1. Introduction

Human society is vulnerable to various crises, ranging from hazardous exposure to toxic substances, natural disasters caused by hurricanes and forest fires, and to the dangerous threats of national security through organized terrorist attacks. Coping with such risks can be complex and controversial, requiring “a broad understanding of harms, losses, or consequences to interested and affected parties.”
[Zerger and Smith 2003] showed that the major impediments of GIS in supporting decisions in high-risk emergency situations has been exploited. Unlike other natural and regularly occurring hazards, emergency events, such as a terrorists attack through chemical or biologic weapons, are less predictable, more dynamic, and have broader social and economic consequences if not managed well within the time and resource constraints.

The challenges confronting crisis managers are extreme in several dimensions. Crises require an extraordinary quantity of resources, such as search and rescue teams, medial assistance, food, and shelter. The demands are highly diverse, geographically dispersed, and largely unpredictable in terms of time, location, and specific resources needed. Moreover, the urgency associated with crises has many implications, such as the need to rapidly identify, collect, and integrate crucial information about the developing situation; to have access to tools and resources that are not cumbersome or difficult to use, particularly in stressful conditions; and to have the capability to make projections and initiate actions in the face of an inevitable degree of uncertainty and incompleteness of information. These characteristics of crisis management distinguish itself from other types of applications. Field studies observing the use of GIS in emergency management [Zerger and Smith 2003] showed that the major impediments of GIS as a decision aid to crisis managers is not the availability of spatial data and analytical models, but instead the user’s ability to access decision-relevant information through human-computer interfaces.

We believe that crisis management applications impose fundamentally distinct requirements to the design of geographical information systems. Such requirements are clearly reflected in the following three aspects. First, geographic information must be delivered within a very short period of time after the information needs arise due to the extreme small window of opportunity for effective actions; second, geographical information presented to crisis managers must be relevant to the task at the hands of crisis managers; third, the geographical information environment must be collaboration-friendly, since crisis managers need to work in teams where maps serve as a shared workspace. A system that serves geographical information needs of crisis managers will not be effectively utilized unless all three design requirements are adequately addressed. This explains why current desktop GIS applications were rarely used by emergency managers as decision support tools; they are cumbersome to use, cannot adapt to the user’s needs, and they are primarily designed for individual use by GIS experts.

As a response to the above identified challenges in designing crisis relevant GIS applications, we have explored the use of human modalities, conversational dialogues, and shared control of visual displays as a new paradigm for improving the utility of geographical information to crisis management teams. To explain the technical feasibility, issues, and potential benefits of such interfaces, we cite two ongoing research prototypes, DAVE_G (Dialogue-Assisted Virtual Environment for Geoinformation) and GCCM (GeoCollaborative Crisis Management).

Interacting with DAVE_G or GCCM human modalities (natural spoken language and free-hand gestures) is relatively effortless and fast, compared to the use of a keyboard and mouse to manipulate Windows, Icons, Menus and Pointers (WIMP) in traditional desktop interfaces. Time is also shortened by placing the burden of formulating map queries to the system, so that there is no waiting for humans to translate information needs to queries (which is a bottleneck of human-GIS interaction). To ensure relevance of the response, both DAVE_G and GCCM use a number of knowledge sources (user models, task knowledge, and discourse context) to plan carefully on the selection, composition, and coordination of multimodal and multimedia output so that the response is helpful, natural, and tailored to the specific user at the moment of interaction. The differences between DAVE_G and GCCM lie in the way they support collaboration. DAVE_G employs a large-screen display as a shared workspace to improve same-place collaboration, while GCCM supports distributed crisis management teams through the use of map-enabled groupware, which allows shared control of geographic depiction of crisis situation on diverse visual devices (ranging from large-screen display to tablet and pocket computers).

The rest of this paper is organized as follow. Section 2 will provide a general discussion on the special human-computer interaction issues for designing emergency management GIS. In Section 3, we propose a roadmap towards GIS support to crisis management, and discuss a few component technologies that contribute to the innovation. In Section 4, we describe two prototype systems, DAVE_G and GCCM, and use scenarios that were developed from our cognitive analysis of hurricane emergency and nuclear threat crisis decisions. Finally, we discuss implications of DAVE_G and GCCM environments to the future role of maps in collaborative crisis management.
2. The Utility of Geographical Information in Crisis Management

Crisis management encompasses four phases of activities ranging from immediate response after an event, mitigation and preparedness efforts before the event, and recovery process [National Research Council 1999], all of which are information and communication intensive. There have been a large number of case studies that demonstrate the scientific benefits of incorporating GIS into crisis management support systems (for examples, see [Goodchild et al. 1993; Vanvoris et al. 1993; Brainard et al. 1996; Chang et al. 1997; Fuest et al. 1998; Thumerer et al. 2000]). While GIS is increasingly used in a more sophisticated fashion in risk analysis and management, interactive maps characterizing dynamic crisis situations are still not accessible to professional managers during actual events. GIS applications are designed to be used by technical experts who prepare cartographic products for anticipated uses prior to a real event. Relatively little practical uses of GIS are found immediately after a crisis event happens. During real-time crisis response, people prefer the use of hard copy cartographic products that were made prior to emergency events (rather than a GIS). This is no surprise since current desktop GIS systems are still hard to use directly by emergency managers. Crisis responders have the following unique constraints: timeliness, relevancy, and collaboration-friendliness (see Figure 1).

Timeliness refers to the requirement that the time elapsed between the rise of an information need and when a map is generated and displayed must be very short in order to be useful. When a crisis happens, there is only a very small window of opportunity to take action. During this time, crisis managers need to gather as much information as they can to derive the best decisions and action plans. For fast developing situations, decisions and action plans have to be constantly re-assessed as new measurements, observations, and reports become available. Timeliness of GIS responses to information needs means lives being saved and asset losses being minimized. However, large delays are often unavoidable when a desktop GIS is used for crisis responses. Since crisis managers often do not have the time and skills to operate a GIS directly, they have to communicate their geographic information needs (together with requirements) to a GIS/modelling expert who will interpret and translate the needs into database queries and data presentation operations. This is a process that normally causes enough delay to turn the users away. It will be even worse if large datasets or sophisticated simulation models are involved.

Relevancy in the context of spatial decision, support for crisis response means that the system must present the right information in the right format to support the user’s task at hand. Crises often bring up new and fast-changing situations that will make most of the pre-designed maps inappropriate. Stein et al [1995] suggested that relevance can be improved by increased interactivity between the decision-maker and the GIS, and interactivity can be achieved by better user interfaces, by allowing external information sources to be incorporated into risk analysis, and by user-directed change in the use of GIS. Gadomski et al [2001] addressed relevancy issues through incorporating an intelligent planning agent that acts on perceived user needs during the interaction session. The need for interactivity was also echoed in a recent National Research Council report (1996) that describes risk characterization as an analytic-deliberative process that allows a user’s reflection, judgment, and choices to be intermingled with model-based analysis. There have been evidences that desktop GIS applications cannot meet the requirement of relevancy. For example, Zerger and Smith [2003] found that emergency managers often complain that GIS-presented maps (pre-designed) are too detailed or too general to be useful. Van Beurden and Douven [1999] demonstrated the effects of different ways of aggregation when presenting geographical information to risk managers, each of which can be judged more or less relevant depending on spatial scale of the crisis.
**Collaboration friendliness** means that the system must have a degree of understanding and awareness that crisis managers work as a team while they are collecting geographical information, interpreting the situation, and making decisions. One way that GIS can support collaboration among crisis managers is to provide a shared visual workspace that facilitates effective communication of spatial knowledge and coordinates their perspectives [MacEachren and Cai (forthcoming)]. Zerger and Smith [2003] observed that emergency management tasks are often done by a group of people who prefer to have a large scale map placed on a table as a shared workspace, rather than relying on a computer operator to display a map on a (small) computer display. A shared map view of crisis events is needed when a new situation is to be briefed to a team of responders, a group of officials, or to the general public. Sharing encourages broader participation of the risk assessment process and allows consensus to be built among multiple affected parties [National Research Council 1996]. The need for collaboration support in a crisis management system may vary with multiple factors. For example, a collaborative team may work together from the same-or-different time and same-or-different places [Ellis et al. 1991; Armstrong 1993]. Sharing may also be affected by the kinds of tasks (risk analysis, or risk characterization, etc.), group size, interaction control, intensity of interaction, and commonality of perspectives (for detailed discussion, see [MacEachren and Brewer 2004]).

The three principle requirements on human use of geographical information during crisis response impose competing design objectives that are unlikely to be resolvable by adapting the traditional geographic information technologies. Although existing methods of geographic information use may be able to address one or two of three dimensions (see Figure 2 for examples), design of GIS to achieve T-R-C all together (see the middle region of Figure 1) is a much harder problem.

### 3. Beyond Desktop: Opportunities for Natural Human-GIS Interactions

Current desktop GIS are designed for individual use by experts in an office environment. They are usually not directly accessible to crisis managers and do not address the special needs of crisis managers in a real crisis event. In the last section, we have developed a better understanding of such special needs and identified the design goal of achieving T-R-C (Timeliness, Relevancy, and Collaboration-friendliness). This requires us to go beyond the existing desktop GIS paradigm, and introduce innovative ideas to human-GIS interactions. Here we suggest opportunities and a road map towards an effective solution through integrating advances in three primary domains: natural, multimodal inter-

![Figure 2](image-url)
3.1 Multimodal Interfaces: Gestures and Spoken Language

Timely delivery of geographic information can be achieved by making the GIS interface transparent and directly accessible to crisis managers without the need of an expert or operator. Efforts to achieve interface transparency for GIS and dynamic maps have focused on natural language forms of human-system interaction [Zue et al. 1990; Mark and Gould 1991; Glass et al. 1995; Lokuge and Ishizaki 1995]. A fundamental difficulty of the natural language approach to map and GIS interfaces is that verbal descriptions of geographic phenomena are often ambiguous, since language does not deal precisely with spatial relations [Egenhofer 1997]. Several authors have suggested that interfaces integrating language and gesture would be a promising approach [Frank and Mark 1991; Blaser and Egenhofer 2000; Zue and Glass 2000].

Integration of speech and gesture has tangible advantages in the context of human-GIS interaction, especially when coping with the complexities of spatial representations. Crisis managers often interact with a GIS operator using spoken language and gestures when talking about information needs, and such skills can be directly applied to the interaction with a multimodal GIS. By integrating speech and gesture recognition, Bolt [1980] discovered that neither had to be perfect, provided they converged on the user's intended meaning. Complex spatial constraints (which are hard to interpret linguistically) can often be easily specified through simple pointing and circling.

Multimodal interactions are inherently superior than desktop interfaces for GIS tasks due to several practical reasons (adapted from Sharma et al. [1998]). First, desktop computing devices, such as a mouse, keyboard, and joystick, are unnatural and cumbersome. Oviatt [1997] has shown that 95 per cent of the subjects in a map manipulation task tend to use gestures together with speech. In another study on Microsoft’s MiPad speech/pen–based personal assistant system, Deng and his colleagues [Deng et al. 2004] reported that multimodal interfaces are 50 per cent faster than open-only interfaces based on measurements of task completion times on emails and appointments. Second, interpreting multimodal messages tends to be more robust and accurate due to the fact that speech and gestures complement each other and mutually disambiguate in the presence of noises. Third, directing computer systems through speech and gesture requires less cognitive effort from humans, because generations of language and gestures are well integrated with the human conceptual processing system. It is the computer that has to do more to recognize multimodal messages and infer the intended meaning. The savings on human cognitive resources is most attractive in crisis management applications because crisis managers are overloaded and under stress in the event of a crisis.

3.2 Dialogue-Enabled Interaction

Capturing spoken language and gesture input is only the first step towards natural, transparent interfaces. Multimodal messages must be properly understood and translated into a series of database, analytical, or cartographic actions executable by computers. Ideally, the system should function well without assuming that the users know the database contents and the system’s command sets, and imposing no pre-defined grammars. In reality, this is a challenging goal and is only practical when the interaction is within a narrow and well-understood domain. There is a semantic gap between the multimodal requests of crisis managers and the data/knowledge stored in a GIS. In order to bridge this gap, we need to introduce a computer agent which serves the role of a GIS operator in mediating the dialogue between the user and the system.

A few theoretical foundations exist that are potentially applicable to the design of dialogue agents for collaborative problem solving in crisis management. Two promising alternatives are the conversational agency theory based on the BDI (Belief, Desire, and Intention) architecture of Bratman et al [1988] and the collaborative planning framework of SharedPlan [Grosz and Kraus 1996]. SharedPlan theory fits naturally to the modelling of intentional structures of collaborative discourse [Lochbaum 1998] and has been demonstrated by the Collagen system to be a sound foundation for building collaborative, mixed-initiative dialogue agents [Rich and Sidner 1998]. Again, these theories and agent architectures have been partially tested in ‘toy’ applications, and we expect that crisis management systems require fuller implementation of the notion of cooperative problem-solving [Bratman 1992; Allwood 2001; Hoc 2001].

For crisis management applications, agent-based approaches that incorporate models of discourse, collaborative planning, and user’s goals and intentions are particularly promising, since crisis situations and action plans have to be constantly re-evaluated and negotiated through collaborative...
problem-solving. A dialogue management agent captures a level of competence of human-human communication. The benefit of incorporating a dialogue management component into multimodal GIS interfaces is the potential of improving the relevance of the computer response to the user’s task at hand. As mentioned earlier, crisis events are not ‘life as usual’ and the course of actions cannot be determined beforehand. This creates difficulties programming agent’s behaviour in design time. An active human-computer dialogue system can overcome such difficulties by (1) tracking and modelling human-GIS interactions as a discourse from which user’s goal and action plans can be recognized, (2) soliciting knowledge of the ongoing tasks from the user when it is not available otherwise, and (3) explicitly grounding the communicative intention through visual and spoken feedbacks. For more details on the roles of dialogues in human-GIS interactions, see [Cai et al. 2005].

3.3 Shared Visual Workspace

A shared visual workspace in the context of crisis management refers to the desire of a shared spatial information environment where multiple people working in a crisis response team can see the same depiction of a situation at roughly the same time. Kraut and colleagues [Kraut et al. 2002] have shown that a ‘shared visual workspace helps collaborators understand the current state of their task and enables them to communicate and ground their conversations efficiently.’ There have been limited studies on the role of visual displays as a mediator for the GIS-enabled decision-making process; exceptions include work by Armstrong et al. [1992]; Jankowski and Nyerges [2001a]; Jankowski and Nyerges [2001b]. In recent work, MacEachren [2003] has identified three roles for collaborative geovisualization: as the object of collaboration, as a support for dialogue, and as a support for coordinated work. These same roles characterize the potential of collaborative, visual, dialogue-enhanced, GIS-based tools for crisis management. A Command Centre team might assess the crisis on a map-based display (as the object of collaboration) while inter-agency collaboration is supported through a complementary tool offering spatial annotation capabilities (providing support for dialogue). Simultaneously, by integrating GPS mobile technologies with the EOC (Emergency Operation Centre) display, EOC staff can monitor and manage activities of field personnel (providing support for coordinated work).

4. System Implementations

In the previous section, we discussed three technological foundations that could lead to innovations in the design of human-GIS interactions. There can be many different ‘roadmaps’ for integrating the three component technologies (multimodal interfaces, human-computer dialogues, and shared visual workspace) into practical solutions to our T-R-C problem. In this section, we describe the one ‘roadmap’ that we have been taking by presenting two research prototypes, DAVE_G and GCCM, that have been implemented by our research group, and show how we address T-R-C in an integrated fashion.

4.1 DAVE_G: Dialogue-Assisted Virtual Environment for Geoinformation

The primary design goal of DAVE_G is to provide a geographical information browsing and decision-support tool for crisis managers (with no GIS training) to quickly access complex spatial information through large-screen displays typically available in EOC rooms. Such rooms are commonly equipped with large screen displays where crisis managers can share a common visual environment while working together. In order to enhance EOC environments with better access to decision-relevant geographic information, we have integrated solutions from natural language and speech processing, vision-based gesture recognition, and conversational dialogue technologies to enable multimodal dialogues with interactive maps served from geographical information systems [Rauschert et al. 2002; MacEachren et al. 2003; Sharma et al. 2003]. In DAVE_G, natural hand gestures and spoken requests are recognized, allowing completely device-free interaction.

Figure 3 shows a snapshot of a user session where two users collaboratively work on a risk assessment of an ongoing hurricane, and geographical information is accessed through spoken language and free-hand gestures. We will briefly describe the design principles of the DAVE_G system, and provide an account on how it addresses the concerns of crisis managers in terms of urgency, relevancy, and sharing.

The development of DAVE_G followed a human-centred approach that involves iterative cycles of learning about users and implementation of system components to accomplish the user’s tasks. Specifically, we used cognitive system engineering methods [Wood 1986; Brewer and McNeese 2003] to explore the intricacies of geospatial information use within our initial
domain context of emergency management and response. Working with the EOC within the State of Florida Hurricane Center (EOC-FL), a series of techniques are being applied to an in-depth, work domain analysis to determine how maps and GIS are used for emergency management in the specific context of hurricane response and management. These techniques include questionnaires, individual and group concept mapping, critical incident analysis, and design storyboarding. Attention has been placed on the use of GIS and map-based displays during emergency situations, therefore in the response stage of emergency management. Such elicited knowledge, combined with generated use scenarios, has been used to inform the implementation of DAVE_G.

The DAVE_G system has three main modules that can run in a distributed or centralized setting (see Figure 4). Communications among modules are handled through DAVE_G with specific dialogue message protocols following XML message standards. The Human Perception module captures a user’s speech/gesture input and generates proper descriptions of recognized words, phrases, sentences, and gestures to be used for high level processing. Each human reception control unit uses a single, non-calibrated active camera to find and track a user’s head and hand in the current field of view. To enable multiple users, the system uses several instances of human reception control. This approach requires having one camera and one microphone for each user. The user can move while interacting with the system as long as he/she stays in the camera view.

Human-GIS Collaboration and Dialogue Management module (HCDM) receives recognized gesture and speech components from all active users (clients), derives the meaningful commands intended by individual users, and coordinates the execution of these commands. When multiple users are active on the system, the HCDM is responsible for two things: (1) performing necessary fusion or multiple input messages and managing conflicts; and (2) handling ill-formed and ambiguous input, translating user’s information needs to executable actions by geographical information servers. In order to manage geographical information dialogue, the HCDM maintains (and dynamically updates) an explicit representation of the dialogue contexts and task planning status.

Finally, the Display and Information Handling module processes requests forwarded from the HCDM module and forms correct GIS queries to be executed by standard query interfaces. It will perform the concept-to-data mapping and identify proper operational sequences. In case of problematic requests, it also raises exception events (to the dialogue manager) with the reasons for query failure. Our current implementation uses ESRI’s ArcIMS as the geographical information server.

4.2 GCCM – GeoCollaborative Crisis Management

Crisis management typically requires one or more EOC to work 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. Figure 5 presents a concrete scenario to illustrate the nature of geocollaborative crisis management activities.

We have developed a map-enabled groupware environment called GCCM (see Figure 6). GCCM is
A gas leak has been detected on campus and the university has been notified. The gas leak is in the Graduate Circle area of campus which is near the campus reactor. There is potential for a large-scale disaster and emergency managers must handle this situation. 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 campus areas. Based on the visual depiction of the situation on maps, immediate decisions are made about where to set up an incident command centre, 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 are deployed, the Command Centre focuses on coordination of the distributed activity among multiple field teams who are using a range of devices and who have a wide range of geospatial information needs.

Figure 4: A modular view of DAVE_G architecture.

Figure 5: A scenario of GeoCollaborative Crisis Management (GCCM): a crisis management centre with the large-screen display collaborating with a first responder in the field.

designed to mediate collaborative activities among emergency managers in EOCs and first responders in the field [Cai 2005]. 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 field teams through multimodal dialogues mediated by GCCM. Field teams have access to hand-held devices that run GCCM client and support user-tool dialogue using 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.

During an interactive session, GCCM mediates all the message flows among team members and reasons about the role of maps in the ongoing tasks in order to determine map contents, presentation format, and sharing requirements. Central features
of this system are its abilities to (1) understand and act on natural multimodal requests for geographical information from crisis managers, (2) allow each member to work with geospatial information individually or collaboratively with others, (3) manage mixed-initiative dialogues for cooperative decision-making, and (4) access existing data and services from an enterprise spatial (and non-spatial) informational infrastructure. The “Dialogue Manager” component is an intelligent agent that mediates the collaborative discourses among humans and devices.

GCCM can interpret stylus input from tablet PCs as deictic or iconic gestures. Examples include the ability to select cities that are on one side of a position (spatial component indicated with a linear gesture), highlight a critical facility (spatial component indicated by a pointing gesture), or exclude locations outside of a region from consideration (spatial component indicated with an area gesture). More generally, users can indicate any specific location or extent through gesture (e.g. “zoom to include this area” – with a pointing or area gesture indicating the referent for this and the interpretation of the request based on which kind of gesture is sensed). On the other hand, speech-based requests are particularly effective for selecting or highlighting named features (e.g. highways, cities, counties), and creating buffers around named places.

5. Discussions and Conclusions

We have looked into reasons that lead to low utility of GIS tools in real-time response to crisis situations, and raised attention to three special requirements that have not been addressed adequately by GIS research communities: timeliness, relevancy, and collaboration-friendliness (T-R-C). Among many solutions to the above problems, this paper takes a human-computer interaction perspective and suggested potential innovations to human-GIS interfaces. In particular, we reviewed advances in three technical domains – multimodal interfaces, human-computer dialogue system, and information display for geovisualization and collaboration. Methods for integrating such technologies into human-GIS interface solutions are demonstrated by our research prototype systems, DAVE_G and GCCM. The current functionalities of DAVE_G and GCCM are still relatively primitive, compared with natural human-human dialogues, but this is taken as the first step towards a new paradigm of interacting with geographic information.

In conclusion, both DAVE_G and GCCM incorporated features of speech/gesture interactions, mixed-initiative dialogues, and shared visual workspaces. These features contribute (individually and in combination) to faster response time, run-time adaptation to user’s immediate tasks, and visually-enabled, uninterrupted collaboration among team members. Users of such systems will regain the control of their information environment, creating novel experiences for interacting with geographical information systems.

We are conducting a series of usability experiments to measure our progress (made in DAVE_G and GCCM) towards addressing the special needs of crisis management. The results will be reported separately. We believe that the power of GIS in visualizing and characterizing crisis and risks should be made (and can be made) accessible to emergency managers. The crisis management community will benefit from geographic information if the special concerns about immediacy, relevancy, and collaboration-friendliness are explicitly addressed in the design of geographic information systems.
Acknowledgement

Part of this work is based upon work supported by the National Science Foundation under Grants BCS-0113030 and EIA-0306845. We acknowledge the contributions of the following graduate students to various parts of this project: Hongmei Wang, Levent Bolleli, Yinkun Xue, Isaac Brewer, and Michael Stryker. The authors thank two reviewers and the guest editor of this special issue for their valuable comments which helped to improve the quality of this paper.

References


**Authors**

Guoray Cai received his B.E and M.E. degrees in Electrical Engineering from Tianjin University, China, in 1983 and 1986 respectively, his M.A. degree in Geography from West Virginia University in 1993, and a Ph.D. degree in information sciences from the University of Pittsburgh in 1999. He was a research scientist in the Institute of Remote Sensing and Applications within the Chinese Academy of Science, Beijing, during 1986-1991. He was also the recipient of a NASA Global Change Graduate Fellowship during 1993-1994. Since 1999, Dr. Cai has been with the Faculty of Information Sciences and Technology, as well as the faculty of Geography at Penn State University. Dr. Cai’s main research interests include geographical information science, spatial databases, human-computer interactions, multimodal and conversational interfaces, map-mediated human-computer-human dialogues, and geocollaborative crisis management.

Alan M. MacEachren received his Ph.D. degree from the University of Kansas, Lawrence, in 1979. He is currently a Professor of Geography and Director of the GeoVISTA Center (www.GeoVISTA.psu.edu) at Pennsylvania State University, University Park. He is the author of *How Maps Work: Representation, Visualization and Design* (New York: Guilford, 1995) and an Associate Editor of *Information Visualization*. His research interests include geographic visualization, interfaces to geospatial information technologies, human spatial cognition as it relates to use of those technologies, human-centered systems, and user-centered design. Dr. MacEachren is currently Chair of the International Cartographic Association Commission on Visualization and Virtual Environments. He is also a Member of the National Research Council Computer Science and Telecommunications Board Committee on the Intersections Between Geospatial Information and Information Technology.