Information Fusion for Civilians: The Prospects of Mega-Collaboration

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Introduction

Current research in information fusion is redefining the role of human participants. This human-centered approach has highlighted the public's potential to observe and report information and to analyze complex problems. This is especially true for problems embedded in social activities and social networks. In this chapter we explore a bottom-up perspective on information fusion in the civilian layer by reviewing how ad-hoc networks of volunteers have formed and functioned to address large-scale problems and by discussing how information and communications technology (ICT) could be designed to support this activity, which we refer to as *mega-collaboration*. The goals are not only to better facilitate civilian responses to crises, but to also interface these bottom-up networks with the top-down structures of military and governmental agencies.

The concept of crowdsourcing explores the analytic and information gathering power of individuals and groups outside of formalized military or governmental structures (Howe, 2008). Although information fusion recognizes the potential value of the civilian layer (also called the "H-Space" Hall, McNeese, Llinas, & Mullen, 2008) it typically casts civilians as resources in a top-down structure. From this top-down perspective, citizens may be passively observed, actively solicited for information, or called openly to investigate a problem.

A different kind of organizational structure to consider is that of teams that form from the bottom up through the efforts of civilian volunteers spontaneously responding to a problem or event. These ad-hoc networks can form to gather information, share knowledge, and take action independently of the command and control structures of official response agencies. There are growing numbers of examples of this phenomenon to study, such as the civilian responses to the September 2001 attacks at the World Trade Center buildings in New York City (Denning, 2006), the 2004 Indian Ocean tsunami, Hurricane Katrina in 2005 (both in Palen & Liu, 2007), and the April 2007 shootings at Virginia Tech (Palen, Vieweg, Sutton, Liu, & Hughes, 2007b). In these and other cases, the public demonstrated remarkable creativity and agility in gathering, processing, and disseminating information by whatever means were available—from Internet posts to paper flyers (Palen & Liu, 2007). This rapid summoning of energy enabled these nascent groups to take effective action on problems even before official responders had arrived on the scene. Civilians on the ground may be more likely to know what and where the problems are and the location and means of obtaining needed resources. However, as these ad-hoc networks are formed rapidly with opportunistic appropriation of communications technology, they become resistant to hierarchical organization and structured communication with official agencies. This resistance is particularly pronounced when trying to bridge official agencies (e.g., FEMA or the National Guard) with civilian efforts.

Mega-Collaboration

The term *mega-collaboration* appears to have been coined by Nielsen (1997) to describe activity on the Web in which independent actions from millions of people (a “city of strangers”), acting in their own interest collectively create a productive environment. This is quite unlike typical collaboration in which team members know each other and share explicit objectives. We prefer to add this higher level of goal orientation and self-organization to Nielsen’s concept, particularly in light of evidence that strangers facing a common problem can and will exploit Internet-based technologies (e.g., social networking sites, blogs, and chat rooms) to seek potential associates, form groups, share information, negotiate strategies, and take action. In practice, mega-collaboration converges toward more typical collaboration, though still on a vast, potentially global, scale.

This phenomenon is highly visible in the crisis response domain, which is the focus of the present discussion. However, mega-collaboration can also be applied to other situations where self-organized public activity should partner with official administrative structures, such as between neighborhood crime watch organizations and municipal police forces. Furthermore, mega-collaboration is not necessarily constrained by local or temporary disabling of communication media. First, although communications infrastructures can be heavily compromised by some crises, especially natural disasters, the aftermath can last months or years, far surpassing the recovery time of the communications networks. Local telecommunications networks are likely to be restored long before the recovery is complete, while people are still assessing the damage and casualties, locating resources, and reestablishing acceptable living and working conditions. Meanwhile, the rest of the global community continues to gather information and organize resources. Mega-collaboration extends long after its precipitating event and across a far wider area.

Mega-collaboration shares many research threads with traditional data fusion, including situation assessment, group cognition, and common operational pictures (COP) as applied toward complex problem solving and resource allocation. Research on these mega-collaborative processes aims to understand these problems more fully and to explore potential sociotechnical solutions. Drawing from the living laboratory approach (McNeese et al., 2005a), we have identified three main thrusts in this area:

- *Understanding the social processes of technologically-mediated communication of ad-hoc teams in response to complex, large-scale events.* A better understanding of these social processes, especially the disjunctions between them, is essential to inform the development of flexible and transparent systems that afford improved situation awareness and facilitate rapid and effective team cognition. This can be achieved by conducting field work, examining case studies, running experiments with volunteers in simulated task environments, and linking theoretical approaches from social psychology, industrial-organizational psychology, and human–computer interaction.
- *Identifying procedural and technological interventions to address the gaps identified above.* Armed with knowledge about the individual and team activities to be supported,

existing technology may be re-evaluated, and new techno-socially appropriate systems can be proposed and developed. Successful results will come from an approach that is simultaneously *user*-centered and *group*-centered.

- *Testing prototypes of tools to support mega-collaboration with human volunteers.* Armed with an understanding of social processes involved in large-scale disaster response, impediments to their smooth functioning, and promising procedural and technological interventions, innovative tools can be developed, tested, and deployed to facilitate communication among potential volunteers, team formation, and collective action and to enable better integration of the civilian layer with disaster response organizations.

The Role of ICT in Disaster Recovery

The advance of information and communication technology (ICT) has added a new dimension to research on disaster relief in terms of both potential problems and potential solutions. Concurrently, the evolving discipline of informatics has been leading to a more rigorous consideration of the implications of ICT development for collaborative information gathering and other activities.

The knowledge and resources needed to confront a crisis are often distributed, politically and physically, among multiple agencies and geographic locations. This situation has led some crisis-response researchers to call for a distributed decision-making network for the management of mega-disasters (Harrald & Jefferson, 2007). However, current technological support for mega-scale distributed collaboration is inadequate (Denning & Yaholkovsky, 2008). Responders need better support through more effective interfaces to help them convert masses of distributed data into appropriate action.

Hurricane Katrina and other recent mega-disasters have spurred a new kind of mega-collaboration in which thousands of people respond to a crisis by spontaneously working together via the Internet (Newlon & Faiola, 2006). Ordinary citizens and their grassroots organizations have rapidly connected volunteers, donors, and aid recipients by updating blogs, electronic mailing lists, and bulletin boards. These technologically-empowered volunteers should be managed as part of the overall response to a disaster to avoid adding to the chaos. However, because they are geographically dispersed and demographically diverse (Denning, 2006), they present a serious management problem.

A trade-off exists between the benefits of command-and-control structures efficiently delivering services under extreme conditions and of thousands of spontaneous volunteers and emergency organizations responding creatively to unforeseen problems (Harrald, 2006). Grassroots self-organization among the affected population contributes to the adaptability, creativity, and improvisation that are critical to the success of the relief effort (Dynes, 1994).

This line of thought has developed into a call to action in a paper on *collaborative adhocracies* by Mendonça, Jefferson, and Harrald (2007). This call specifically targets ICT designs that rely on outdated approaches to disaster response. They instead propose *emergent interoperability* as a more appropriate approach to the design of ICT for disaster response. By this they mean a structured methodology for making use of a wide range of available ICTs selected in real-time to support both individuals and groups involved in the emergency response.

In a similar vein, Denning (2006) describes how multi-organizational networks form after a disaster and the factors that determine their success. A hastily formed network (HFN) is a rapidly established network of people from different communities who work together to achieve an urgent mission in a shared conversation space. The HFN encompasses both the communication system and how users interact within it. Creating well-functioning HFNs poses a challenge for ICT design. After examining the responses to both the 2001 World Trade Center attack and Hurricane Katrina, Denning observes, "[The] effectiveness of the HFN rests on the quality of the conversation space established at the outset" (Denning, 2006, p. 17). If participants can agree on interaction rules and reach a consensus on the definition of the problem, the likelihood of success greatly increases. This process of negotiation is what mega-collaboration tools should be designed to support.

Calls for ICT Innovation for Disaster Collaboration Support

Palen, Vieweg, Sutton, Liu, and Hughes (Palen et al., 2007b) document the public's use of social networking during the Virginia Tech shooting in April 2007. Private citizens (many of whom were located far from Virginia) performed much unsolicited work in compiling a list of victims and connecting students, staff, and faculty with distant worried relatives. In fact, an HFN had already compiled a complete list of victims before the officials in charge at the scene had released theirs. This is yet another example of ICT-enabled collaboration and information gathering by the public outstripping the official response (also see James & Rashed, 2006; Schneider & Foot, 2004). Although the public's new-found agility for self-organization might be seen as beneficial, it also invites potential dangers if the gap between public and bureaucratic agility continues to widen. Palen, Hiltz, and Liu (2007a) address this issue by describing ethnographic studies on the World Trade Center attack, the London Tube bombings, Hurricane Katrina, the California wildfires, the SARS epidemic, and various earthquakes around the world. These studies show that the public usually respond first to a crisis and do not relinquish their role once the official effort begins. This has been true, even when the only available methods of response and communication were digging with bare hands and posting paper flyers. Therefore, it is not surprising that the public has led the way in adopting novel technology applications in times of crisis. Widely available ICT advances challenge the conventional models used by government planners and will require a new relationship between official responders, nongovernmental organizations (NGOs), and the public (Currion, de Silva, & Van de Walle, 2007; McNeese et al., 2006). These advances enable new designs for software tools that foster effective collaboration between official responders and private citizens.

Information Fusion through Mega-Collaborative Processes and Tools

Social and Cultural Processes

In general, collaboration demands that individual participants function as a team, traversing the team-building stages of *forming, storming, norming,* and *performing* (Tuckman, 1965). To succeed at team-building, teammates must combine their individual mental models of the problem into a team model. This involves both the convergent processes of information pooling and cognitive consensus and the divergent processes of specialization and transactive memory (i.e., transmission of the cooperative information to the appropriate expert; Mohammed & Dumville, 2001). Therefore, large-scale collaboration in a distributed environment requires an interface that captures individual mental models and facilitates the negotiation of team models. The goal of mega-collaborative systems is to aid in the comparison and merging of these models such that a hierarchy of consensus, organized tasking, and a common operational picture emerge from this expansive community of individual participants.

The design of a large-scale collaborative interface poses social, psychological, and technological research questions. The formation of mental models is a dynamic process involving both the individual and the situation. Capturing such models requires a flexible interface capable of representing many different kinds of entities and relations. An even greater challenge is facilitating the model-negotiation process among a dispersed and heterogeneous team. These challenges are particularly daunting, because they must be met for a team of thousands. Ongoing research offers potential solutions (Klein, Pfaff, & Drury, 2009; Newlon, MacDorman, & Scerri, 2008a; Newlon, Faiola, & MacDorman, 2008b). This chapter provides a synthesis of these approaches for developing a tool for managing mega-disasters.

Research on team dynamics has increased our understanding of cooperation, suggesting new tools for online collaboration. Ess and Sudweeks (2005) and Hewling (2005) describe how virtual-group participants from different organizational cultures negotiate a new *third culture*. This new culture is created out of the participants' unique online encounters. Certain individual personality traits have been identified that affect interpersonal interactions, such as conscientiousness, agreeableness, and neuroticism (Mount, Barrick, & Stewart, 1998). Several studies have been conducted on virtual teams (Farnham, Chesley, McGhee, Kawal, & Landau, 2000; Powell, Piccoli, & Ives, 2004) and *extreme teams* with several hundred members. The latter are typically seen in emergency response situations (Scerri, Farinelli, Okamoto, & Tambe, 2005; Scerri, Xu, Liao, Lai, & Sycara, 2004).

Collaboration Management

To organize human-reported information into a meaningful conversation, some level of collaborative administration is necessary. Information management challenges must also be overcome to link the civilian layer with tactical operations. One approach to address this is *collaboration engineering*, which facilitates the decomposition and design of repeatable collaboration processes for teams working on high-value collaborative tasks (Briggs, de Vreede, & Nunamaker, 2003). The goal is to provide neutral guidance and structure to the collaborative process without requiring a trained meeting facilitator. Collaboration engineering supports team modeling by constructing a negotiation process from a sequence of individual process segments called *thinkLets* (de Vreede, Kolfschoten, & Briggs, 2006). A thinkLet is *"a named, packaged facilitation technique captured as a pattern that collaboration engineers can incorporate into process designs*" (de Vreede et al., 2006, p. 1). Collaboration processes divide into several goal categories: divergence, reduction, clarification, organization, evaluation, and consensus building. By breaking up the team activity into segments, each with one of these goals, it is possible to build a negotiation process that captures all the ideas contributed while allowing participants to focus quickly on what is important.

In field trials novice group leaders found it relatively easy to master and execute thinkLet-based process designs. Novices led these processes without the weeks or months of apprenticeship typically needed to learn collaboration facilitation (Agres et al. 2005; Vreede & Briggs 2005).

Collaboration engineering researchers have employed the thinkLet pattern language to design a number of collaboration process that have been implemented successfully in commercial, government, and military organizations for such applications as crisis response training and operational execution (Appelman & Driel, 2005), bio-containment (Smith et al., 2006), and policy analysis (Enserink, 2003).

Collaboration engineering has thus far focused on generating text-based dialogues. The next step to support mega-collaboration is to extend thinkLets to complex mental models stored in a relational database. The application of collaboration engineering to distributed environments is just starting. An exploratory study using Groove as a distributed collaboration platform illustrated the potential of thinkLets to support distributed teams in the effective execution of a requirements definition task (Tarmizi et al., 2007). This study also showed a variety of important areas of future research, such as the degree to which thinkLet-based processes must be adapted to ICT, the design and evaluation of effective thinkLets for distributed collaboration, and the nature of leadership in temporary distributed teams.

The Contribution of Artificial Intelligence

Even with these approaches, managing the development of team models on the massive scale of a mega-disaster will require artificial intelligence. Several studies have documented the success of large-scale team management using autonomous software agents. In each case, the team was divided into sub-teams and managed by communications among the agents via a small-worlds network (Scerri et al., 2005; Scerri et al., 2004; Schurr et al., 2005). This kind of process can manage the comparison and synchronization of models by sub-teams of users, thereby facilitating information pooling, cognitive consensus, and transactive memory. A mixed-initiative interface augmented by data-mining techniques would allow both humans and software agents to extract actionable information from the project database.

Collaboration among autonomous software agents, and between these agents and humans, has shown great potential for disaster response (Tate, 2006). However, the research mentioned above on small-world networks involved simulations in which autonomous software agents adopted theoretical roles representing human actors. Instead of replacing human actors with sense-making software agents, it is possible to employ human teams for sense-making in an agent-managed network. This structure combines the strengths of humans for observation and inference and the high availability of computers for rapid comparison and organization of information. Such an alliance would allow the agents to monitor the need for collaborative action and to broker both the information exchange and the collaborative sequence in a manner aligned with the thinkLet designs described above.

Individual and Team Interfaces

A user-friendly interface and intuitive functionality are essential to allow individuals to connect over the Internet, discuss important issues, and develop teams to take action. As teams form, the interface should support the development of individual and team mental models via the front-end input and output, as well as the back-end team management mechanisms. This is necessary to organize the goals and actions that are of common interest to the participants. This interface should enable teams to organize a robust picture of their shared data while automatically creating the data structure to manage it (i.e., the interface maintains a shared meaning in the data without forcing users to add semantic markup). Exploring this common picture together as a team-building exercise encourages a shift from competitive to cooperative behavior (Farnham et al., 2000).

However, there are also several constraints to consider, such as gaining access to the tool, developing sufficient interest to use the system and participate with other teams, and understanding both the subject matter and the system interface. All of this must be performed under condititions that may be highly stressful. Although individuals have employed existing Web-based tools (such as Facebook, MySpace, Second Life, Flickr, and others) for ad-hoc information fusion in past crises, these systems, designed for social tasks that are not mission-critical, have proven unwieldy and inefficient for crisis response (Palen et al., 2007b). This demonstrates an interest in participation and a need for new online venues and meeting places designed to support grass-roots information fusion. We propose that this can be achieved through a system that allows individuals to share mental models of the situation and provides support to visualize, compare, and merge these models for organized collaborative team efforts.

Preliminary tests of our current prototype interface indicate that sophisticated interface design can enable a tool to guide individuals through the definition of their mental models (Newlon et al., 2008a; Newlon, Pfaff, Patel, De Vreede, & MacDorman, 2009; Newlon et al., 2008b). As frameworks for network application development have matured, capturing the users' concepts and routing them to a back-end database has become easier through a process mediated by middle-tier business logic. These concepts are restructured into a set of entities and relations that can be categorized as events, goals, tasks, roles, actors, and resources (van der Veer & van Welie, 2000). In addition, the online conversation surrounding this process can be captured and preserved in its context (Newlon, 2007). The interface must support users in converting their thoughts into representations that can be compared with those of their teammates.

Implications for Design and Development

Our current experimental work is inspired by the recognized need for coordination among spontaneous grassroots responders. A long-term goal is a deployable Internet-based mega-collaboration tool (MCT). The central concept behind the tool is that a massive problem (e.g., rebuilding a demolished home) can be incrementally engaged by multiple small sub-teams ("we need to find more lumber"), each developing a model to define part of the problem through a protocol consisting of collaboration engineering thinkLets. Consolidating these models in agent-augmented compare-merge playoff sessions will allow mega-teams to agree on the definition of the problem and coordinate effective action. This enables a paradigm shift in employing Web 2.0 technologies to increase the effectiveness of crisis response, allowing for larger teams and a wider range of topics. It is the mental model refinement via compare-merge sessions, the scalability of the mega-teams, and the computational swiftness by which the agents facilitate these collaborative actions that demonstrate how categorically different the approach is from those of traditional groupware applications.

As an example of this communication process, representatives from different sub-teams would use this tool to resolve conflicts by negotiating with one another. For instance, if two teams plan to evacuate the same church, each will send representatives to a negotiating team, bringing with them a data structure identifying the church, the goal of evacuating it, and other information their group has gathered about the situation. For consolidation purposes, the details from each model will be combined, and any duplicate items will be eliminated. The team representatives can then negotiate via the chat room what resources are still needed.

The Mega-Collaboration Tool

The current work builds on specifications that have been developed over a series of preliminary studies (Newlon et al., 2008a; Newlon et al., 2009; Newlon et al., 2008b). A prototype tool has been constructed and tested using light-weight, browser-based, open-source software. Tests of the tool have determined that it enhances an online team's effectiveness as measured by how well it defines its problem space and comes to agreement on what actions to take. However, these tests have only examined within-team behaviors and attitudes. Future work will evaluate the tool's performance when multiple individual teams are combined into a mega-team.

Cognitive walkthroughs in the tool's preliminary design stages indicate the problem-definition task impedes use. To overcome this, a problem-definition protocol was introduced that enables each teammate to form an individual mental model of the problem and then to negotiate a team model. As the teammates work, the tool reflects their progress by adding structures to the database, which it draws on to create visualizations for the team. A chat window lets teammates communicate during any of the coordination stages.

The database supporting this activity is sufficiently general that teammates can flexibly create their own problem definitions (Newlon, 2007; Newlon & Faiola, 2006). Although the data-definition protocol encourages teammates to define their problem in terms of *events*, *goals*, *tasks*, *resources*, and *roles*, the database treats each of these definitions as a generic entity. The name and description of each entity is therefore added to the entity table. Because one person's *goal* may be another person's *event* or *role*, a situation table identifies the particular situation in which a given entity is being represented. This allows entities to be combined if they are found to be identical, without losing the situational differences between the two definitions. The database also has a relations table that allows for the relationships among the different entities to be expressed. The result has been a reconfigurable database that can store very complex data.

Use Cases

To further define the MCT concept, we developed a number of theoretical user profiles and use cases drawn from users and events documented following Hurricane Katrina. The representative users for which we developed profiles are in

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Table 1. User Profiles

Type	User	Motivating Goal for Use
Local Emergency Responders	District Fire Superintendent	Determination of Priorities
Volunteer Labor Organizations	Firefighters' Union Coordinator	Resource Coordination
Non-Profit Aid Organizations	Red Cross Coordinator	Resource Coordination
Military Organizations	National Guard Coordinator	Response Activity Tracking
Federal Emergency Responders	FEMA Coordinator	Jurisdiction Coordination
Concerned Common Citizens	Store Manager	Resource Donation
Volunteer Workers	Social Worker	Resource Donation
Volunteer Experts	Computer Expert	Technology Donation
Affected Individuals	Relative	Rescue of Family Members

These demonstrate the diverse needs resulting from a major disaster, which point toward effective strategies for how the technology could meet those needs. It was immediately apparent that individuals and groups would require customized or customizable interfaces. However, all the information should be drawn from a common database. Further, the automated agents would have to act independently to coordinate the asynchronous information gathering and model development processes among the groups.

Required Features

Typical online collaborative actions would have to be supported, such as basic security features and account management, as well as a number of different possible interactions between users. These are presented in
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Table 2. Interaction Requirements

ID	Interaction	ID	Interaction
1	Find Site	10	Develop Mental Models
2	Use Site	11	Negotiate Group Models
3	Find Area of Interest	12	Vote
4	Participate	13	Take Turns
5	Converse	14	Exchange Information and Resources
6	Create Team	15	Form Teams of Agents

ID	Interaction	ID	Interaction
7	Join Team	16	Agent-Mediated Playoffs
8	Leave Team	17	Inter-Group Negotiation
9	Disband Team	18	Provide Help

This initial set of user profiles and interaction requirements was developed into a set of preliminary specifications and a concept prototype (Newlon & Faiola, 2006). A more detailed paper prototype was refined during a series of focus group sessions. Their results led to the first working prototype of the MCT, which was subsequently used to refine the team-building interface and test the effect that negotiation of mental models had on the team decision making process (Newlon et al., 2008a). The initial version of the MCT was developed using an AJAX-based interface with a PHP and MySQL back-end. An open-source database structure was selected to maximize the future connectivity of the MCT with other information fusion systems.

Early findings strongly supported the theoretical underpinnings of information fusion at the grassroots level. Conversation analysis of the tests indicated that teams with an emergent bottom-up development of leadership produced more successful action plans. Teams also preferred to have a single leader instead of sharing leadership among all teammates. Individually developed models were generally disorganized lists of information and ideas, but the subsequent compare-and-merge process proved highly effective in resolving all of that information into a complex hierarchical group model. This complex information structure was maintained when the model was drawn into an action plan. However, the action plans from the control teams, which had no access to the modeling functionality, remained as disorganized lists of ideas.

A subsequent two-part study examined participants' experiences using the first- and second-generation modeling interfaces. In the first part of the study, we gathered ideas for revising the first-generation interface. Participants were assigned randomly to an *interface team* or a *control team*. Interface teams completed a brief tutorial and began the model-building process for an assigned problem (namely, creating a business plan). Control teams worked on the same problem space using the interface's text-chat functionality, which was the only component of the interface available to them. Both teams experienced difficulties adapting their problem space to the interface. Following the initial tests, we introduced a new front-end built in Adobe Flex (Figure 1; Newlon et al., 2009).

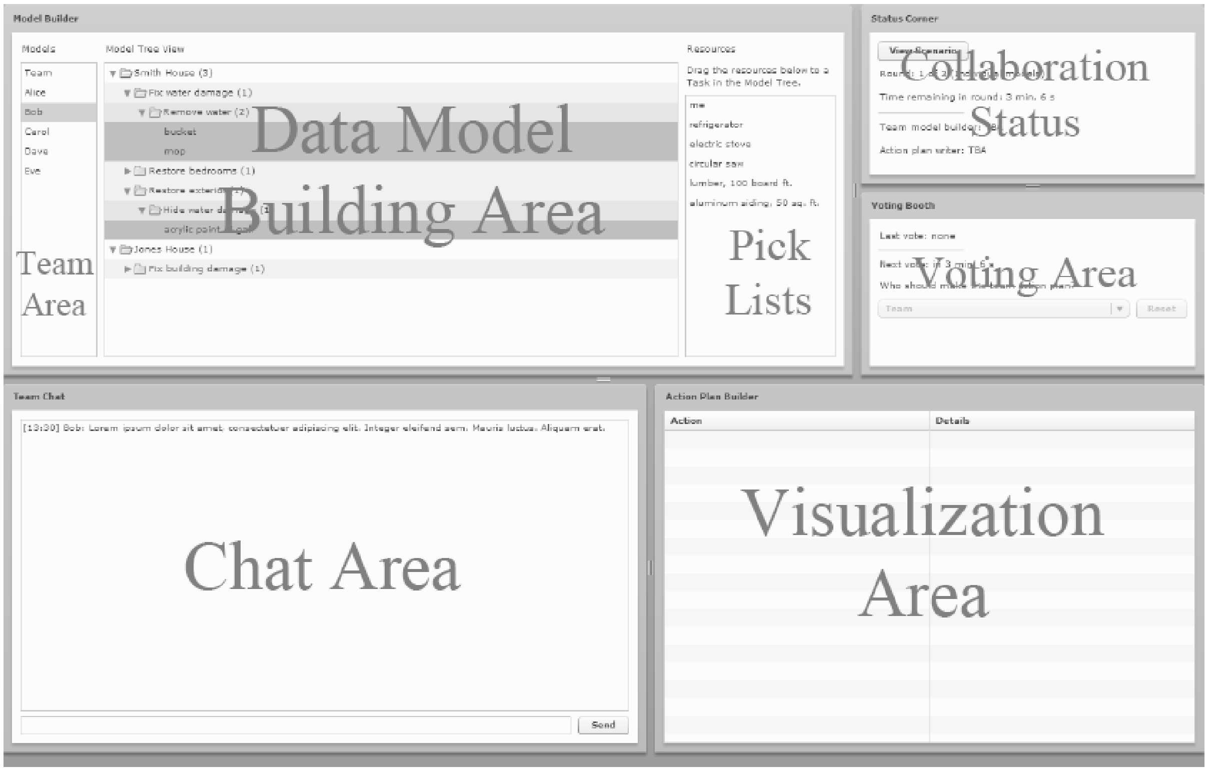

Figure 1. Second generation of the mega-collaboration prototype interface

Because civilians new to mega-collaboration may know little about the constraints and workflow of the software, the second part of the study used ten participants who had no prior experience with either interface. We tested participants individually, assigning each person to one of the two interfaces and giving each a list of commonly performed tasks. After completing the tasks, participants evaluated the interface along a diverse set of usability factors, including information quality, interface quality, interface learnability, interface aesthetics, and emotions elicited by the interface. Participants also responded to items regarding team-creation functionality, input and output interfaces, and the model building process (Newlon et al., 2009).

The usability studies indicated that the interface's flexibility is vital to the successful practice of mega-collaboration. The most common usability-related discrepancies between the two prototypes involved data input, visualization, and data categorization. Participants believed that the second-generation interface was significantly better suited for first-time users. They also believed the second-generation interface was more enjoyable and more tasteful. The second interface was associated more strongly with the descriptive term *energetic* and the emotional term *frenzied* (versus *sluggish*). Participants reported that the forced categorization of each mental-model object as an event, goal, task, role, or resource was too rigid. They requested more ways to manipulate their data, including cut-and-paste, importing from external data sources, and temporal organization. In post-study interviews, participants requested the ability to work with partial data hierarchies by attaching, detaching, and reorganizing them. The strengths of a shared predefined structure for mental-model objects should be considered in relation to the impositions the structure makes on its users. Even if everyone in a group derives his or her solution-finding process from the bottom up, individual collaborators may construct mental models as narratives or in iterative revisions. Expecting a group to work solely in one direction (e.g., from the problems to the goals or vice versa) is inefficient at best and counterproductive at worst.

Usability results help guide the development of the interface, but behavioral observations are especially valuable in revealing how individuals come together and create structures—team structures as well as information structures—in a relatively free-form and self-guided fashion. With further study, the MCT's efficacy can surpass that of repurposed social networking tools for enabling civilian information gathering in response to a crisis.

Conclusions

The mega-collaborative approach to information fusion is innovative in the following respects:

(1) Citizen volunteers are encouraged to develop their own problem-definition models and are supported in the negotiation and consolidation of these models in virtual teams.
(2) The compare/merge features will leverage the strengths of people at conceptualizing information and the strengths of computers at managing information. This synergy will be accomplished by having the participants construct and negotiate their own models and by having autonomous software agents track and route the data.
(3) Formats of collaboration engineering that were formerly based on unstructured text will be adapted to complex, hierarchical data structures supported by the autonomous agents.
(4) The proposed tool will transform the multidimensional, heterogeneous data resulting from disasters into formalized data structures, thereby allowing distributed decision-making networks to be integrated with centralized command structures.
(5) By allowing parallel, asynchronous data flow, the proposed tool will scale the virtual teams to sizes that previously could not be handled efficiently.

The goal of supporting mega-collaboration is too ambitious for any single research program to pursue comprehensively, but this chapter has presented examples to encourage more thinking and research in this complex area.

We believe that these technologies are best tested in environments that effectively mimic the real-world conditions the tools are designed for. Current user tests have so far been conducted with static scenarios, but as the MCT becomes more stable and powerful, tests will be conducted using NeoCITIES (McNeese et al., 2005b), a computer-based scaled-world simulating the situation assessment and resource allocation tasks of distributed emergency crisis-management teams. In NeoCITIES, the group activity consists of distributed individuals jointly gathering information about emergency events, allocating resources to address these events, and detecting emerging threats and patterns of activity from an underlying scenario. This experimental approach provides a holistic assessment of distributed cognition with real-time performance, tool-use, and team communication measures.

Information fusion of human-reported data presents a host of computational difficulties, such as the descriptive subjectivity of reports (compared to the calibrated accuracy of physical sensors), expression of the information in natural language, and general autonomy of the actors in the system. Thus, machine readability and manageability of the ad-hoc team network activities have become priorities. As mentioned previously, we are particularly interested in the potential impact of augmenting these processes through artificially intelligent mixed-initiative agents to enhance situation awareness and process management. A reliable instrument for converting human-supplied data into easily accessible information will improve the impact of the decisions made by the autonomous agents and the effectiveness of the overall response to the crisis.

The expected outcome of this work is that responders to a crisis will be able to locate information in their area of interest or expertise and contribute additional information, resources, and decision-making power to address the crisis. The results are expected to enhance substantially the effectiveness of disaster response as well as provide valuable insight into the processes by which ad-hoc teams become mega-collaborative organizations.

The successful development of tools for mega-collaboration will enhance society's ability to respond not only to disasters, but to any problem that requires broad understanding and agreement. The principles discussed in this chapter can be applied to almost any team-based project and may inspire new methods of decentralized decision-making and coordination.

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