Chapter 15
Envisioning the Emergency Operations Centre of the Future

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Abstract Emergencies, crises, and disasters happen frequently, with significant impact on the lives of countless people. To respond to these events, many organizations including the Police, EMS, and Fire departments work together in a collaborative effort to mitigate the effects of these events. In addition, these agencies are often joined by third-party organizations such as the Red Cross or utility companies. For all of these groups to work together, an Emergency Operations Centre (EOC) acts as a hub for centralized communication and planning. Despite the significant role of the EOC, many existing EOCs still rely on aging technologies, leaving many potential improvements available by adopting new technologies. Considering the impact of emergencies on human lives and lost resources, and the scale of these emergencies, even a minor improvement can lead to significant benefits and cost-savings. Emergency Operations Centre of the Future (EOC-F) is an exploration into the integration of various novel technologies in EOC design, in an effort to make emergency response more efficient and collaborative. We have built a multi-surface environment (MSE) which utilizes various digital surfaces including display walls, tabletops, tablet devices, and mobile/wearable computing devices. Within this multi-surface EOC, we look at proxemic interactions and augmented reality as useful ways to transfer and access information. We also discuss how analysis of information gathered within the EOC, as well as social media, can lead to more informed decision making during emergency response.

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15.1 Introduction

Emergencies, crises, and disasters happen when people least expect them to. Some notable examples include: earthquakes in Christchurch, New Zealand (2011), tsunamis in Japan (2011), flooding in Southern Alberta, Canada (2013), and a missing plane in Malaysia (2014). To respond to these disasters, organizations such as the Fire department, Police Department, EMS and others work together to discuss and plan within a co-located emergency operations center (EOC) (Fig. 15.1). Crisis management teams that meet face to face in emergency situations also exist in major corporations and public organizations. These teams have specific needs but their information system support can be very limited. Despite accommodating various teams within the same space, existing EOCs provide few supporting tools to encourage collaboration between the teams. There is a significant opportunity to utilize new technologies to address these concerns, while providing a more effective response to emergencies.

Beside reductions to lost lives and injuries, an improved response has also a substantial cost savings potential, both for the public sector as well as for industry. The costs of the Southern Alberta floods in 2013, earthquakes in Christchurch, and tsunamis in Japan are estimated to be $5 billion, $18 billion, and $35 billion USD respectively. While the cost reductions coming from a more effective handling of the crisis are hard to estimate, even small percentage gains can potentially lead to large savings.

Fig. 15.1 Calgary Emergency Management Agency (CEMA). The City of Calgary, 2016

The Emergency Operations Centre of the Future (EOC-F) is a collaborative project between the University of Calgary and C4i Consultants to explore and prototype emergency operation planning and operation tools. The goal of this project is to investigate how analytics-based, spatially-aware multi-surface environments (MSE) can support teams managing emergencies in an EOC. Perhaps the greatest challenge for any decision-making entity is the ability to efficiently gather, process, and visualize information in a timely manner, allowing the best decisions to be made as early as possible. By investigating local emergency agencies and their EOCs, we have identified many opportunities for improving emergency response operations including: inter-organization interoperability, communication within the EOC, communication between the EOC and field responders, and situational awareness of field responders. In addition, we look at how social media analytics can be harnessed as a valuable source of citizen-based, on-the-ground information, without creating significant overhead for EOC operators.

We prototype and qualitatively evaluate an EOC design which improves on existing solutions by making use of new technologies to address the problems identified above. The system was built on design principles derived from both existing research and the constant feedback of emergency personnel, discussed subsequently. We then present a usage scenario for the new system to demonstrate the potential, and compare to existing systems. We conclude with some of our results, and discuss some of our continuing work for EOC-F.

15.2 Background

15.2.1 Disaster Management

Disasters occur on a daily basis, on various scales, and emergency services can receive thousands of calls per day [1, 11]. While some situations can be resolved with relatively few resources, emergencies often require the cooperation of multiple agencies, often involving personnel whose primary job responsibility is *not* emergency management. For example, a fire in a populated downtown area may require the police to manage civilian access and evacuations, while firefighters focus on controlling the fire. EMS may be on-site to treat injuries, while providing support to the firefighters operating in a hazardous environment. Utility companies collaborate with these agencies to assess and reduce potential dangers, such as damaged gas pipes or electric wires. When an emergency situation becomes prolonged, it is common for the involved parties to establish a shared headquarters, the emergency operations center (EOC), to facilitate information sharing, resource management, and operations planning. The EOC becomes the central command and control facility, interacting with other entities such as the media as well as NGOs like the Red Cross. Given its significant role in emergency management, it becomes apparent that an improved EOC will benefit every aspect of emergency response.

15.2.2 Emergency Operations Centers

An underlying problem with existing EOC solutions is the lack of built-in support for collaboration within and between teams, often from multiple organizations [27]. While EOCs often have designated areas and computing terminals for various organizations such as the police or EMS, support for inter-organization collaboration usually means having enough space to physical accommodate the various teams. In many cases, members of an EOC work independently at their own terminals, with few tools to encourage collaboration. An example of this is the Calgary Emergency Management Agency (CEMA) which can be described as somewhat disorderly, despite being touted for its rapid response during the Southern Alberta Floods in 2013 [53]. Operators were seated at individual cubicles, and simply shouted out any emerging needs to other operators, with corresponding parties shouting back. It was likened by the mayor of Calgary to a game of Whack-A-Mole.

With a lack of connectivity between members of the EOC as well as responders in the field, it becomes apparent how information transfer can be slow, inaccurate, and often very repetitive. Imagine an operator receiving a call from a field responder, with information about an ongoing event. The operator would manually record information such as the location of the event, while making notes of the event. The operator would then have to manually locate relevant parties, such as the incident commander of the EOC and members of relevant agencies. The information would have to be repeated to each person perhaps separately, a very time-consuming process. Assuming a decision was made for backup to be dispatched, the response team in the field would also have to receive the same information manually, before finally heading to the location. An improved response through greater connectivity could allow the operator to digitally retrieve the location of the caller, record any event details, and digitally distribute the information to relevant parties. The resulting decision would be automatically forwarded to the response team, along with any relevant information about the event. Because location data is sent digitally, the response team can easily enable navigation without having to manually enter the address. The movements of the response team can then be tracked live in the EOC, again through an automated process.

With so many apparent benefits to greater connectivity and automation within EOCs, it seems logical that these tools should be integrated into all EOCs. However, this is not currently the case, because many commercial solutions target specific roles within an EOC, while others provide only a part of the EOC [17]. It is not uncommon for multiple vendors to supply various parts of an EOC, each with its own software suite. For example, WebEOC supports incident management and information access on individual terminals, but lacks integration with large display surfaces used for face-to-face collaboration between multiple users [49]. Other parts of the EOC remain disconnected, and any potential integration with existing or future components can be costly.

Despite difficulties in developing and maintaining a fully interconnected EOC, the benefits are nontrivial and it is worthwhile to examine the possibilities of such a system. Beyond the immediate advantages leveraged during an incident, a connected system can also benefit the response preparation and training phases. Events can be logged from all the connected devices, detailing when information was received, the people involved, and the decisions made during emergency management. These records can prove very useful when reviewing an incident, revisiting all the captured events leading up to any actions taken. The data can then be further analyzed for improving future incident responses, and reused for training purposes.

In recent years, solutions which promoted better connectivity and integration between various teams have been deployed to great results. IBM's Intelligent Operations Center was deployed in response to Typhoon Haiyan to coordinate numerous distributed teams, while the NYPD's Domain Awareness System has become the leading example of how large-scale deployment of connected devices can empower EOCs. Similarly, we believe the connectivity and collaborative spaces of multi-surface environments can be applied to EOC design to great effect.

15.3 Related Work

15.3.1 Designing an Emergency Operations Center

Although most relevant works focus on specific technologies within the emergency response domain, some recent studies have started looking at the EOC as a whole, discussing the role of technology in relation to many aspects of the EOC. An influential report published by the European Commission discusses several important topics, including: the need for an EOC to support multiple devices, the functions of a large wall-sized display, the physical design of an EOC to support social media analysis, and individual "lenses" to facilitate independent interactions within collaborative interactions [10, 20, 23]. Their findings helped guide us toward our current design of EOC-F, with respect to the inclusion and placement of devices, the role of large displays, and personalized devices for users.

Another recent study into collaborative work in disaster response stressed the volatile nature of disasters, and the need for an EOC which can handle four types of uncertainties. Uncertainty in the environment and in equipment available pushed us towards a modular design, based around "redundancy and graceful degradation" [19]. For EOC-F, a modular design not only means the potential to scale up the system, but also the ability to function with minimal pieces of the EOC-F. One device can have multiple configurations, allowing it to perform several roles within the EOC. Devices such as a digital whiteboard can be written on like a regular whiteboard to help conduct planning, and if a connection is available, it can also share the hand-written information with other devices. The third uncertainty is that of available data, such as satellite imagery, local maps, and population data. Fischer et al. describe a design which provides "flexible support for situation analysis", suggesting the need for incorporating various streams of information in an adhoc manner. When collecting information from varying sources, we run into the fourth uncertainty regarding the origin and integrity of information. Articulating and accounting for this uncertainty is important for making informed decisions, affecting our design for social media integration.

Previous research by others, supported by repeated user consultations with many emergency management organizations in various roles, have led us to develop EOC-F, a multi-surface environment for emergency response.

15.3.2 Multi-surface Environments

A multi-surface environment (MSE) is a room where multiple computational devices are located and potentially communicate together. MSEs may contain any combination of phones, tablets, laptops, digital tabletops, projectors and large high-resolution display walls for various domain specific applications. An example of one of the earlier MSEs is the Wild Room [5].

MSEs offer rich opportunities for new applications, interactions, and collaboration. Creating these environments is difficult and integrating traditional software is a challenge for the design of MSE applications [18]. While some researchers have explored emergency management applications on individual devices, we are unaware of any research that has used and evaluated MSEs for emergency management purposes. For this reason, we consider our research project innovative, with potential for significant contribution to the scientific field as well as high commercial potential.

Our eGrid system was a prototype application utilizing a digital tabletop for utility companies to enable collaboration of control center team members in their daily tasks of analyzing and managing the electrical grids of a city [43] as well as dealing with outages. The application uses a multi-touch table that allows multiple users to interact concurrently with domain specific Geographic Information Systems (GIS) data. However, the application does not consider the specific context of emergency management nor the necessary integration of other devices within a team.

Another MSE application is coMap, an interactive tabletop application that facilitates collaborative situation analysis and planning in crisis management teams [16]. Users can interact with coMAP using multi-touch as well as pen input with Anoto digital pens directly on the table. Others that have also explored Anoto digital pens on tabletops (for air traffic control rooms) found that the input was problematic and using the digital pens required specially designed proprietary paper [42]—something quite limiting during an emergency situation.

CERMIT uses light emitting tangible devices and mobile phones to interact with a tabletop for emergency management [37]. CoTracker is an application that uses tangible graspable objects on a tabletop for emergency management [2, 26]. µEmergency is a multi-user collaborative application for emergency management on very large-scale, interactive tabletops which allows people to carry out face-to-face communication based on a horizontal global map and uses tangible objects placed on the table for input [38]. However, none of these applications have been integrated into a larger MSE nor did they integrate with commercial emergency planning and operations software.

CodeSpace is an application that used phones, laptops, and a vertical touch display to support collaboration in meetings targeted at software development [7]. The application allows information to be shared across devices but does not support different roles, which are necessary in an EOC.

The Sky Hunter system is an application that uses a tabletop and iPads to display geospatial data, which allows a heterogeneous group of analysts to explore possible locations for oil and gas exploration [46]. The application allows geospatial information to be shared between devices, but the application is limited to a small digital table and a single iPad.

The MRI Table Kinect is an application for visualizing volumetric data such as CT and MRI imagery that uses an iPad and a tabletop [44]. The application supports slicing the volumetric data by moving an iPad or hand in the physical space above the table to explore the data in more detail which is displayed either on the iPad or another large screen. The approach can be utilized in an EOC to interact with volumetric geospatial data (e.g. 3D models of buildings or streetscapes).

15.3.3 Multi-surface Environment Toolkits

Creating applications that support multiple devices in MSEs is challenging, as it requires development for different form factors and platforms. Ideally, one application could be deployed to many different devices; however, this usually limits the user experience on each of the devices and also has yet to be applied to an EOC situation. Paterno et al. present a framework for describing various design dimensions that can help in better understanding the features provided by tools and applications for multi-device environments [36]. jQMultiTouch is a lightweight web toolkit and development framework for multi-touch interfaces that is designed to perform on many different devices and platforms [33]. XDStudio is an attempt to support interactive development of cross-device web interfaces, which has two modes [34]. In the simulated mode, one device is used as the central authoring device, while target devices are simulated. In the on device mode, the design process is also controlled by a main device, but directly involves target devices. XDKinect is a lightweight framework that facilitates development of cross-device applications using Kinect to facilitate user interactions [35]. None of these applications have been integrated into a MSE for emergency management.

Our Multi-Surface Environment API (MSEAPI) was developed for sharing information amongst devices, using proxemics and gestural interactions [3, 9]. Using Microsoft Kinect cameras, the system can detect and track where people and devices are located in the environment. This spatial awareness allows simple proxemic interactions to be used in information transfer between users and devices. For example, a user can point a tablet at another user in the room, and simply flick on the screen towards the other user. The latter will then receive the information on their device, making digital content sharing as natural as passing a physical document around. One of the projects which made use of MSEAPI was ePlan, a software tool for simulating large scale emergencies to train civic operators on responding to different emergencies [13].

Our Society of Devices Toolkit (SoD Toolkit) is the successor to MSEAPI, and supports more proxemic interactions compared to MSEAPI. This new toolkit creates spatially-aware environments that are modular and easily extendable with new devices and can be spread over multiple rooms. As a result, projects such as EOC-F which rely on the toolkit are also modular and can be scaled for different scenarios. The SoD Toolkit integrates additional sensors and devices to provide greater environmental awareness. Several new additions include the LEAP sensor, iBeacon, and Google Tango. Beyond integrating data streams from each of these devices, the SoD Toolkit makes sense of this information and affords higher-level interactions between connected devices. The toolkit also provides APIs for multiple platforms, making it possible to integrate new sensors and devices as they become available. The extensibility of the SoD Toolkit makes it suitable for supporting EOC-F by providing ease of integration of new technologies. Novel proxemics and gestural recognition make interactions in EOC-F natural and intuitive.

15.3.4 Gesturing in a Multi-surface Environment

Determining what gestural interactions are suitable for multi-surface environments (MSEs) is an open research question. Various researchers have explored interactions for visualization walls, tabletops, and the combination of many devices in a MSE. However, gesture preferences are specific to different scenarios and use cases, and gestural interactions within an EOC remain untested. Designing interactions appropriate for applications in MSE EOCs is one of the important research challenges that our team is addressing.

Nancel et al. conducted a user study of mid-air interactions on a large visualization wall [32]. They studied different families of location independent, mid-air input techniques for pan-zoom navigation on wall-sized displays. They also identified key factors for the design of such techniques: handedness (uni vs. bimanual input), gesture type (linear or circular movements), and level of guidance to accomplish the gestures in mid-air (movements restricted to a 1D path, a 2D surface or free movement in 3D space).

Wobbrock et al. conducted a user study with 20 participants to explore what gestures would be appropriate for a tabletop [54]. Participants performed a total of 1080 gestures for 27 commands with one and two hands, which resulted in a user-defined set of gestures. The findings showed that participants rarely cared about the number of fingers used in a gesture, one hand was preferred over two, and desktop idioms strongly influenced how users came up with gestures.

Seyed et al. conducted a Wizard of Oz user study to elicit gestures in a multi-surface environment using an iPad, tabletop, and wall display [45]. Participants performed a total of 816 gestures for 16 commands. Initial designs of gestures and peripheral interactions in MSEs have been proposed for pulling content from another device, pouring content from a tablet onto a tabletop, and sending content through flick gestures [13, 39]. However, these gestures and possible alternatives have not been empirically evaluated with EOC personnel. The resulting set of gestures likely does not cover all the tasks performed in an EOC. Considering the relative infancy of MSE research and the growing popularity of MSEs, further evaluations of gestures and other interactions within specific domains will be necessary.

15.3.5 Proxemic Interactions

Proxemic interactions are another type of interaction enabled by spatially-aware MSEs. Like gesture interactions, proxemics allow users to perform intuitive actions that are natural to them. Existing research on proxemics interactions examine how users perceive their relative positions to other people and devices, and how this perception can facilitate different actions. Hall [21] defined proxemic zones surrounding a person, including intimate distance, personal distance, social distance, and public distance. Vogel and Balakrishnan [52] explored proxemics in relation to public ambient displays, while Ballendat et al. [4] used sensors to track people and devices within a ubiquitous environment. Marquardt et al. [31] looked at spatial relationships within ubiquitous environments, specifically focusing on five proxemics dimensions: orientation, distance, motion, identity, and location. The combination of gestures and spatial awareness have resulted in natural actions for content transfer, including: simulating a throwing action, flicking towards another device, or pouring content from one device to another [9, 15]. The intuitive nature of these actions allow users to easily learn and adopt an unfamiliar system, a procedure which is often encountered in EOCs when new personal needs to be quickly integrated during emergencies to create a coordinated response.

15.3.6 Sense-Making, Visual Analytics, and Social Media

Although EOCs already aggregate various information streams from multiple agencies, a significant amount of information can be harnessed from the public. While it takes time for first responders to arrive on the scene of an incident, citizens on the ground are often able to provide critical information via social media as an incident unfolds, making this information extremely valuable. Making effective use of this information can reduce resource costs for deployment, but the flood of information can be overwhelming to process as well. Sense-making and visual analytics can help extract critical pieces of the information, in a timely manner essential to emergency response.

Sense-making is the process of searching for a representation and encoding data in that representation to answer task-specific questions [40]. Different operations during sense-making require different cognitive and external resources. Representations are chosen and changed to reduce the cost of operations in an information-processing task.

Visual analytics builds upon sense-making and is the science of analytical reasoning facilitated by a visual interactive interface and the use of information visualization techniques [14]. Visual analytics can attack certain problems whose size, complexity, and need for closely coupled human and machine analysis may make them otherwise intractable.

A number of researchers have explored using visual analytics and information visualization techniques for emergency management [24, 28, 55, 56] and understanding social media in the context of emergency response and crisis scenarios for earthquakes, fires and floods [41, 47, 51]. However, we are unaware of any published results exploring visual analytics and social media for emergency response management integrated with MSEs.

15.3.7 Wearable Computing

Although significant research has focused on extracting information from public media sources, communications with first responders remains mostly unchanged with many emergency agencies still using VHF or UHF radio [8]. This is very interesting, when we consider the increasing capabilities of mobile devices to capture and communicate much more information than radios. Despite mobile devices reducing in both size and cost, they have been unable to replace the radio as the primary tool for information transfer during an emergency. Several factors contribute to this dilemma, including a greater learning curve for responders, lack of resources to process the additional information, and an additional burden on responders to make use of the device.

A recent trend in mobile computing with body-worn devices may finally be able to overcome these problems. Wearable computing is the study of designing, building, or using miniature body-borne computational and sensory devices [6]. Wearable computers may be worn under, over, or in clothing, or may also be themselves clothes. Although wearable computers have only become popular among consumers recently, the idea itself has existed for much longer.

As early as 1994, 1996, a "wearable computer system equipped with head-mounted display, camera(s), and wireless communications" called WearCam already existed as an early precursor to existing wearable computers [29]. Early exploration of wearable computing for emergency response involved firefighters playing a simulated game with a gas mask [25], but the prototype was not evaluated within a real scenario. Cernea et al. developed their own wearable device for firefighters to use on their forearms [12]. However, the wearable unit was considered too big and heavy to be successfully employed in real rescue operations. This rather common limitation is beginning to disappear, with the advent of smaller and more powerful devices.

An important aspect of modern wearable computers is the number of sensors embedded into them, constantly collecting information about the wearer and their surroundings. Through these sensors, EOC operators can easily discern the status of field responders including their safety, location, and movements such as chasing after a suspect. In addition, responders can send back visual information through body-mounted cameras, while information from the EOC can be easily visualized by the responders. While visual and location information cannot be communicated effectively over radio, an address can be directly visualized on a head-mounted display (HMD) in a map, with navigation support for the responder. More recently, Google’s Project Tango enabled augmented reality in the form of mobile phones and tablets [48], while Microsoft’s HoloLens combined augmented reality with head-mounted displays [22]. Using augmented reality, information can be overlaid on real-world objects to further improve how we display and interact with information. With so many new channels of information transfer, communications and situational awareness can be improved over existing methods.

In addition to using wearable computing in the field, we also see opportunities for these technologies within the EOC. As far as we are aware, there has been no integration of modern wearable computing devices (such as Google Glass) into MSEs for domain-specific applications such as emergency response.

15.4 Requirements Gathering

To ensure our system was designed with users in mind, we consulted local emergency response agencies through multiple stages of our design. This was done in collaboration with our industry partner C4i Consultants, who specialize in training software for emergency response and military operations. More recent consultations include extensive requirements gathering with local firefighters, police officers, emergency management officers, industry groups, and research groups, conducted over 3 months. An emergency management workshop was then held in Banff at Cyber Summit 2015, featuring a demo of EOC-F. An open-house was then hosted at the University of Calgary, with over 60 professionals participating over two days. Subsequent interviews were held with the Calgary Police Service, focusing on communication and information needs for first responders.

A recurring theme was the desire for organizations to protect their responders, by improving communication channels and increasing situational awareness of both responders and EOC operators. Within this theme, we grouped the requirements into three categories: (1) field responder status, (2) location and navigation, and (3) communications and media support. First and foremost was the health and wellbeing of first responders. Beyond ensuring responders were alive, EOC operators wanted to know if responders were experiencing physical or mental fatigue. Next, EOC operators wanted to know the locations of responders at all times, with the ability to navigate them to points of interest including the locations of fellow responders. Finally, communications between the EOC and responders needed to be bi-directional and capable of transmitting different media formats such as photos or videos. The last category corresponds with literature from Toups et al. [50], which describes the challenges of one-way communication and the dangers associated with poor situational awareness.

15.5 Next Generation EOC

As previously stated, the Emergency Operations Centre of the Future (EOC-F) is an investigation into how analytics-based, spatially-aware multi-surface environments (MSE) can support teams managing emergencies in an Emergency Operations Centre (EOC) (Fig. 15.2). Emergencies are often unique, and an EOC has to handle a vast variety of scenarios. Similarly, EOCs can range from small localized teams to much larger collaborative efforts, situated in dedicated buildings or deployed as a mobile response. EOC-F is designed to be both mobile and scalable, so that it can be adapted and deployed in various situations even when faced with many uncertainties.

Fig. 15.2 EOC-F display wall, tabletop, and tablets

15.5.1 Technology

To support the numerous roles and activities within an EOC and the field responders interacting with the EOC, a comprehensive range of devices are included in EOC-F. Within EOC-F, collaboration planning is done around one or more interactive tabletops, while large wall-sized displays provide a common operating picture for the entire EOC. A digital whiteboard provides more traditional means of planning, but allows handwritten notes to be digitally distributed to other devices such as the tabletops. Operators carry tablet devices which facilitate planning with smaller groups or independently. Proxemic interactions between the various devices are enabled either by placing cameras within the EOC, or by using spatially-aware tablets. In the field, first responders are equipped with mobile phones or wearable devices to connect them to the EOC. Here we present details of each device in EOC-F (Table 15.1), while the following sections describe various use cases for EOC-F.

15.5.2 Spatial Awareness, Proxemics Interactions

While further analysis of interactions and gestures for these environments is required, EOC-F currently supports several novel interactions in addition to being a spatially-aware system. The interactions are part of the prototyping process and will be the basis for subsequent usability studies.

The two basic gestures are *flick* and *pour* (Fig. 15.3). The *flick* gesture can be performed on a tablet device by holding and swiping either towards or away from the user. Since the system is spatially-aware, the user can point their tablet at another device (wall display, tabletop, or tablet) and perform a *flick* gesture to send information to that device. For example, *flicking* across the room towards the tabletop will allow the tabletop to display the same location on the map as the tablet.

The *pour* gesture can be done by positioning a tablet above a tabletop, and flipping the tablet over as if to pour the contents of the screen onto the tabletop. This gesture can be used to share information from the tablet to the tabletop, essentially making the information public to the EOC. For example, a response plan drawn up by the police is initially only visible to the police, but can be shared with other organizations by *pouring* the plan onto the tabletop.

These gestures rely on the locations and orientations of people and devices within the MSE, and are provided by the SoD Toolkit and its sensors. In addition to gesture recognition, proxemics allows natural interactions to take place. One such use is the control of the wall display through a tablet. A user can walk up to the wall display, and are then able to modify what information is displayed on it. Another example is the sharing of information to everyone around you based on proximity, rather than having to individually share information one at a time during a group discussion.

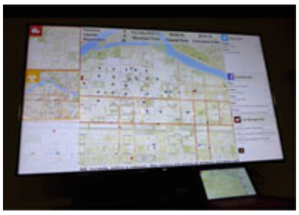
Table 15.1 Technology components of EOC-F

Tabletop

The Microsoft Perceptive Pixel is a 55" touch-enabled surface which supports collaborative planning around the table. It replaces traditional paper maps, providing a number of tools to improve the planning process. Some features include:

- live location and status updates of field responders
- annotation tools to draw up plans
- multilayer support so multiple plans can be considered
- route planning for responders, with automatic notifications sent to the field

Display wall



The Visualization Studio at the University of Calgary measures 4.88 metres by 1.85 metres (195 inches by 73 inches), and has a resolution of 9600 x 3600 pixels. It is used to provide a common operating picture to the entire EOC, and contains the following information:

- general information regarding ongoing incidents (eg. elapsed time, incident status, alerts)
- a large map synchronized to the view on the tabletop; increases situational awareness of all EOC operators, and can be used to present incident updates or response plans

Digital whiteboard

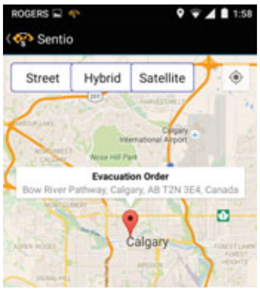
The SMART kapp® board is a digital whiteboard which bridges the familiarity of traditional planning tools with the connectivity of multi-surface environments. Notes and plans can be handwritten with regular dry-erase markers. Once completed, the contents can be digitally distributed to other devices such as the tabletop, wall display, or even view in the field on mobile devices.

Tablet

Microsoft Surface Pro 3 tablets act as portable planning devices, providing similar tools to the tabletop. Tablets are role-specific, and provide tailored tools for different roles. For example, evacuation and roadblock tools may be exclusive to the police. The tablets can be used for drawing up plans either independently or with a small group, before being shared to the EOC via the tabletop or wall display. Information can be shared simply by pointing the device to another surface, and swiping the content in that direction. Such proxemic interactions make content sharing intuitive, and reduce the learning curve of users not familiar with the EOC (eg. NGOs or volunteers).

In a mobile or impromptu EOC where large displays and tabletops are not available, tablet devices can be substituted to simulate a tabletop or shared display.

Mobile phone



Although tablets can be deployed in the field, most responders do not carry a tablet device. However, mobile phones have become ubiquitous, with many responders carrying both a personal device and a work-issued device. These devices can be used as an extension of the multi-surface environment within the EOC, providing greater situational awareness to both the responder and the EOC. The EOC can track the location of responders through GPS embedded within the devices, while responders can receive notifications from the EOC. For example, an operator in the EOC can create an evacuation zone on the tabletop, with automatic notifications sent to all affected responders.

Wearable devices

Although not as common as mobile phones, wearable devices have become more popular in recent years, with many fitness bands, smart watches, and smart eyewear available commercially. One such device is the Recon Jet, a pair of sunglasses integrated with a video camera, GPS sensor, and a small LCD display. In EOC-F, geotagged photos and videos can be sent back to the EOC, and be directly displayed on the tabletop or wall display maps. Notifications from the EOC are displayed in the heads-up-display (HUD), and dispatch orders can be visualized on a map with navigation support. All this is done hands-free, allowing responders to focus on ongoing tasks.

Augmented reality

Using devices with depth sensing capability such as Google's Project Tango tablet, a device can become spatially-aware of its surroundings. Using this awareness, the devices can display 3D visualizations in augmented reality, creating an immersive planning environment. For example, virtual 3D models of buildings can be placed on the tabletop map, providing greater context to EOC operators. By moving the tablet through the visualizations of buildings, floor plans can be viewed as well.

Spatial awareness

Spatial awareness enables proxemic interactions within a multi-surface environment, by tracking the locations and orientations of people and devices. EOC-F uses the SoD Toolkit to make sense of this information, so that actions such as flick or pour can be used to transfer information intuitively. To do the tracking, Microsoft Kinect depth-sensing cameras are placed within the environment. Alternatively, spatially-aware devices such as those used for augmented reality in EOC-F can also be used to provide spatial tracking.

Fig. 15.3 Transferring content through proxemic interactions: Flick (*left*) and Pour (*right*)

15.5.3 Social Media Analytics

With the proliferation of networked mobile devices, the public have become a vital source of real-time information during an emergency crisis. The public is often able to alert officials to immediate problems, well before any responders arrive on scene. They are a low-cost source of information, and provide a lot of information for relatively little resources spent. However, the sheer amount of information received becomes problematic when emergencies allow little time for careful and thorough analysis. This is where social media analytics can help extract the most relevant information, reducing the burden on EOC operators and improving the overall response effort.

In EOC-F, social media streams such as Facebook and Twitter are displayed on the wall display. To ensure only useful information is displayed to the EOC, a Social Media Analyst filters through the vast amount of updates before they reach the rest of the EOC [30]. Social media analytics help automate and accelerate this process, through criteria filters such as keywords, timestamps, or geolocation data.

Interactions with 3D Geospatial Data in MSE

The integration of Google's Project Tango allows cutting-edge interactions with geospatial data, most notably 3D models in augmented reality (AR). Building models are overlaid on the tabletop map or can be positioned as virtual matter inside the EOC space, allowing much more information to be visualized in the same space (Fig. 15.4). With 3D models as virtual matter, personnel are able to interact with the same objects from different perspectives while the system maps their devices' coordinate systems to the physical space of the room. Operators can also access building plans by viewing cross-sections of these models. Rather than losing track of personnel once they enter a building, operators can closely follow their movements and support them with detailed directions.

The virtual models are placed on the table just like a real object, meaning multiple operators using their own devices will see the same models. For example, if someone points to a particular building, another user with their own device will see the same building being pointed to (Fig. 15.5). This shared space allows collaborative planning to continue beyond the 2D planning table. Both the technology and its integration are still in their early stages, providing a great opportunity for

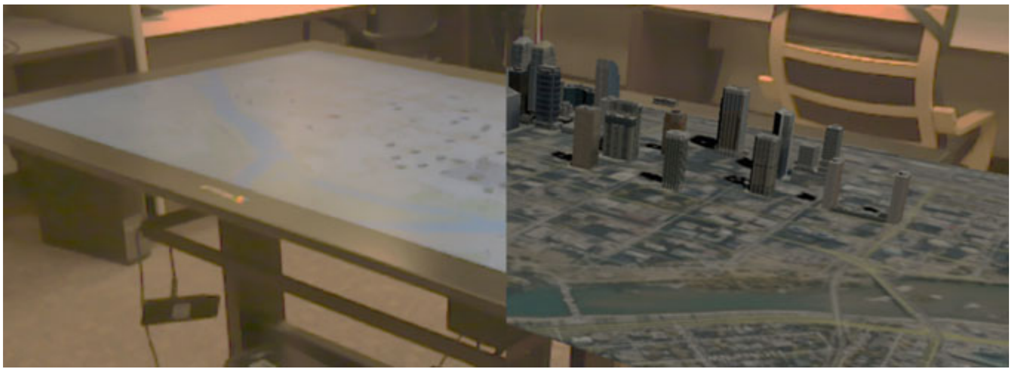


Fig. 15.4 Planning table with map displayed (*left*), and same table with 3D model overlaid using augmented reality (*right*)

Fig. 15.5 A user is pointing to a building, seen through his own device (*top*). The same user is visible through another user's device, pointing to the same location on the map (*bottom*)

future work to investigate interaction techniques with virtual matter in an EOC. These interactions can also be used in other applications, including remote collaborative planning or field-use by on-site responders.

15.5.4 Sample Configurations

In a permanent and stationary EOC, larger devices such as the display wall and tabletop may already be in place for regular use. For the integration of external agencies such as the Red Cross or utility companies, their representatives may be provided with tablet devices to quickly join in the planning process. Field responder from the EOC may already be equipped with wearable devices, while additional responders may be provided with such devices if available. If this is not possible, responders can access the same tools from the wearable devices using a mobile phone.

Other than permanently situated EOCs, there are many scenarios which use rapidly deployed ad hoc EOCs. Mobile Command Vehicles such as those used by the US Department of Homeland Security are designed for mobile deployment, limiting the available equipment. Temporary EOCs may also be setup in close proximity to incidents, and are often located in public buildings such as community centres. In these types of deployments, many of the previously mentioned uncertainties [19] can have a significant effect on the EOC setup. To account for these variables, EOC-F can operate with minimal equipment, with many components remaining partially operable even in suboptimal environments. In a minimalistic setup, a single tablet can replace the tabletop for collaborative planning.

15.5.5 Usage Scenario

EOC-F is a multi-surface environment (MSE) formed by a combination of the numerous components described above. To better illustrate the use of the various surfaces and spaces within the MSE for emergency response, we walk through a potential scenario involving a train derailment.

A train has derailed in downtown Calgary, where the tracks intersect with several high-traffic areas. Nearby responders from the Police, EMS, and Fire departments are already en route. As the EOC operators prepare to respond, representatives from various organizations, including the government as well as the railroad company, gather in a meeting room to assess the situation. Key tasks are handwritten on a digital whiteboard, and the contents are digitally transferred to the EOC tabletop and mobile devices in the field.

At this point, EOC operators are collecting information from various sources. Photos taken by on-scene responders automatically show up on the wall display map. A social media analyst monitors and filters through social media feeds such as Twitter, pushing relevant information to a feed on the wall display. Information begins to aggregate on the wall display, providing a common operating picture for everyone in the EOC. From the gathered information, it is determined that the derailment has resulted in a large chemical spill. A hazmat team in the field assesses the risk and draws up evacuation areas on a tablet device, sharing the information with the EOC. In response, the police create plans for roadblocks and detours around the incident, then shares the plans with the other agencies by *pouring* their plans onto the tabletop.

To evacuate citizens from buildings near the chemical spill, the fire department needs to know more about the buildings in the area. Using augmented reality enabled tablets, firefighters both in the EOC and on-scene are able to see a 3D virtual model of the incident area. They can determine the height of the buildings, which affects the time required to complete the evacuation. By moving the tablet through the virtual model, responders can easily look inside the buildings to access floorplans.

After considering several plans on the tabletop, a response plan is finalized. GPS sensors in mobile devices carried by field responders allow EOC operators to see where responders are located, directly on the tabletop map. By creating an exclusion zone on the tabletop, all responders within the area are automatically notified of the evacuation and provided with directions for the shortest path out of the area. To direct reinforcements to the incident location, responders are selected on the tabletop and a destination is set on the map. The destination, shortest paths, and ETAs are automatically calculated and sent to responders' mobile devices. Rather than having to ask and confirm addresses or directions over radio, responders can immediately head to the incident by starting navigation on the mobile devices. Because the locations of all responders are known, on-scene responders are aware of when reinforcements will arrive.

During the evacuation and spill containment, responders are working hard to ensure the safety of the citizens. However, it is equally important to keep responders safe, as they encounter unexpected and often dangerous situations during an emergency. Pairing responders' mobile devices with wearable health sensors can help the EOC monitor the safety of responders. If a responder's heartbeat or movement becomes irregular, EOC operators are automatically notified of the discrepancy so that help can be provided if needed.

15.5.6 System Evaluation

EOC-F combines many aspects of emergency management, and it is important to constantly involve end-users so that their requirements and feedback are accounted for. Throughout the iterative process, we frequently provide demos to our industry partners and local emergency management agencies (Fig. 15.6). They compare our system with the ones they use every day, and drive the development of EOC-F with their wants and needs. Role-specific experts such as social media analysts or incident commanders are often invited to help design or trial parts of EOC-F, so we can involve the full spectrum of users. Thanks to the involvement of all these users, EOC-F can be enhanced iteratively based on real user needs and valuable feedback.

15.5.7 Continuing Work

The EOC-F project continues to investigate and create new technologies to support emergency response planning and operation, in collaboration with our industry partner. To support crisis management teams, we will expand our work in

Fig. 15.6 Demo of EOC-F to local emergency response agencies and industry partners, in the Visualization Studio at the University of Calgary

multi-surface technology, analytics and wearable computing approaches. To enhance the handling of future emergencies, we are developing collaboration technology for a posteriori analysis of data gathered during an emergency and feed the lessons learned into training exercises.

While much of our work has focused on the ongoing emergency response, being able to predict what might happen in the event of an emergency is critical. Developed what-if scenarios allow for more effective decision-making on where to deploy resources, manage public safety, and manage the operation of the emergency response. Accurate scenarios also facilitate more effective emergency management training.

In addition to Predictive Emergency Analytics, After Action Review Emergency Analytics is equally crucial to preparedness in emergency response. It is important to be able to review what actions were taken and why decisions were made to help improve upon effective emergency management practices. Keeping a history of decisions, actions, and user interactions is critical to analyzing what happened during an emergency. The records serve to validate decisions made during the emergency, in the event these decisions are reviewed and criticized during the aftermath. Being able to effectively and efficiently analyze this data will give insight into the emergency and help improve the process for any future emergencies.

Part of the effort to collect data during an emergency is to use various sensors embedded in wearable technology. While EOC-F already collects heartrate, location, and movement information, there are many other sensors which can be used to improve safety of responders and situational awareness of EOC operators. Current solutions require responders to actively convey much of this information through radio, while EOC operators listen and record this information manually. This can be very inefficient in many cases. For example, a photo can instantly describe the situation, but cannot be sent through radio. Instead, a less accurate description is given verbally. We will expand on our current use of sensors, with the expectation that automatic logging and analysis of sensor data will lead to greater awareness in the EOC. The automated and consistent logging of data will also benefit subsequent reviews of the response effort.

15.6 Conclusion

The development of EOC-F has facilitated the investigation of how analytics-based, spatially-aware multi-surface environments can support teams managing emergencies in an EOC. We have created a prototype EOC in a multi-surface environment which integrates new technologies to support emergency response. Novel interactions and automated processes support emergency management in time-sensitive emergency situations. Future work to better utilize sensors will provide the information needed to improve the prediction, handling, and review of emergencies. Iterative feedback from end-users will continue to guide the development of EOC-F, enhancing public safety and emergency preparedness through the integration of new technologies.

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