Map-Mediated GeoCollaborative Crisis Management

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Abstract. Managing crises requires collecting geographical intelligence and making spatial decisions through collaborative efforts among multiple, distributed agencies and task groups. Crisis management also requires close coordination among individuals and groups of individuals who need to collaboratively derive information from geospatial data and use that information in coordinated ways. However, geospatial information systems do not currently support group work and can not meet the information needs of crisis managers. This paper describes a group interface for geographical information system, featuring multimodal human input, conversational dialogues, and same-time, different place communications among teams.

1 Introduction

Crisis events, like the 9.11 attack and the recent tsunami devastation in South Asia, have dramatic impact to human society, economy and our environment. Crisis management activities, involving immediate response, recovery, mitigation, and preparedness, present large scale and complex problems where government in all levels plays a key role. Geographical information systems have been indispensable in all stages of crisis management, where computers are used to map out evolving crisis events, affected human and infrastructure assets, as well as actions taken and resources applied). Their use, however, has been mostly confined to single users within single agency. The potential for maps and related geospatial technologies to be the media for collaborative activities among distributed agencies and teams have been discussed (MacEachren 2000, 2001, Muntz et al. 2003, MacEachren and Brewer 2004), but feasible technological infrastructure and tools are not yet available. An interdisciplinary team from Penn State University (comprised of GIScientists, information Scientists and computer scientists) has joined efforts with collaborators from federal, state, and local agencies to develop an approach to and technology to support GeoCollaborative Crisis Management (GCCM). The project faces two broad challenges: (1) *we have little understanding on the roles of geographical information in distributed crisis management activities*; and (2) *we have no existing computational models and experiences in developing geospatial information technologies and human-computer systems to facilitate geocollaborative crisis management*. We

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address this chicken-and-egg problem by human-centered information systems design approach (Flanagan et al. 1997).

This paper presents our progress towards supporting geocollaborative activities through innovations on two aspects (namely *group work with GIS*, *multimodal dialogue interfaces*) and their integration (see section 3 and 4). We briefly describe our initial implementation of GCCM_Connection, a dialogue-enabled multimodal, multi-parties interface to geographical information systems for crisis response. Before we introduce technical advances, it is necessary to understand the nature of collaborative activities in crisis management.

2 GeoCollaborative Crisis Management

Crisis management includes both strategic assessment (work to prepare for and avert crises) and emergency response (activities designed to minimize loss of life and property). Managing crises requires collecting geographical intelligence and making spatial decisions through collaborative efforts among multiple, distributed agencies and task groups. Typically, one or more emergency operation centers (EOC) works in cooperation with teams of field responders through communication of the situation and coordination of actions. In such collaborative processes, maps encourage efficient communication of knowledge, perceptions, judgment, and actions. This is best explained by a scenario below:

> *The Crystal River nuclear power plant has notified officials that an accident occurred, resulting in a potential radioactive particulate release within 9 hours. Response professionals with a range of expertise, work to determine the impact area, order and carry out evacuations, and deploy RAD health teams to identify 'hot zones' in residential and agricultural areas. Based on available information, immediate decisions must be made about where and how to evacuate or quarantine residents, establishing decontamination checkpoints, deploying rescue and RAD health teams, ordering in-place sheltering, and prioritizing situations. As field personnel deploy, the command Center focuses on coordination of the distributed activity among many participants who are using a range of devices and who have a wide range of geospatial information needs.*

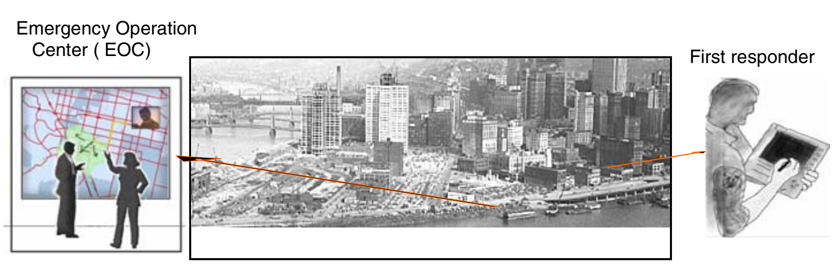

Fig. 1. A scenario of *GeoCollaborative Crisis Management (GCCM):* a crisis management center with the large-screen display collaborating with a first responder in the field

We have been collaborating with the Florida hurricane response center, New York / New Jersey Port Authority, the Pennsylvania Incident Response System, and multiple U.S. EPA units. We worked directly with agency experts to produce explicit representations crisis management components, their interrelations, and changes in both through stages of a crisis event.

3 Group Work and GIS

Neither geospatial information technologies nor groupware (Roseman and Greenberg 1992) and Co-opWare (Darnton 1995) technologies support group work with geographical information (MacEachren 2000). Both the CSCW community and the GIScience community have recognized the importance of supporting collaborative work with geographical information in the last decade, but the communities seems to have been taken two distinct approaches:

(1) *Extending a GIS with some ad-hoc features of group support.* This is the approach taken by most geographical information scientists, especially those in spatial decision-making context. Some interesting extensions include: *shared graphics* (Armstrong 1994), *argumentation map* (Rinner 2001), and shared interaction and annotation on the map view (Shiffer 1998, Rogers et al. 2002, MacEachren et al. 2005).

(2) *Extending groupware toolkits by selected GIS functions.* This is the approach taken by those from CSCW community. For example, *GroupArc* (Churcher and Churcher 1999) is an extension of GroupKit (Roseman and Greenberg 1992) to support video conferencing with geographic information. *Toucan Navigate* (www.infopatterns.net) is an extension of Groove (www.groove.net) to support 'virtual map room' functions.

Our approach to enable group work with geographical information in geocollaborative crisis management is fundamentally different from existing ones. The central idea is to use a collaboration agent to combine selected GIS and collaborative functions dynamically (at run-time) according to the need of the ongoing activity. This is based on the belief that a geocollaborative application is likely to need a small subset of functions from GIS and groupware, but what this subset is depends on the kinds of collaborative activities. This view is inline with the *task-technology fit* theory (Zigurs and Buckland 1998) that was developed in the domain of computer-supported co-operative work (CSCW).

4 Multimodal Dialogue Interfaces

Toward the multimodal, multi-user human-computer-human dialogue-enabled environment envisioned in GCCM, we developed methods for both capturing and understanding individual modalities for interaction, as well as the fusion of information at various levels. Algorithms for tracking multiple people and recognizing continuous gestures have been developed and integrated with speech recognition (Sharma et al. 2003). For quick deployment of multimodal interfaces in

EOC environment, we created a Multimodal Interface Platform for Geographic Information (GeoMIP) (Agrawal et al. 2004). GeoMIP is both an interface and application development tool. It supports speech and free-hand gesture inputs for interacting with a map-based interface to GIS. A close integration of speech recognition, dialog management and database further improves the usability of the system.

The design of mobile field devices for first responders takes advantage of pen-based gesture capturing and speech technologies as natural input modalities. Besides technological issues of multimodal fusion, the system adapts to the mobile contexts by explicitly reasoning on the role, task and goals of the device user. Each step within crisis management generates different tasks and goals. However, the overall goal of mobile system design should be to provide useful devices to the whole activity of the user, supporting easy and error-free operation even during stressful situations (Nielsen 1993).

Our approach to mediate human-GIS dialogues is to incorporate computational theories of contexts, intentions, and collaborative plans to support efficient dialogue strategies with a heterogeneous set of devices in the geospatial domain (Cai et al. 2005). Our design of GCCM is also informed by the cognitive-semiotic conceptual framework sketched by MacEachren (MacEachren 1995) and collaborative discourse theory (Grosz and Sidner 1986, Grosz and Kraus 1996, Lochbaum 1998).

5 The System: GCCM_Connection

We have developed a map-enabled groupware environment called GCCM_Connection (see figure 2). GCCM_Connection is a distributed multi-agent system that is designed to mediate collaborative activities among emergency managers in emergency operation centers (EOCs) and first responders in the field. Here we assume that the EOCs are equipped with a large-screen display together with microphones and cameras to capture human speech and free-hand gestures and support human-system dialogue. The EOC coordinates with hand-held device clients that support user-tool dialogue with natural speech and pen-based gestures. All communications are through XML-based web service protocols. Mobile devices use wireless connections, while the EOC system(s) use high-speed network connections.

6 Discussion and Conclusion

The overall goal of GCCM project has been to deepen our understanding on the (existing and potential) roles of geospatial information technologies as well to develop advanced human-computer systems supporting geocollaborative crisis management. This goal has been partially addressed through our analysis of work domains and through the integration of groupware, multimodal interfaces, GIS, semantic modeling and dialogue management into a suite of software modules, GCCM-Connection. Future work will extend both the framework and implementation to support geocollaboration across multiple levels of government agencies, better design of visual mediation, and adapt to device capabilities and local contexts for field users.

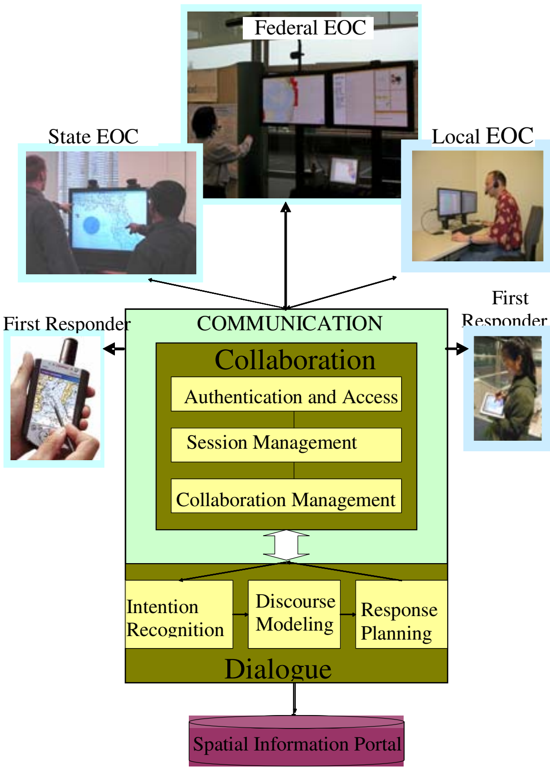

Fig. 2. GCCM_Connection Environment

To ensure the relevancy of solution development, we carefully couple two aspects of our work following the principles of human-centered systems (Flanagan et al. 1997). On one hand, we employ cognitive systems engineering methods (Brewer 2002, Hoffman et al. 2002) to seek deep understanding of the crisis management domain and the roles of geospatial information. The other component of our work is on developing advanced technologies that meets the special human-computer interaction requirements for crisis response activities (Cai et al. 2005).

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References

1. Agrawal P, Rauschert I, Inochanon K, Bolelli L, Fuhrmann S, Brewer I, Cai G, MacEachren A and Sharma R 2004 Multimodal Interface Platform for Geographical Information Systems (GeoMIP) in Crisis Management. In *International Conference on Multimodal Interfaces*. State College, PA
2. Armstrong M P 1994 Requirements for the development of GIS-based group decison-support systems. *Journal of the American Society of Information Science* 45: 669-77
3. Brewer I 2002 Cognitive Systems Engineering and GIScience: Lessons learned from a work domain analysis for the design of a collaborative, multimodal emergency management GIS. In *International Conference on Geographical Information Science 2002*. Boulder, CO: 22-25
4. Cai G, Sharma R, MacEachren A M and Brewer I 2005 Human-GIS Interaction Issues in Crisis Response. *International Journal of Risk Assessment and Management* special issue on GIS in Crisis management(In Press)
5. Cai G, Wang H, MacEachren A M and Fuhrmann S 2005 Natural Conversational Interfaces to Geospatial Databases. *Transactions in GIS* 9(2): 199-221
6. Churcher C and Churcher N 1999 Realtime Conferencing in GIS. *Transactions in GIS* 3(1): 23-30
7. Darnton G 1995 Working together: a management summary of CSCW. *Computing & Control Engineering Journal* 6(1): 37 -42
8. Flanagan J, Huang T, Jones P and Kasif S 1997 *Human-Centered Systems: Information, Interactivity, and Intelligence*, National Science Foundation and University of Illinois at Urbana-Champaign, Arlington, VA
9. Flanagan J, Huang T, Jones P and Kasif S 1997 National Science Foundation Workshop on Human-Centered Systems: Information, Interactivity, and Intelligence,
10. Grosz B J and Kraus S 1996 Collaborative plans for complex group action. *Artificial Intelligence* 86: 269-357
11. Grosz B J and Sidner C L 1986 Attention, intentions, and the structure of discourse. *Computational Linguistics* 12: 175-204
12. Hoffman R R, Klein G and Laughery K R 2002 The state of cognitive systems engineering. *IEEE Intelligent Systems* 17(1): 73-75
13. Lochbaum K E 1998 A collaborative planning model of intentional structure. *Computational Linguistics* 24(4): 525-72
14. MacEachren A M 1995 *How maps work: representation, visualization and design*. New York, Guilford Press
15. MacEachren A M 2000 Cartography and GIS: facilitating collaboration. *Progress in Human Geography* 24(3): 445-56
16. MacEachren A M 2001 Cartography and GIS: extending collaborative tools to support virtual teams. *Progress in Human Geography* 25(3): 431-44
17. MacEachren A M and Brewer I 2004 Developing a conceptual framework for visually-enabled geocollaboration. *International Journal of Geographical Information Science* 18(1): 1-34
18. MacEachren A M, Cai G, Sharma R, Brewer I and Rauschert I 2005 Enabling collaborative geoinformation access and decision-making through a natural, multimodal interface. *Internaional Journal of Geographical Information Science* 19(1): 1-26

19. Muntz R R, Barclay T, Dozier J, Faloutsos C, Maceachren A M, Martin J L, Pancake C M and Satyanarayanan M 2003 *IT Roadmap to a Geospatial Future, report of the Committee on Intersections Between Geospatial Information and Information Technology*. Washington, DC, National Academy of Sciences Press
20. Nielsen J 1993 *Usability Engineering*. Boston, AP Professional
21. Rinner C 2001 Argumentation maps: GIS-based discussion support for online planning. *Environment and Planning B-Planning & Design* 28: 847-63
22. Rogers Y, Brignull H and Scaife M 2002 Designing Dynamic Interactive Visualisations to Support Collaboration and Cognition. In *First International Symposium on Collaborative Information Visualization Environments, IV 2002, London, July 10-12, 2002*: 39-50
23. Roseman M and Greenberg S 1992 GroupKit: A groupware toolkit for building real-time conferencing applications. In *Proceedings of the ACM CSCW Conference on Computer Supported Cooperative Work*. Toronto, Canada: 43-50
24. Sharma R, Yeasin M, Krahnstoever N, Rauschert, Cai G, Brewer I, MacEachren A and Sengupta K 2003 Speech-gesture driven multimodal interfaces for crisis management. *Proceedings of the IEEE* 91(9): 1327-54
25. Shiffer M J 1998 Multimedia GIS for planning support and public discourse. *Cartography and Geographic Information Systems* 25(2): 89-94
26. Zigurs I and Buckland B K 1998 A Theory of Task/Technology Fit and Group Support Systems Effectiveness. *MIS Quarterly* 22: 313-34