Building a flexible common operational picture to support situation awareness in crisis management

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ABSTRACT

Decision support systems for emergency management tend to focus on making a lot of data meaningful to particular users via a common operational picture (COP). This paper describes one such system, but one that goes further by making the COP flexible enough to support multiple users. Large crises involve frequent role switching between different actors in a response. Hence, predicting the support needs of a given user of a COP is difficult at best, complicating the design process. The solution described here is to use interactive information overlays to enable different users to fit the COP to their particular SA needs. The design was evaluated in two user workshops and a demonstration. In general, it was well-received, but domain experts cautioned that the tool must be usable not only in large crises but in everyday operations, or else it will not be used.

Keywords

Decision support, situation awareness, common operational picture, crisis management, user research.

INTRODUCTION

Operations during an emergency response are usually led from a local command post close to the scene of the incident, often in a car, caravan, or tent (The National Police Directorate in Norway , 2007; Nilsson, 2010). The post serves as an information and communications hub that gives field commanders the best possible access to critical information. As information and communications technology advances, however, so does the amount of data flowing into that hub: Data from social media, new types of sensors, RFID-tagged resources, GPS signals, real-time digital mapping tools, and other sources pour into the command post. The challenge of "access" is thus changing from one of gathering enough data about the environment for effective decision making, to one of making sense of all the data that are available.

Solutions are thus needed to help those in the command post manage and interact with all of the available information in a way that fosters better awareness of the situation. This paper describes the design and evaluation behind one such solution, an emergency command system being developed in the BRIDGE project (2011). The central component of that system is a touchscreen table display called *the Master,* a reference to its role in harnessing and presenting information from different sources. It is intended to be the main point for incident and agency commanders and their staff to access information about a disaster and the response to it, including operational zones, plans, resources, risks, casualties, and history. It will also increase inter-agency awareness by linking commanders both with field personnel and with other response agencies, facilitating information sharing and the establishment of a common but customizable operational picture (COP). Like the command post itself, then, the *Master* is an information and communications hub.

Systems like the *Master* are an increasingly common focus of research and development in emergency response and multi-agency collaboration, particularly in regard to presenting a COP. Büscher and Mogensen (2007), for example, used ethnographical studies and participatory design techniques to design a prototype for a common operational picture to be shared by multiple agencies. That prototype provides a realistic (2.5D) presentation of the terrain at the scene of an incident, displays available resources, and provides a means for drawing the operational area, travel routes, and other zones. Jiang, Hong, Takayama, and Landay (2004) also address the common operational picture, including incident details and resource management, but they focus more on solutions specifically for firefighters. In a prototype called Firewall, for example, a wall-sized display shows field commanders sensor feeds indicating the fire area and the location of firefighters, overlaid on a floor plan. They address only firefighters in their studies and suggested solutions, but the authors argue that similarities between agencies (like common procedures and training) make their results applicable for other agencies.

Other notable work in this area includes the @aGlance project (www.aglance.dk), which has prototyped a COP that combines 2.5D maps, 3D models of buildings, resource tracking, and integrated pictures and videos from surveillance cameras. Kristensen, Kyng, and Palen (2006) and Kyng, Nielsen, and Kristensen (2006) investigate systems that provide a COP that shows incident details and allows monitoring and resource management.

Systems like the ones above all have the same general goal of making an abundance of data meaningful to users via some sort of COP. And whether by design or accident, many of them arguably meet that goal by supporting user situation awareness in some way. Situation awareness (SA) refers to how well individuals and teams know and understand what is going on around them (Endsley, 2000). Good SA provides a better foundation (though not a guarantee) for effective decision making, and an effective COP will compile and present information in a way that supports good SA.

The *Master* has the same goal, but it attempts to go a step further by making the COP flexible, or customizable, to fit the needs of different users. Crises, particularly prolonged ones or those spread out geographically, tend to involve frequent transfer of roles and responsibilities between different actors in a response. As a result, predicting who will undertake what specific role in a crisis situation is difficult at best (Turoff, et al., 2004), complicating the design of systems to support a user's SA. Which user or role should the system support? Our solution is to enable the users to fit the COP to their particular SA needs, while still maintaining access to what is going on elsewhere in the crisis.

The Method section, below, describes the development and validation strategy behind the concept. It is followed by a description of the resulting design of the solution.

METHOD

Our initial designs for a flexible COP were built on results of our group's current and previous projects dealing with emergency response. In particular, we relied on research findings from the EMERGENCY project (Nilsson and Stølen, 2011), and early requirements analysis from the BRIDGE project (2011). However, in keeping with user-centered design principles, we also iteratively built up and validated our designs based on user feedback, which we gathered via two user workshops and a demonstration with potential end-users (i.e., emergency response personnel).

User-centered design and short development cycles are two prevailing trends in the development of ICT-based applications and services. The goal of the user-centered design approach is to ensure that the development of an interactive system takes the needs, desires, and challenges of its users into account (9241-210, 2010). However, it can be difficult to involve domain experts consistently throughout the innovation process, from the early phases of context research and idea generation through the later phases of development, refinement, and implementation (Følstad, 2007). Workshops at different stages of development can help by gathering a group of experts together in one place for focused, practitioner-oriented discussions of a given domain and solution.

In the workshops contributing to the design of the *Master*, the experts consisted of professionals from the fire, police, health, and local municipality emergency services. The first workshop involved 10 experts from Norwegian agencies, and the second had 13 from the UK. For each workshop, we split the participants into working groups that contained at least one member of each agency. A researcher facilitated and coordinated each group, assigned exercises, clarified methodological issues, and kept time. Another researcher made audio and video recordings of the group, while a third supported the data collection process by observing, taking notes, and taking photographs.

We broke each workshop into three consecutive sessions: a *domain analysis session*, for examining current intra- and inter-agency work practices in large-scale emergency management; a *blue-sky session*, for targeting future tools to tackle today's challenges; and a *co-design session*, for involving users in the system design via prototypes of varying fidelity. The sessions occurred in that order, the idea being that (1) a domain analysis session focusing on current work practices and challenges would be a suitable "warm-up" for and lead naturally into the blue-sky session, which focuses on future needs; (2) the blue-sky session should occur before introducing the *Master* concept and ideas in the co-design session, to avoid influencing the experts opinions and ideas; and (3) the blue-sky session could also serve as an "acid test" to check whether any of the future tools that the experts suggest resemble any elements of the *Master* concept and prototypes.

Domain analysis session

This session involved posing questions to trigger discussions of current work practices in large-scale emergencies. We considered two questions to be the most important and therefore posed them to all three groups:

(1) How do you set up emergency organisations on-site? Which roles and responsibilities can you identify?

(2) How do you obtain an understanding of the unfolding emergency situation? How do you maintain such an understanding?

The remaining questions were distributed among the groups and addressed communication issues, the decision making process, resource management, risk analysis, and interaction with bystanders, media, and experts.

Eliciting domain knowledge from an inter-agency perspective involved a combination of brainstorming and affinity diagramming, followed by an ad-hoc, hierarchical grouping of the results into structures and themes (Lazar, Feng, & Hochheiser, 2009). The idea was to group and structure the collected information to highlight the relationships between various issues in the topics discussed (Beyer & Holtzblatt, 1998). Participants used colored sticky notes (see Figure 1), with one color for each agency (police, fire, and health) and two common colors for indicating specific information needs and specific challenges.

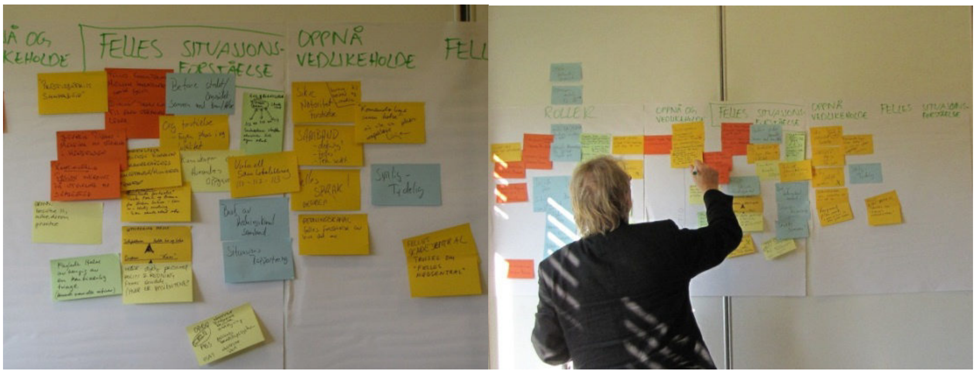

Figure 1: Domain analysis using sticky notes and affinity diagramming. Color scheme: red = fire, green = health, blue = police, yellow = information need, orange = challenge.

Blue-sky session

The blue-sky session involved brainstorming principles adapted from Osborne (1953). We encouraged the domain experts to think beyond current technology, budgets, workflow, and roles. Participants had 10 minutes to generate ideas on their own. After that, they shared their ideas with the rest of the group and discussed relations and implications from an inter-agency perspective.

Co-design session

For each workshop, we worked with paper prototypes to better encourage exploration of the design concept (Beyer and Holtzblatt, 1998). Paper prototypes are practical in early user research because they put the focus on the structure of a system rather than the user interface details. Furthermore, hand-drawn paper prototypes invite change, making it easier to draw potential users into a discussion what they need in the system and why, and thus improving the co-design process between the researchers and the domain experts.

For the second workshop, the focus shifted from exploration of the design concept to getting detailed design feedback, so we refined the paper prototype to better encourage discussion in that direction. For example, we built the new prototype around specific use cases and presented it to the domain experts in the context of a specific scenario (an explosion in a chemical plant). The prototype also progressed from paper to plastic – namely, a table-sized plastic map sprinkled with icons, menus, and other UI components. The components were glued onto transparency overlays to let us simulate dynamic behavior and interactions.

Finally, parts of the *Master* were implemented in a working prototype for a demonstration. The demonstration involved the live simulation of an underground tunnel collapse, performed in a series of underground testing tunnels in Switzerland. Participants and observers included field responders, commanders, and other interested parties, who all had a chance to provide feedback on the *Master* implementation.

The next section describes the resulting *Master* design, followed by general positive and negative feedback on the design that came out of the workshops and demo.

THE MASTER

The *Master* is a command and control system for use in emergency management. The name comes from its purpose, which is to serve as a master framework that collects and enables interaction with different streams of information. It is intended to be a means for users to access, filter, visualize, and share (in other words, to master) all the information collected during an emergency response.

The Master is a large touch-screen display that provides a common operational picture (COP) for command staff in large, multi-agency emergency response efforts. Its basic form is an interactive (2D) map on which users can designate and detail the operational area. The operational area is the main geographical area in which an operation takes place. That area may include different zones with varying access restrictions, along with the Master's relative location to those zones, which is important to the establishment of a common operational picture (Büscher and Mogensen, 2007; Kuusisto, Kuusisto, and Armistead, 2005). Figure 2 shows the simplified but implemented version of the Master used during the demonstration. The map in the image is zoomed in on a section of an underground tunnel.

Figure 2: A screenshot of the user interface for the implemented *Master* used during the tunnel demonstration. It shows simplified versions of the *eTriage* and *Resource Manager* overlays.

Beyond the map and operational area, the *Master* focuses on supporting situation awareness of four aspects of emergency operations: risk assessment, triage, resource management, and response history and progress. Our discussions with users have shown those to be among the top considerations in command decision-making. However, the different aspects tend to be of more importance to particular agencies or members of the command staff – e.g., triage for medical officers, resources for police or fire officers, history and risk for whichever agency is in command. Given that any of those agencies might be using the *Master* at any given moment, we saw the need for a flexible COP that would give users access to a shared picture of the situation, but would also let them modify it to their particular information needs.

Overlays

The primary goal of the *Master*'s flexible COP is to enable users to fit it to their particular SA needs, while still maintaining access to the overall picture. As well, because the tool will likely be used by different people in different roles within large, distributed teams, a secondary goal is for it to support inter-agency awareness. Discussions during our first workshop confirmed that need, with participants mentioning that one of the main challenges in emergency operations is communications, or more generally, information exchange between and even within agencies. On the one hand, agencies often don't share enough information about what they have learned or what they are doing or planning. On the other hand, they also often communicate *too* much by filling the emergency radio channels with information that not all agencies need to know, creating a lot of noise. The result is poor awareness of other parties in the emergency response.

Our solution for meeting both requirements was to provide information relevant to each of the four aspects of emergency operations mentioned above (risk, triage, resources, and history and planning) through a set of four interactive information overlays. Each overlay (1) lets users from different agencies (e.g., fire commander, police commander, medical commander) focus on their individual SA needs by hiding or deemphasizing information that is currently not needed, (2) provides a common source of information about the situation and the resources involved in the response that users from all agencies can access as needed, and (3) reduces the need for radio communications by providing some of that information visually via the *Master*.

The following subsections describe each overlay.

Resource Manager

Perhaps the primary overlay in the *Master* is the *Resource Manager*, which provides users both with a detailed overview of all resources (e.g. personnel, vehicles, equipment) across agencies that are deployed in the emergency response effort, and with tools for negotiating the distribution of those resources (see Pottebaum, Konstantopoulos, Koch, and Paliouras, 2007). Resource management is essential to any emergency response effort, both in terms of tracking resources and in knowing to what tasks different resources have been allocated. Normally in large efforts, such tracking and negotiation must occur in close cooperation with a central staff responsible for managing the logistics of the response. According to feedback from the workshops, such negotiation and tracking is often time-consuming and inaccurate, largely due to the fact that it is handled through radio communication. Hence, the *Resource Manager* aims to increase the efficiency of such activities by enabling automated tracking and computer-supported allocation of resources – for example, by tying into sensor technologies and other ICTs under development in the BRIDGE project (2001).

The key activities the *Resource Manager* supports are the following:

- *Resource monitoring*: Combined with the *Master*'s interactive map, the *Resource Manager* provides an overview of vehicles, personnel, and other tracked resources participating in the emergency response effort. Each tracked resource is displayed as an icon in the map, showing in real time the resource's current location and status (i.e., whether the resource is busy or waiting for orders). Different types of resources (e.g., police personnel, fire vehicles) are represented by different icons that have been carefully designed to reveal the characteristics of the resources to the user. In addition, to accommodate the notion of a flexible COP that supports different users with different information needs, the *Resource Manager* overlay has been divided into sub-layers according to type of resources (e.g., police resources vs. medical resources). Users can hide or show those sub-layers according to their needs.
- *Resource detailing*: During the co-design sessions in the workshops, participants stated that it is of crucial importance to show the tasks to which resources are currently assigned. So, we added a label above the icons that describes a resource's current task, such as triaging patients or search and rescue. (See the zoomed-in segment of Figure 2 for an example.) Further, users can interact with the overlay to show additional information about the resources. For example, participants in the second workshop approved of tapping the icon for a personnel resource to get more information about that person, including his or her skills and expertise, role, and available equipment. Combined with its monitoring capabilities, then, the *Resource Manager* provides material necessary to increase its users' awareness of the variety and number of resources taking part in the emergency response effort, as well as their individual location, type, and capabilities (see Endsley, 1995).
- *Resource assignment*: A key function of the *Resource Manager* is to support the negotiation and distribution of available resources during an emergency response. Users can allocate resources to specific tasks and locations by dragging and dropping the corresponding icons either to a new location on the map or onto another map icon (e.g., a patient, a hazard). Dropping the resource will produce a

pie menu from which users can select a pre-defined task (e.g., search and rescue, set up roadblock) to assign it, with the list of available tasks depending on the location or type of icon onto which the resource is placed. The *Resource Manager* conveys the assignment to the resource via a handheld device in the possession of the latter, allowing the resource to reply (i.e., confirm or decline the order). Feedback from the co-design sessions suggests that such computer-based support for negotiating resource allocation has the potential to reduce the need for radio communication, which would make resource management more efficient. As well, the *Resource Manager* also supports semi-automatic resource allocation, in which the users just specifies the number and types of resources they want allocated to a specific task. Based on the location, status and capabilities of the available resources, the *Resource Manager* will then automatically allocate the best-suited resources to the task.

- *Resource allocation*: By synthesizing information about individual resources and integrating that information with the other overlays provided in the *Master*, users can achieve a holistic view of the current state of resource deployment, including the proximity of resources to other elements such as risk areas, victims, and buildings. That holistic view can help both in assessing the current need for resource backup, and in making inferences about which resources are best-suited to handle specific tasks. Further support comes from an information window available to users that provides an estimate of how much of the tracked resource pool is currently in use, and how much is idle. An estimate of the task durations for busy resources is also available. Experienced users can then anticipate where resources will be located in the near future, whether they will be busy or available, which tasks they will be assigned to, and when those tasks will be completed. To some extent, this insight can help users to estimate future resource depletion given current consumption.

Risk Analyzer

Risk assessment is essential in emergency response, to anticipate potential hazards and better protect the life and health of both responders and the public. Our workshops revealed that, in many cases, risks are closely connected to constructed entities such as buildings and infrastructure (tunnels, train stations, bridges). Unfortunately, disasters generally do not allow enough time to thoroughly assess the risks associated with such entities. The main idea behind the *Risk Analyzer*, then, is to perform risk analyses *beforehand* and store the resulting models in a library that can be accessed via an overlay in the *Master*. Those models are either object-specific (e.g., a risk model for a specific bridge) or object-type specific (e.g., a risk model for a certain type of bridge).

The users of the Risk Analyzer mainly work within a module in the Master that uses a graphical risk analysis notation, i.e., a variant of the CORAS risk modelling language (Lund et al., 2011). However, the results of that analysis are shown as an overlay in *Master*.

The key activities the *Risk Analyzer* supports are the following:

- *Understanding the risk environment*: Participants in the blue-sky and co-design sessions of both workshops stressed the need to be able to access key information, such as building plans, about constructed entities during a crisis response. The *Risk Analyzer* provides a library of risk models for that purpose. Users can adjust them during a crisis and input actual values of any probabilities, consequences, and parameters that may influence the estimate. As noted during the blue-sky session of the first workshop, however, such adjustment depends on access to up-to-date pictures and measurements of the entity in question, showing, for example, its current state, or the types and concentration of any dangerous substances. In cases in which up-to-date pictures and measurements are not available, simulations of the consequences of previous but similar incidents may help users to obtain a better picture of the actual situation. The Risk Analyzer overlay has access to such information based on the results of other work in the BRIDGE project (2011).
- *Consulting experts*: During the blue-sky session of the first workshop and the co-design session of the second, participants stressed the importance of having access to experts who can make clear the risks associated with a given location, entity, or hazard (e.g., how poisonous a certain gas is). To that end, the *Risk Analyzer* overlay ties into a system developed in another part of the BRIDGE project that enables communications within a network of relevant experts.
- *Anticipating hazards*: One of the strongest features of the *Risk Analyzer* is the support it provides for anticipating how a risky situation may develop, including potential complications. Combined and juxtaposed with the overlays showing the locations of personnel (*Resource Manager*) and casualties (*eTriage*), the risk models give valuable information about developments that may occur in the near

future, including probabilities and consequences. Simulations are important for assessing the latter – e.g., if there is a high probability that a gas tank will explode, which areas should be evacuated?

Timeline

The *Timeline* overlay is a tool to help users build and maintain the temporal aspects of their situation awareness. Just as the *Master*'s interactive map supports spatial understanding of an unfolding situation, an interactive graphical timeline should support temporal understanding. In particular, the *Timeline* will arrange the event and incident information logged during an emergency response (e.g., communications, situation reports, event start and end times, news reports, information from bystanders/victims, responder activities, weather reports, the current state of crisis) along an interactive, graphical continuum from old to current. It will also plot certain planned or anticipated events (e.g., planned tasks, forecast weather, anticipated spread of fire or some other crisis element) along that continuum. Figure 3 shows a wireframe of the non-map portion of the overlay.

As well, we intend the *Timeline* to be closely integrated with the map in *Master*, combining temporal and spatial information and effectively adding another dimension to the 2D or 3D map displays commonly used in command and control. In other words, users will be able to move back and forth through the timeline and see how events on the map have changed. It should thus help them both to build and to maintain an overview of what has been done, perhaps providing a foundation for anticipating how the situation may develop. In addition, the *Timeline* should prove useful in after-action reviews by helping reviewers determine whether given activities were sequenced and coordinated appropriately and efficiently.

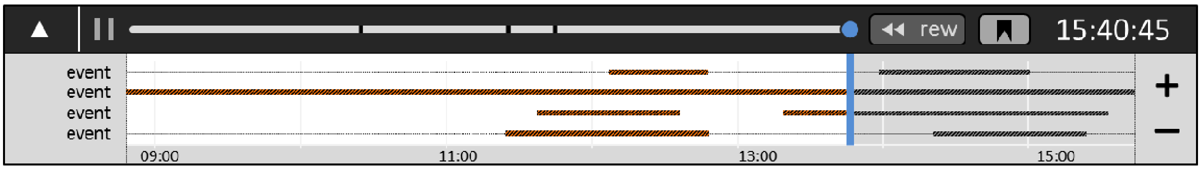

Figure 3: A wireframe for part of the *Timeline* overlay, showing bookmarking capability (the black breaks in the top timeline slider) and event tracking and projection (the colored, horizontal lines). The component is designed for a touchscreen, so users can slide it to either side to scroll horizontally, or apply a pinch gesture to change the timescale.

The *Timeline* overlay is not included in the current implementation of the *Master*, but rather is a concept planned for later versions. Hence, although we presented it during the workshops, it did not receive as much attention as the other overlays. Fortunately, a handful of other studies in the area have examined and evaluated methods of temporal and timeline visualization, and their results can support the validation efforts for this overlay in our workshops. One of the more recent studies, and most relevant to this overlay, comes from Gryszkiewicz and Chen (2012). They designed a prototype crisis management system that emphasizes temporal info, and then evaluated and refined it via workshops with domain experts. From those workshops, they produced a set of six temporally focused design principles for crisis management system, several of which are relevant to the *Timeline* overlay.

The key activities the *Timeline* supports are the following:

- *Temporal awareness*: Temporal awareness is a key component of situation awareness (Endsley et al., 2003). So, we designed the *Timeline* primarily to provide an overview of events leading up to the current state of a crisis, as well as any ongoing and planned activities. Visually, the timeline provides a snapshot of that information for at-a-glance consumption. However, users can also drag back and forth along it, which will cause dynamic elements in the map to revert to the state (generally, position or area of effect) they were at that point in time. Also, as suggested by our workshop participants, users are able to “bookmark” the current state of the situation for easy comparison with future states. The visuals and interactions are solutions for building temporal awareness, corresponding to Gryszkiewicz and Chen’s (2012) design principle of making information about past events in ongoing crises easily accessible. In addition, the workshop participants in Gryszkiewicz and Chen (2012) said that a timeline visualization could also help the otherwise challenging problem of making the next command shift in a longer-term crisis aware of what has happened so far. In other words, it can support temporal awareness both in individuals and across groups.
- *Event coordination and management*: Two other design principles in Gryszkiewicz and Chen (2012) recommend highlighting relationships between asynchronous activities on the one hand, and indicating how events and activities may develop on the other. The *Timeline* overlay addresses the first principle by using stacked, horizontal lines to represent the start time and duration of different events (generally,

tasks of some sort). It addresses the second by showing the estimated duration and end time of ongoing tasks. The idea is to provide users with an at-a-glance schedule of important tasks (and their progress) in the crisis response.

- *Temporal scaling*: Gryszkiewicz and Chen (2012) determined that different user roles, different tasks, and different crises will require the presentation of information on different timescales (e.g., a few hours vs. a few days vs. a few months or more). Users of the *Master* can expand or contract the scale of the *Timeline* accordingly via pinch and stretch gestures or, in non-touch displays, the "+" and "-" buttons common to most any digital map and also seen in Gryszkiewicz and Chen's timeline prototype.

eTriage

Triage is the process of sorting and prioritizing casualties into groups based on the severity of their condition and the need for medical assistance. It generally happens before treatment and transportation (Rehn, Vigerust, Andersen, and Vollebæk, 2009), and it involves labeling a patient with a triage tag that can range from a paper tag to colored tape to an electronic device. Color is used to designate the severity of a casualty's condition according to international principles: red for critical cases needing immediate life-saving treatment; yellow for injuries that can wait some hours; green for minor injuries; black/white for those who are (seemingly) dead.

The *eTriage* overlay provides triage status and other casualty information to the *Master* via a prototype bracelet with an electronic device capable of storing and transmitting such information. The need for a flexible tool that supports pre-hospital triage was stressed by the experts during the blue-sky session in the first workshop. (This overlay was not presented in the second one.) Specifically, the domain experts envisioned a GPS-based "casualty monitor" that would send vital physiological data (O_2 saturation, blood pressure, heart rate, respiration rate) via a transmission link to paramedics, the commander of the health services, and the associated operations center. Note that they mentioned the need for such a device before they were introduced to the *eTriage* prototype, providing some validation for the tool's usefulness.

The key activities that *eTriage* supports are the following:

- *Monitoring casualties and their status:* By registering and tallying the number of victims and their locations in an emergency, *eTriage* provides a medical overview essential for decision making by command staff and paramedics. In addition, the workshop participants noted that large incidents often involve paramedics and first responders from several regions and institutions, each of them using different triage tag systems and incompatible routines. A system such as *eTriage* could help bridge those gaps.
- *Effective deployment of medical resources:* In combination with the *Resource Manager*, *eTriage* shows command staff the locations of casualties juxtaposed with the positions of available paramedics, aiding medical coordination in the field and providing a better overview for the health commander. Also, casualties' conditions can change over time, making triage an iterative process involving a constant reassessment of the medical situation. The *eTriage* overlay supports that process by enabling display changes in patient status from one category to another, helping commanders to better plan the evacuation process (e.g., which patient goes to which hospital, by what type of vehicle, and in what sequence). The colored dots in Figure 2 show an example of casualty indications and their health status. A critical casualty (red dot) has been selected to pull up that person's vital signs, transmitted via their *eTriage* bracelet. Also, although planned for later versions, one goal of *eTriage* is to use the triage bracelets and other sensors to monitor vital signs such as heart rate, respiration, O2 saturation, body posture, and movement, enabling prediction of how a patient's condition may develop. That could help commanders to marshal medical resources to where they will likely be needed in the near future. The log of events from the *eTriage* module is integrated with the functionality provided by the timeline overlay, contributing to the total logging of events and enabling aftermath evaluation of the incident.

General feedback from workshops

The workshops organized to evaluate the *Master* concept resulted in a wellspring of feedback and reflections from relevant end-users, contributing to the current state of the system described in the previous sections. Some of the feedback addressed specific aspects of the user interface, while other feedback concerned the concept as a whole. In this section, we provide an overview of the most important information gathered during the workshops.

In general, the *Master* concept was received with both optimism and skepticism. Commanders working in the emergency agencies, and who also highlighted current challenges in establishing and maintaining situation awareness during emergency response, confirmed the need for the system. Among other things, it was emphasized that the concept, by offering capabilities for sharing and presenting information across agencies, could significantly facilitate cross-agency collaboration. Further, the system's ability to reduce the need for radio communication (which is often time-consuming) was highlighted by the end-users. Both points above address important aspects of emergency work that impact on the process of establishing and maintaining situation awareness. In addition, the ability to conduct cross-agency risk assessments electronically was regarded as a very important aspect of the *Master*. As of today, for example, the police receive any risk assessments concerning hazardous materials from the fire and rescue services.

The participants also expressed several critical concerns regarding the applicability of the system in a real-world setting. One problem is that the system, by targeting larger incidents that involve multi-agency collaboration, would not necessarily be used on a day-to-day basis. And as one participant explained, if a tool is not used regularly during smaller, everyday events, it is unlikely to be used in uncommon, large-scale emergencies. Hence, future versions of the *Master* must be adapted and presented as a tool that can support the everyday work of emergency personnel. As an important part of this adaptation, tablet and other mobile versions of the system should be developed.

The end-users also came forward with suggestions as to how the *Master* system should be used during an emergency. For instance, it was suggested that the *Master* should be a tool not only for tactical personnel, but also for the personnel working on the operative and strategic levels. In fact, the participants emphasized that most of the information visible in the map should be specified or given by the personnel working on the operative level, and not by those at the scene of the incident. The rationale for that suggestion was that on-scene personnel have to focus their attention on what's going on at the incident site itself, leaving them little time to specify details on an electronic map. Another suggestion was that the system should have a dedicated user in the command post who would keep it up to date. That could relieve the rest of the team of the burden and let them focus on other tasks. Participants also pointed out that the *Master* should be able to log all activity during an emergency, and to document the basis on which decisions were made. The Timeline overlay provides some of that ability, but it will be necessary to include the capability to log users' interaction with the *Master*.

CONCLUSION AND FUTURE DEVELOPMENT

We presented here a customizable COP that, we suggest, supports higher levels of SA in four aspects of crisis management: risk assessment, triage, resource management, and incident history. Hence, it may provide different commanders and command staff in large, multi-agency emergency operations with a better foundation for decision-making (via higher-level SA), a means of maintaining a common situation overview while also interacting with information relevant to their role (via the overlays), and a means of better sharing information (via the COP and the overlays).

Throughout the remainder of the BRIDGE project (2011), the *Master* will undergo further revisions in terms of user needs analysis, requirements engineering, redesign, and evaluation with end-users. In the first of these iterations, the focus will be on improving the functionality for adding and editing elements in the interactive map, adding timeline functionality, and on extending the pool of information the *Master* makes available to its users. With respect to the latter, new overlays will be added to the interactive map, providing predefined emergency plans and detailed information about critical infrastructure. Further extensions planned for the *Master* includes role-dependent user interfaces, functionality for viewing 3D models, voice-user interface for interacting with the map through speech, and detailed logging of users interactions with the system.

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