the expert to have a shared communication medium through which to converse. A shared communication medium is one that provides the analyst and the participants with a mutually accessible record of the discussion domain [19]. The analyst and expert work to develop and refine the model during the interviewing process. This approach not only provides analysts with flexible, yet structured discussions, but also allows an immediate means by which the elicited knowledge can be visualized, represented, and verified. This technique also reduces the demands on placed on the analyst to interpret the data correctly, by allowing real-time verification [19].

Moreover, concept maps allow the knowledge elicitation expert to capture the temporal domain through the use of embedded timelines that help to explain complex relationships that arise during collaborative, time critical situations. Furthermore, concept mapping can be used for collaborative analysis of multiple domain experts, and they can be compared with one another to ascertain differences among problem solving procedures or individual tasks [19]. Because the final model or representation of the user's problem domain is constructed during the actual data collection session, this technique represents the full continuum of a methodological and conceptual cognitive systems engineering approach. Detailed accounts of the process for implementing concept mapping approach in CSE are provided in [9],[19]. A sample concept map from the onsite WDA, and its role in the creation of realistic scenario of GIS use during emergency management will be presented.

Acknowledgements:
This material is based upon work supported by the National Science Foundation under Grant No.BCS-0113030, PI: Alan M. MacEachren, CoPIs: Rajeev Sharma and Guoray Cai.

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