Towards Ubiquitous Emergency Management Systems

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ABSTRACT
This contribution introduces an emergency management system design based on platform-independent multi-touch technology as an interactive, ubiquitous front-end technology for pervasive sensor and communication components. This combination aims at supporting decision making and analyses during all phases of the emergency management process. From stakeholders providing planning information beforehand to end users communicating via their mobile phones or even distributed sensor networks, the system taps into a wide range of data sources and offers a comprehensive, digestible view on the data using multi-touch surfaces in the operations centre. In order to integrate legacy data sources and to keep the system open for the integration of additional data sources in the future, a model based approach is used. Demonstration versions of the system's components based on current multi-touch frameworks and hardware as well as mobile apps and communities are also presented.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Input Devices and Strategies; D.2.11 [**Software Architectures**]: Domain-specific Architectures;

General Terms
Design, human factors, software engineering.

Keywords
Multi-touch, emergency management, crisis response, mobile.

1. INTRODUCTION
In emergency situations, the stakeholders responsible for the organization and execution of the emergency management have to cope with complex situations and short time frames for reaction. Therefore, they often have to make quick decisions based on the data available to them. Emergency management systems (EMS) provide the capability to provide crucial information support and to enable disaster forces to manage disaster events, including detection and analysis of incidents [10].

According to [35] the lifecycle of a crisis or emergency comprises of several stages:

(1) a pre-event stage allowing the development of strategy and plans;

(2) a stage immediately before or after a crisis or disaster occurs which requires the implementation of strategies to deal with its impacts;

(3) continued implementation of strategies to control or reduce the severity of the crisis/disaster; and,

(4) a long term recovery or resolution phase allowing for evaluation and feedback into future prevention and planning strategies for destinations and businesses.

Emergency management systems that utilize ubiquitous components can provide relevant information during all phases of the emergency lifecycle that can contribute to saving human lives. In this contribution we propose a system design for ubiquitous emergency management that addresses these potentials. We base our approach on pervasive information gathering components that are connected to ubiquitous monitor devices handled by e.g. first responders.

We start with a short review of related work in section 2. We outline our overall approach in section 3 and discuss its implementation in section 4, before we summarize our results.

2. RELATED WORK
There has been a lot of work on supporting crisis control rooms with visualization and interaction on large displays, e.g. [20] [40], including multi-touch solutions [14]. Multi-touch has also been used in related disciplines such as IT security for visualizing the outputs of intrusion detection systems [17], as interface to large scale simulation in the context of astrophysics [16], or as front end for sensor networks [27].

Such systems are often used in this context as visualizing spatial information is one of the technology's strengths [39]. An overview of spatial information and geographic information systems in the context of emergency management is given in [12].

Micire et al. [28] offer a broad set of technologies integrated into a multi-touch interface for disaster response. Similarly, the German SoKNOS project has developed a broad visualization and data integration approach [13] for supporting *"the response and the recovery from natural and socio-technical disasters"* [31]. SoKNOS also provides planning components, and integrates web services and sensors. We envision a system where planning and learning from past events are more central, and which is able to data mine web communities, as well as provide real time information from integrated mobile apps.

Zibuschka et al. [42] present a multi-touch design aimed at supporting the planning stages of emergency management. The presented design integrates information provided by the individual stakeholders to provide a common picture to support planning of large public events. We extend this approach by adding additional support for the after-event stages, and integrate a broader set of data sources, such as mobile apps and web sites such as social networks or news sites.

Nóbrega et al [29] present a system which simulates the propagation of disaster such as floods, and can visualize the scenarios on an interactive display for operative briefings. Simulation is not currently our main focus, but the visualized scenarios are similar.

Generally speaking, none of the systems presented offer support for the full emergency management life cycle. They often focus on the operations during a disaster, neglecting the planning and learning phases before and after the event. This is especially relevant as in case of disaster, it may not be prudent to rely on the availability of a technical system too much; much less its established ubiquitous components such as mining of external information or collection of information from end-users. Our contribution aims to fill this gap.

3. APPROACH

Our approach is built on three main ideas:

– Disaster management involves a lot of spatial information, and it makes sense to build an overarching information integration framework around this information [18], to improve communication possibilities and awareness of information from other stakeholders or from the field, which are key issues in emergency management [34].

– Multi-touch interfaces are very well suited for visualizing [27] and interacting with [15] spatial information.

– As already pointed out in the related work, we feel that disaster management systems should focus more on the pre-event and resolution phases [35], as infrastructure failures can knock out the system infrastructure for information integration [26].

Realizing a system built on these basic ideas, we try to meet the basic requirements for emergency management systems identified by Scherner et al. [38]. They are:

– system effectiveness
– reliability
– cost efficiency
– smooth service integration
– multilateral user interaction
– availability
– security.

To address these factors, we build on the reference architecture given by Roßnagel et al [37].

3.1 Vision

Our vision is to make emergency management systems truly ubiquitous in nature, combining mobile and/or pervasive sensors (in the broadest sense) and mobile terminals in general with ubiquitous Roomware [32] approaches supporting the staff in the crisis control centre. The components are tied together by a model-driven data integration engine fusing data from various sources (Figure 1).

In the field, sensor networks pervasively collect information. In the current implementation, those are mainly mobile clients handled by end users or first responders, but the future vision includes sensor networks (including “smart dust”, appliances for detection of e.g. explosives and similar systems).

In addition, the system is also able to retrieve information from arbitrary web sites, e.g. third party news sites and communities, using a web mining approach. In the future, this component may leverage the ontologies used in the data integration for full-fledged reasoning on the Semantic Web or similar large-scale data integration approaches, but it is useful for monitoring social media and news even as is. In addition, interfaces for relevant information systems at involved organisations can be provided,

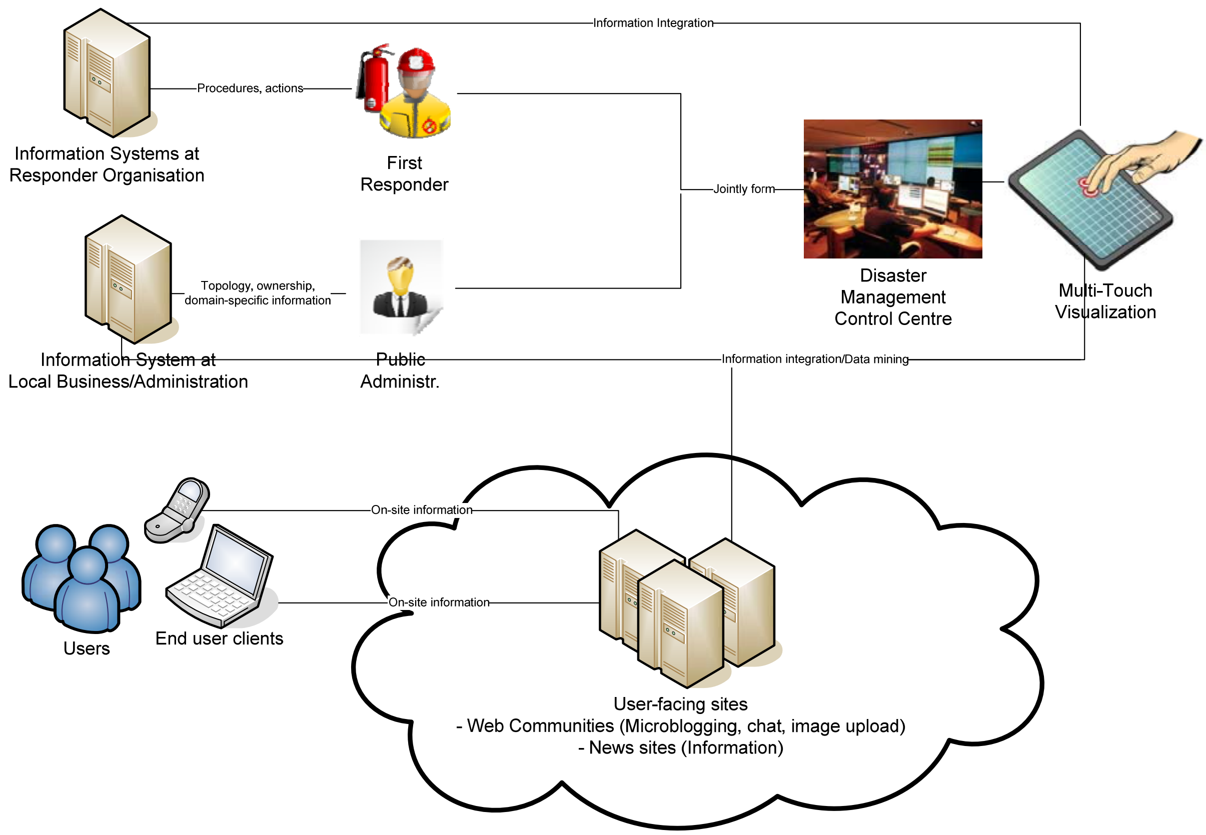

Figure1: Deployment Overview

allowing for integration of data like property and liability information from the local administration, or event reports from first responder organisations. The data collected this way makes the emergency management system immediately useful to its users [7].

The incoming information is digested using a data integration back-end that is built on ontologies, bringing the heterogeneous inputs into a form that can be displayed as spatial data on a map. For cases where this is not sensible, additional UI ontologies can be supplied to configure specific display modes for the information.

The visualization is performed on interactive displays back at the crisis control centre, providing a more complete picture of the situation in the field during operations and later during after-event briefing. The same visualizations may also be used by pervasive screens in e.g. first responder vehicles or mobile clients. For this, it is very beneficial to use a portable multitouch API solution supporting all common operating systems [24], including on mobile terminals.

Personnel at crisis control centres can benefit from collaborative interaction to improve information sharing and communication, especially during the pre-event and event resolution phases of the lifecycle [42].

In large part, this vision is similar to what is presented (purely as a video illustrating the vision) in [33], which is a work by collaborators. However, the system we envision has an additional focus on pre-event and event resolution support [35]. We can also offer a realization of the system based on today's technologies, described in the next sections.

3.2 Current Realization

To realize this vision today, we implement a system using current multi-touch surfaces, such as tables and tablets, as a front end, with a back-end consisting of on the one hand customized apps on mobile phones distributed by the stakeholders in various contexts (e.g. large public events [37]) and on the other hand with broad data integration capabilities, for deployment at e.g. control centres. As we are focussing on the post- and pre-event phases, we are not so much focussed on the communication interface to first responders in the field, instead focussing on interfaces to information systems at the involved organisations, as well as collecting input from users that were/are connected to the internet during the event, or reports acquired using data mining components from e.g. news sites post-event. An overview of this approach is given in Figure 1.

So, the system integrates several of the ubiquity aspects given in the vision. Mobile phones have a market penetration of more than 100% in the EU [30], and people are using them to push information about their surroundings all the time. We leverage this by integrating contemporary mobile apps with an information integration component and a collaborative multi-touch visualization that can also be brought to the small displays of mobile devices using the portable MT4j framework [24], as described in the next section.

4. IMPLEMENTATION

Earlier versions of the multi-touch and mobile components were developed in national project VeRSiert, but integration is still ongoing. In addition, the components are recontextualized in relation to the disaster management life cycle, covering more phases, specifically post-event support.

The mobile communities within the system are based on the design presented by [38] [37], offering both value-added services in the context of tourism/large public events/transportation and emergency services such as emergency notifications.

4.1 Mobile Services

The mobile service platform utilized in our current mobile service infrastructure is presented in [36]. It can be utilized for emergency management and commercial mobile value-adding service as described in the previous section. It offers modular basic services that were identified based on the value-adding event management and emergency services [36]. These basic services include:

- chat platform
- micro-blogging platform
- localization of users
- multicast and broadcast messages
- mobile ticketing
- mobile payment

As the same underlying technologies can be used for both value-added and emergency management services economies of scale significantly reduce the associated costs. In addition, by offering a service platform implementing those building blocks, a quick development of value-adding mobile services can be achieved [36].

We have implemented a system prototype, based on customized Open Source components for the server side, and using Google's Android [1] platform for implementation of the client application [36].

On the server side, we use StatusNet's Laconica micro-blogging service [2] (providing support for persistent, asynchronous, bidirectional communication between stakeholders such as end users and emergency managers). To also offer a synchronous, non-persistent communication channel allowing for group communications, we use the OpenFire [3] server implementing the eXtensible Messaging and Presence Protocol (XMPP) [36].

On the client, components like routing, chat client, micro-blogging connector and friend finder have been implemented using the Android API, in part based on additional online services like Google Maps [4] and components of the mobile phone, e.g. the Global Positioning System (GPS). Further basic services can be implemented as modular components. A rebranding of the client application was integrated, to allow for additional distribution channels, and enabling the system to reap the benefits associated with strong brand names in the context of new product deployment [36] [41].

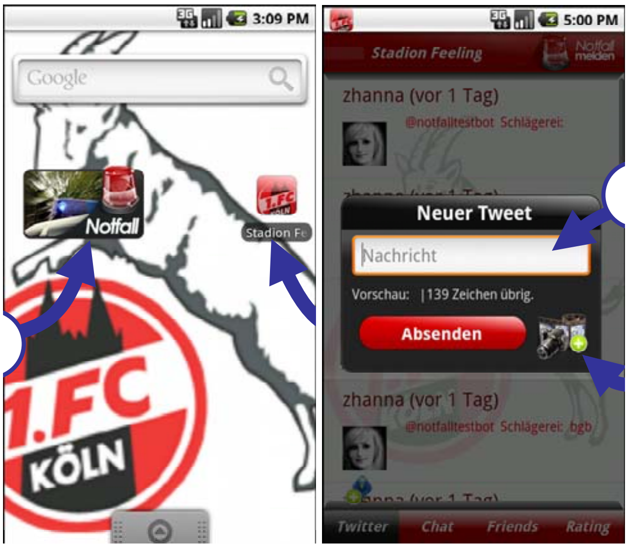

Figure 2:Prototype screenshots (widget and app, running app)

In addition to the app, we implemented a widget component for quick access to the emergency functionality (see Figure 2).

4.2 Pervasive Sensors

Another interesting type of data provider for emergency management is distributed sensor units. These devices can provide information e.g. about fire, toxic gasses or radiation. Furthermore, camera based systems can e.g. be used as a sensor for the detection of unusual large crowds [21]. While at the current state of the art, extensive use of sensors is quite expensive and difficult, the large amount of research activity in this area may provide cheaper and better suited solutions in the future.

At the current state of implementation, we use Sun SPOT devices [5] (Figure 3) as an example of mobile distributed sensor devices. It contains several on-board sensors and it provides breakouts which can be connected to external sensors. The device communicates via radio transmission as well as via a USB interface. While the device is still quite expensive and much bigger than sensors in the vision of smart dust, the device behaves similar regarding the way it communicates and the data that it produces.

Figure 3: Sun SPOTs as mobile sensor devices

4.3 Data Extraction

Within the World Wide Web already a lot of structured or semi-structured information exists which can be queried using standardized interfaces. For example, the Open Search interface [6] provides access to several content management systems, blogging systems and search engines and can be used to retrieve information from many existing sources in the web. Information sources without a dedicated external interface often can also be accessed using bots and parsers with additional effort for interfacing, extraction and additional maintenance efforts in case of changing structures of the information sources.

4.4 Multi-touch User Interface

The multi-touch front-end provides an integrated view of the available emergency management information. This includes information provided by the stakeholders as well as information from the other components of the overall system (sensors, mobile services and data extracted from the WWW). Location-dependent data is visualized on a map. There are several kinds of maps that can be used, e.g. aerial shots or roadmaps.

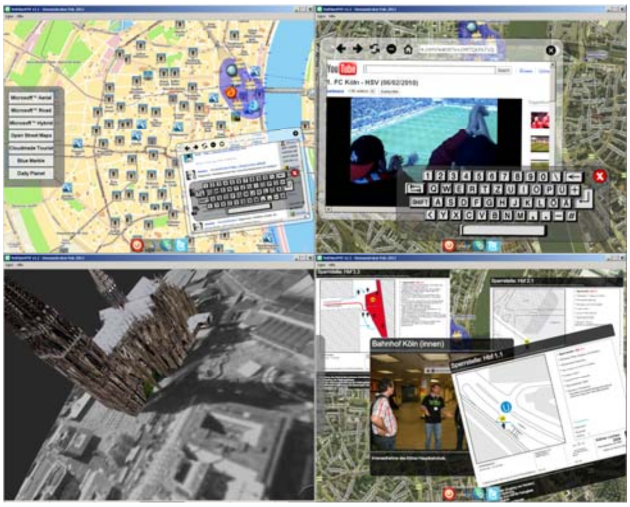

Figure 4: Screenshot prototype (Multi-touch application visualizing different kinds of location based information)

The multi-touch user interface is realized using “Multi-touch for Java” (MT4j), which is an open source framework for rapid development of multi-touch applications on the Java platform [24]. MT4j runs on Microsoft Windows, Linux and Mac OSX. It supports several multi-touch input protocols such as WM_TOUCH [23] on Windows 7 or the platform independent open source protocol standard TUIO [22]. In the meantime, a first alpha version of MT4j exists for Google’s Android platform so that future versions of our multi-touch application can also be run on Android Tablets. Currently, we also think about an adaption of the application’s user interface to the smaller display dimension of Android smartphones.

For collaborative use during the pre-event and event resolution phases [30], a 42 inch multi-touch terminal is used. The terminal runs on Windows XP. On the terminal, multi-touch motion data is transferred via the TUIO protocol. Stakeholders can also run the application on any windows or Linux PC. If the hardware is not capable of multi-touch, the application can also be controlled using traditional input devices like keyboard and mouse or a track pad. This allows the stakeholders to use the application on their normal PC and to contribute e.g. planning information directly via the application.

The application manages the underlying data using the relational database system HSQLDB [19]. Multi-media content like images, videos or 3D models are stored as files and referenced from the database. Since all data including the database itself and all multi-media content is stored in one file system folder, it is possible to store the whole data in a single archive file. Since the system allows importing database archives in read-only mode, there is a simple way to merge data from the different stakeholder's systems.

4.5 Model Based Data Integration

Within the overall system, different kinds of information have to be collected and managed. Against the background of proprietary implementations and heterogeneous data structures as well as semantic differences in the data provided by the various data sources, a model based approach is used. We use ontologies to describe the data sources as well as the information provided by the various platform-internal and external data sources. This approach has already proven to be purposeful, especially in heterogeneous environments [8] [9]. For the realization of the description models, we decided to use the web ontology language (OWL) [25]. OWL is a XML-based ontology description language which is built upon the less expressive W3C standards RDF [7] and RDFS [11]. OWL itself offers three variants that contain different subsets of the OWL syntax. While OWL lite is focussed on simple classifications and restrictions OWL DL and OWL full offer much more expressiveness but also increase the complexity. We decided to use OWL DL because OWL lite is not expressive enough and OWL full does allow complex definitions on which no formal decision making is possible.

In order to allow operating on a defined data structure, a unified data model is used. It describes all the information, the system can operate with. In a data source description model, meta-information about the specific data sources is stored. A visualization model for each data source allows the customization of the user interface. It describes which specific information is visualized and how it is presented. This leads to a high configurability of the front-end to end-user requirements while minimizing costs for minor changes.

A data source connector for each data source has to be implemented. It accesses the data using the given mechanism depending on the specific data source. For example, the data provided by the mobile services is stored in a RDBS and queried via SQL by the connector. A data management module provides scheduling functionality for data fetching. It fetches data using the data source connectors. The management module is also responsible for the storage of the fetched data.

5. CONCLUSION

In this contribution, we presented a ubiquitous emergency management system design, based on the integration of mobile and multi-touch components in the front end with sensor fusion and data mining capabilities in the back end. As we derived our system from evaluated designs from literature, we hope to address the requirements given in [38].

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