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What You See Is What I Need: Mobile Reporting Practices in Emergencies

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Abstract. Decisions of emergency response organisations (police, fire fighters, infrastructure providers, etc.) rely on accurate and timely information. Some necessary information is integrated into control centre's IT (weather, availability of electricity, gauge information, etc.), but almost every decision needs to be based on very specific information of the current crisis situation. Due to the unpredictable nature of a crisis, gathering this kind of information requires much improvisation and articulation work which we aim to support. We present a study on how different emergency response organisations communicate with teams on-site to generate necessary information for the coordinating instances, and we described, implemented and evaluated an interaction concept as well as a prototype to support this communication by a semi-structured request-and-report system based on Android devices. We learned that (1) the accuracy of request and reports can be improved by using an appropriate metadata structure in addition to creating multimedia-based information content, (2) requirements of trusted and fast information need to be respected in support concepts although they may even be contradictory, and (3) the coordination strategy of the emergency response organisation also shapes the way this interaction needs to be designed.

Introduction

Nowadays cooperation often goes beyond spatial and organisational boundaries. One challenge for cooperation in heterogeneous settings is to provide information in the appropriate amount, level of detail, format and point in time. In such settings, the sender is faced with the challenge of perceiving the outer context, as well as anticipating what the recipient already knows. If both are successful, communication can concentrate on the essentials, otherwise failures arise as a 'lack of information' or an 'information overload' (Toffler, 1970). In CSCW a distinction between (mainly distributed) cooperative work,

that covers the tasks itself, and articulation work, that includes all activities to coordinate the tasks among individuals, is common (Schmidt & Bannon, 1992). Articulation work is necessary if one participant is not able to accomplish the whole task by himself. If we look at the case of emergency services, it is obvious that one unit cannot manage the situation alone, therefore collaboration and, consequently, articulation is required. In terms of emergency management, articulation work includes reports of on-site units to the control centre, information provided by the control centre or even communication between different units or organisations (Reuter et al., 2012). Emergency services face an "unlimited variety of incidents that require interpretation, decision and coordination" (Normark & Randall, 2005). The increasing emergence of mobile devices, data flats and almost all-encompassing internet during the last years created new possibilities that allow communication and may support cooperation from anywhere. However, the dynamics and specifics of emergencies aggravate finding appropriate approaches to articulate information needs among all actors (Heath & Luff, 1992).

In order to support articulation and reporting, we concentrate on a scenario, where on-site units and off-site units have to share a common understanding of a situation. The focus lies on preventing 'lack of information' as well as 'information overload', at the same time increasing the quality of information, which should ensure a better basis for cooperative decision-making. In a qualitative empirical study of emergency services we explored their mobile collaboration practices, as well as possibilities to support those practices via mobile devices and applications. From these pre-studies, we have summarized the requirements for a mobile interaction approach, which allows semi-structured information requests and corresponding reports to stimulate a high-quality information basis. After introducing the resulting Android application "MoRep", which is supposed to support communication among emergency services, it will be evaluated by emergency services representatives concerning its impact on working practices and potentials to support articulation work in emergencies.

Related Work

Unexpected problems, dynamic changes of situations or environmental and knowledge limitations lead to the need for improvisation (Stein, 2011) - especially in crises and emergencies. To support improvisation during emergency management it is essential to know the characteristics of the field. Based on an analysis of the response to the 2001 World Trade Centre attack, the following characteristics of emergency management can be considered as reasons for improvisation (Mendonca, 2007). Firstly, (a) *rarity* of incidences limits opportunities for training and learning. Furthermore, (b) *time pressure* forces a convergence of planning and execution. (c) *Uncertainty* is present because the development of an extreme incidence is hardly predictable. Furthermore, extreme events have (d) *high and broad consequences*, therefore there is a need to manage interdependencies among a wide range of physical and social systems. The (e) *complexity* of the event arises, partly due to the high and broad consequences. Finally, (f) *multiple*

decision makers and responding organisations may negotiate while responding to the event. Nevertheless, all organisations that help guaranteeing civil security have developed systematic approaches to deal with these uncertainties and to allow for planned, coordinated activities in crises. Still, many situations require spontaneous, ad-hoc decisions and short-term (re-)planning. The collapse of role systems need not result in a disaster, if people develop skills in improvisation (Weick, 1993). The ability to improvise remains a valuable asset for individuals and organisations, and is usually cultivated in crisis trainings and grows with experience (Ley, et al., 2012). Computer-based systems can support these processes, if the design is informed by an understanding of the cognitive processes involved in responding to unanticipated contingencies (Mendonca, 2007).

The type, quantity and quality of information, that an agent needs within a given decision making context to complete a specific task, is called information demand, whereas objective and subjective information demands are not always identical. The objective demand includes information, which should be available according to a specific task. The subjective demand includes all information that is relevant in the agents' opinion. The information supply includes all external and internal information to which an agent can access at a certain time. O'Reilly (1980) studied how the amount of information affects the quality of the decisions made. He shows that actors, who claimed not receiving enough information to complete the tasks, were less satisfied, but made better decisions. On the other side, actors, who claimed that they were overloaded, were more satisfied, but the decision quality was not as good. But the impression that the 'lack of information' has less negative effects than the 'information overload' is relativized by the finding that a lower satisfaction of actors is closely linked to an *"increased tendency by senders to distort information during transmission"* (O'Reilly, 1980). Therefore both problems have the same relevance. They are characterized by subjectivity, which outlines one of our main argument: *"What one perceives as information overload, may be perfectly manageable to the other"* (Mulder et al., 2006). However, not only the amount of information plays an important role in decision making, but also the quality and the format (Ho & Tang, 2001). Both are subjective as well and can vary according to the individual (Naumann & Rolker, 2000) or scenario (Christofzik & Reuter, 2013).

As already mentioned, in emergency management, decisions have an extensive impact. They are based on incremental information from on-site reports and messages. Especially the forces need to make decisions *"under conditions of incomplete or inaccurate information in a context of changing and possibly ambiguous hazard consequences and response objectives [...] under considerable time pressure"* (Paton, 2003). Bharosa et al. (2009) showed that, during exercises, Commando Place Incident Team (COPI) leaders spent on average "*30 min or more collecting information and directing the operations of their own agency, followed by a 15-min interaction with other COPI members"*. Lundberg and Asplund (2011) analysed groups involved in regional and international operations, with regard to the flow and exchange of information and communication and found that these organisations mistrust their IT systems or do not accept them, because they do not want to pay for training as well as the proper

equipment. To assure trust, acceptance and a safe handling of the systems, the systems should be used in the everyday work, not just in emergencies (Kyng et al., 2006). Further problems exist in the area of situation awareness. The lack of communicating task-oriented, dynamic information and the related 'information overload' lead to serious problems during the response phase (Prasanna et al., 2011). Further on, in collaborative environments, the different roles and expertise of group members make sense making even more challenging, because group members do not only need to understand task-related information but also need to comprehend the relative relevance of the information available (Paul & Reddy, 2010). Other occurring problems concern the finding of a correct recipient, unclear channels of communication (Ley et al., 2012), time-consuming, ineffective forms of messages (Lundberg & Asplund, 2011) and different interpretations of used terminologies (Reuter et al., 2012). Some of the problems could be solved by appropriate communication technologies albeit the main challenge is to articulate the individual information need in an easy way.

Information technology can support articulation work (Schmidt & Bannon, 1992). Currently, radio is the most important communication technology for emergency services in Germany. The digital radio, which is presently being introduced, makes it possible to use a single shared nationwide network, which creates new forms of communication. In contrast to analogue, the digital radio enables to transmit data on a narrow-band, but the rate is limited to 3 kbit/s, which does not allow transmitting much data, like multimedia. Based on empirical studies Guerrero et al. (2006) and Peng et al. (2007) developed conception frameworks, which determine appropriate devices besides digital radio for certain cooperation contexts. Both frameworks deem tablet PCs and PDAs as the most suitable in terms of mobility. Since the frameworks release, smartphones and tablets have become more popular and powerful and combine the performance of PDAs with the multimedia support of mobile phones, where the integrated sensors will be extended in the future (Gomez & Bartolacci, 2011). Both, smartphones and tablets meet the requirements of everyday using and are fundamental elements of CSCW technology for mobile workers (Tamaru et al., 2005). Besides the devices, the growing range of mobile technologies such as LTE creates new possibilities for transmitting big amounts of data.

Various approaches already focus on supporting cooperation with the additional help of mobile devices. There officers-in-charge are information providers and consumers, whereas units on-site are primarily information providers (Nilsson & Stølen, 2010). The officers-in-charge, either on-site or in the control centre, are mainly decision makers, whose decisions result in actions performed by on-site units. Büscher and Mogensen (2007) present different prototypes to enable command centres capturing live information about on-site movements and situation assessment in order to be able to construct a better situation overview without having to disturb on-site units via verbal communication. Catarci et al. (2010) present a system, in which each on-site unit uses a PDA that was supervised by a process management system, which orchestrates the units and conducts external data services. The mobile devices are able to receive tasks, to add comments to captured pictures and videos, to share these and to display them on a map application. Another more content-oriented concept was introduced by Singh and Ableiter (2009).

Their application 'TwiddleNet' makes it possible to send and receive multimedia data, where the smartphones took on the dual-role of a server and a client. These data are available as a feed and are accessible via 'pull' or 'push' service. Those applications, which allow almost real-time reports, including multimedia data with location information, are able to increase situation awareness (Betts et al., 2005). Bergstrand and Landgren (2011) analysed the communication impact of live videos from the incident place to the control centre and found, that the videos improved situation assessment in the control centre enormously. Due to the bottom-up flow of communication, the on-site units provided information driven by their own motivation or previous radio transmission, which led to problems with prioritization: *"When you decide to use the camera, you also decide not to do other things"* (Incident Commander in Bergstrand & Landgren, 2011). Wu et al. (2011) presented, in contrast to Bergstrand and Landgren (2011), a 2-way system including top-down communication, which is based on CIVIL, a mobile application allowing up- and downloading geo-referenced data. Professionals as well as citizens can use the application, which means that citizens become an active part of crisis management. Problems arose due to the amount of data, because a majority of the pictures caused an overloaded map application. A suggested solution was a picture cluster, but the question remains of *"how to choose a representative photo to describe the entire group of pictures"* (Wu et al., 2011). Such a similar problem arose while using the application 'diretto' (Erb et al., 2011), which allows transferring images and other formats to a previously asked query. The system Ushahidi (Okolloh, 2009) has a similar approach, but without previously asked questions. An application which is aimed at supporting collaborative situation awareness and decision making in the specialized case of a chemical industrial accident is 'DIADEM' (Winterboer et al., 2011). With DIADEM, the control centre can ask selected agents to take pictures, which are automatically geo-tagged and displayed on a digital map in the control centre.

Most approaches pursue a kind of push mechanism, where the information is received in the form of notifications and the recipient has no option to articulate the information need or to specify the needed format. Apart from problems that occur with voice transmission (Schöning et al., 2009), Bergstrand and Landgren (2011) showed that – despite possible enhancements of situation awareness – already available photos from on-site response teams are not regularly used. Therefore, decision makers should have the possibility to improvise and articulate their individual information needs in an appropriated way. Prototypes of Büscher and Mogensen (2007) allow pulling information in an appropriate way, but these do not address directly improvisational activities and try to substitute verbal requests. Other existing systems (Catarci et al., 2010; Winterboer et al., 2011) allow to request information, where these requests are often merely text messages and the decision makers have no option to articulate or specify their information needs and formats in a further dynamic, fine-grained, but still simple way.

Taking the existing reporting practice and existing approaches into account the research question of this paper is: How should emergency services articulate their information needs and how can mobile applications support articulation work in emergencies? The following empirical study will explore mobile collaboration practices

of emergency services, as well as possible means to support these practices via mobile devices and applications.

Research Field

The findings and the concept in this paper are derived from a study focusing on collaboration, situation assessment and decision-making practices during coping and recovery work at emergency response agencies in Germany. The study was conducted in two regions. County A is a densely wooded, hilly and rural county, whereas county B consists of 10 growing and urban communes. In both regions, we focus on several organisations affected: Infrastructure suppliers (e.g. power supplier), public strategic administration (e.g. crisis management, county administration), public operative administration (e.g. police, fire department) and citizens. The organization of police and fire fighter forces differ among the counties: County 2 provides professionals, whereas fire fighters of county 1 are mostly members of voluntary fire departments. Here, just members of the control centre have salaried positions.

Empirical Study

The basis for the data analysis was the result of various empirical works during the years 2010 to 2012 in the application field. The studies were embedded in a scenario framework, which was developed together with actors from police and fire department, county administration and an electricity provider. It includes a windstorm with many incidents and energy breakdowns. The purpose of the scenario was to be able to quickly create a common understanding of an occurring emergency and therefore it helped to increase the validity and comparability in our interviews. We conducted 5 inter-organisational group discussions, each lasted about 4 hours. The aim of the group discussions was to understand communication practice of inter-organisational crisis management. Furthermore, we conducted 22 individual interviews with actors from the participating organisations (table 1). Each interview lasted between 1 and 2 hours and followed a guideline, which was separated into three parts. The first part focused on the participants' role, qualification, tasks and work activities under normal conditions. The second part covered the participants' tasks during emergencies in our developed scenario framework. The third part covered applied information and communication systems and perceived problems with these tools. Group discussions and interviews were audio recorded and later transcribed for subsequent data analysis.

No.	County	Organisation	Role	Control Centre	On-Site Leader	On-Site Other
I01	A	Administration	Regulatory Authority	X	X	
I02	A	Police Department	Head of Control Centre	X	X	
I03	A	Police Department	Head of Section	X	X	
I04	A	Police Department	Patrol Duty			X

I05	A	Fire Department	District Fire Chief	X		
I06	A	Fire Department	Deputy Head of Control Centre	X		
I07	A	Fire Department	Workmanship			X
I24	A	Fire Department	Head of Control Centre	X		
I08	B	Administration	Office Civil Protection	X		
I09	B	Fire Department	Chief Officer / Chief of Fire Dept.	X		
I10	B	Fire Department	Operation Controllers		X	
I11	B	Fire Department	Clerical Grade Watch Department			X
I12	B	Fire Department	Control Centre Dispatcher	X		
I13	B	Fire Department	Head of Control Centre	X	X	
I14	B	Police Department	Member of the Permanent Staff	X		
I15	B	Police Department	Head of Control Centre	X		
I16	B	Police Department	Head of Group		X	
I18	both	Energy Network Operator	Higher Area, High Voltage	X		
I19	both	Energy Network Operator	Operation Engineer, High Voltage		X	
I20	both	Energy Network Operator	Operation Technician, Low Voltage		X	
I21	both	Energy Network Operator	Dispatcher, Low Voltage	X		
I22	both	Energy Network Operator	Workmanship Technical Incidents		X	

Table 1: Interviewees of the empirical study (phase 1): information and collaborative practices

The empirical study showed that, especially in police and fire departments, decision makers depend on on-site information to be able to make appropriate decisions. Therefore, the organisations of the second empirical phase in 2012, which researches the effects of dynamic information requests and their fine-grained specifications to create a high qualitative base for making decisions, were fire and police department with their different management and lead structures. The police coordinate operations directly from the control centre *("lead from the behind"*), in the fire department, however, the officer-in-charge is on-site and the control centre only supports him *("lead from the front"*). To be able to study the mobile collaboration practices more closely, additional 5 partially structured interviews were conducted in 2012 which lasted in average 60 minutes, in which the current practices were analysed, also in regards to the creation, exchange and use of information by the response teams and the works in the control centre (see table 2).

No.	County	Organisation	Role	Control Centre	On-Site Leader	On-Site Other
IM01	A	Police Department	Head of Control Centre	X	X	
IM02	A	Fire Department	Administrator of the Control Centre	X	X	
IM03	A	Fire Department	Control Centre Data Support / Digital Radio Coordinator	X	X	X
IM04	A	Police Department	Head of Police Station		X	
IM05	B	Fire Department	Department Chief Control Centre	X	X	X

Table 2: Interviewees of the empirical study (phase 2): mobile collaboration practices

Results: Mobile Reporting Practices

In the following, the empirical results concerning the information and communication practices and the articulation of information needs are presented.

Information and Communication Practices

Emergency management requires making decisions in-situ based on current conditions. Hence, it is necessary to keep track of the occurrences. Some of the information, which is used for the work tasks in operations management, is provided by "official" information systems. In major catastrophic events or in case of weather alerts these internal information resources are enriched by many external, *informal information resources*, which are necessary in various situations. Many actors individually collect supplementary information from various sources (e.g. the current weather condition outside the building, phone calls or webcams that are focused against the wind direction) to obtain a better overview of the situation: *"You need as much information as possible"* (I24). Or: *"I need verified information for a decision about a particular situation"* (I05), which needs to be *"as detailed and accurate as possible to give an exact representation of the situation"* (I06). Nevertheless information from own personnel is judged as being very valuable. The heads of control centres (I01, I09) mentioned that visual on-site impressions are crucial, because if you *"explain to someone that there is an accident with 300 injured people, both of us have a very different imagination of the situation"* (I09). Therefore, *"the most reliable information is what I have seen myself"* (I05), where the difficulty exists *"that we can't look through the phone and we don't see how it looks like on-site."* (I06). The response team on-site already knows, that it can be important to send visual data to the control centre, because *"if you've seen it yourself, you have a better overview of the situation"* (I10). Currently verbal communication is executed via radio. In the control centre *"the flood of communication kills us in our daily work"* (I03), where the permanent risk of *"being overloaded by information"* (I03) exists, that *"in the end you don't understand what's going on anymore, because there is too much input and you can't handle the information"* (I03). On the other side, the on-site team complains about having not enough information: *"It would be great to have more information on-site"* (I07), because currently *"the office-in-charge wants something done and then we have to understand what he means"* (I07).

The information demand is very subjective: *"What we need in order to be able to make a decision varies from individual to individual"* (I03) and cannot be specified in advance. Nevertheless all agents agreed that particular criteria need to be met: (a) The emergency work is based on situation maps, therefore *"the necessary GPS coordinates need to be included, so that you know the location the information comes from and don't have to guess"* (IM05). (b) Sending and receiving information in different data formats is desirable (I05), while pictures and videos are seen as most relevant (IM04) and long text messages critical (IM03). (c) It is necessary that it is visible which user took the picture (IM03) and that (d) the information is time-stamped (IM01). The information between the control centre and on-site units' needs to be 100% synchronized (IM05), because *"during an operation there is nothing worse than talking about different things"* (IM05).

When communicating no unit in the hierarchical structure may be left out, even if it means a larger amount of time (IM01), for example, a sub section leader will always communicate only with his section leader and not directly with the head of operations

(IM01). The control centre always communicates at the level of section leaders (IM01), where information from the section leader does not need to be evaluated and can be used immediately (IM01). Involving citizen-generated information into crisis management is seen critical: *"Someone who does not have a background in emergency services would hardly be able to deliver necessary information in such a situation"* (I02). Sending pictures by citizens *"will get out of control if everyone takes pictures. [...] If you've had an accident or anything else happened to you, you wouldn't want a stranger to take pictures"* (I01). Of course scenarios exist where citizen-generated information might be useful and could contribute to situational awareness (Vieweg et al., 2010), but due to the interviewees mentioned that applications for supporting direct communication should only be available to emergency services, we blanked out the dimension of citizen-generated information in our paper.

Articulation of Information Needs

A wide range of emergency response actions show that situation assessment is often a collaborative task. To deal with the uncertain and changing environment during emergencies, usually a big number of people are involved in gathering or analysing data, decision making and monitoring of implementations and consequences. However, in order to articulate information needs, infrastructures are needed. Independent from knowledge about both frameworks for selecting devices for specific contexts (Guerrero et al., 2006; Peng et al., 2007) the interviewees confirmed: "*if we're talking about an ideal situation, then I have a smartphone in my patrol car and the officer-in-charge uses a different device that gives him even more functionality"* (IM04). Right now the communication path is still via radio, but smartphones are already used for purposes like using Google Maps for satellite views or navigation (I04), because the control centre gives an address and the on-site team often does not know the exact location. Moreover, mobile devices are not only interesting for the on-site units, but also for the actors in the control centre since they are not present 24/7 so that they have mobile access to information (I13). The participants asked for a simple and easy-to-use hardware *"with as few features as possible, so that a unit, who has never used it before, can be trained quickly"* (IM04) and it *should* be used almost daily to establish routines (I06). An important feature is to be able to take videos or photos quickly and record voice data and write short messages all without using a pen (IM03). The hardware needs to be quickly ready for use, *"if we need to boot an additional notebook, then it won't be used"* (I04).

Usually the on-site teams are responsible to deliver relevant information, so information is provided via push mechanisms. This practice has some disadvantages. One problem also occurred during our interviews: On-site teams often do not know which information they have to transmit or they prioritize outgoing reports very low, especially volunteer forces (IM01, IM02). Therefore the current control centre practice is to request information from the incident place actively (pull mechanism) and to not wait for appropriate reports. By requesting information actively, it is possible to prevent that *"everybody just takes pictures and sends them back, without really knowing what is*

going on" (IM05). During the dynamic requests for information, the return format of information often needs to be specified (IM04). In case of such requests, the control centre *"should see the location of a unit and instruct him to take a picture"* (IM02). Currently the determination of the units' locations only works verbally via radio: *"I take my radio and contact him: Where are you? At best he will answer: I'm here or there"* (IM05). *"Ideally, besides the location, you see whether the unit is busy or not"* (I03). These articulations currently take a lot of time. Therefore the forces mentioned that, based on the location, there should be an option to navigate units remotely: *"If I see their locations and also the plans on a map, I could say: "Go five meters further, that's where the next hydrant should be"* (IM02). Due to the high dynamics and improvisation within response teams, people can be spontaneously assigned to new roles. Therefore, requests need to be always assigned to roles, never to persons (IM01, IM03). Besides the influences from an incident itself, *organisational factors* and structures can bear unpredictable challenges. That is why each actor will have to be able to divert from given routines to be capable of acting even if the given structures and circumstances change: *"If a system is strongly rigid and structured, and then one component is missing, mostly the whole system will collapse. For this, informal acting can be helpful."* (I01).

A Semi-structured Mobile Reporting Concept

Decision making in crisis management depends on incremental written or mostly verbal on-site reports. The empirical results on current practices of emergency services show a need for improvisational action in order to get appropriate reports. Information producers in the form of on-site units are not always able to anticipate the needs of their counterparts in the control centres, so arising ‚information overload' or ‚lack of information' negatively affect decisions.

Control centres are mainly interested in impressions from the incident place supported by visual multimedia data to get remotely a situation overview. The cycle of semi-structured information requests and reports (Figure 1) visualizes the concept grounded on the empirically studied work practice. If the written or verbal on-site reports do not satisfy their needs, the control centre needs to have the option to actively articulate information needs. Currently this dynamic requesting activity is not supported: Using the radio verbally, the control centre complains about being flooded with information and the on-site units are left with much space for interpretations: *"The office-in-charge wants something done and then we have to understand what it means"* (I07). Therefore a mechanism which allows semi-structured information requests and does not leave space for interpretations could support their cooperation. Due to the fact that information needs vary from individual to individual, reports should be easy to specify for each user, and some context information always needs to be captured automatically: the coordinates of the location, the source and the time, which identify the information as a whole (IM03). These context data need to be available when looking at the information. By requesting or reporting information, the predefined hierarchical organisational structure has to be

considered, for example, the sub section leader is not allowed to send information to the control centre directly, because otherwise the section leader is skipped. On the other hand, the control centre is not allowed to request information from the sub section leader directly, because otherwise the section leader is skipped again.

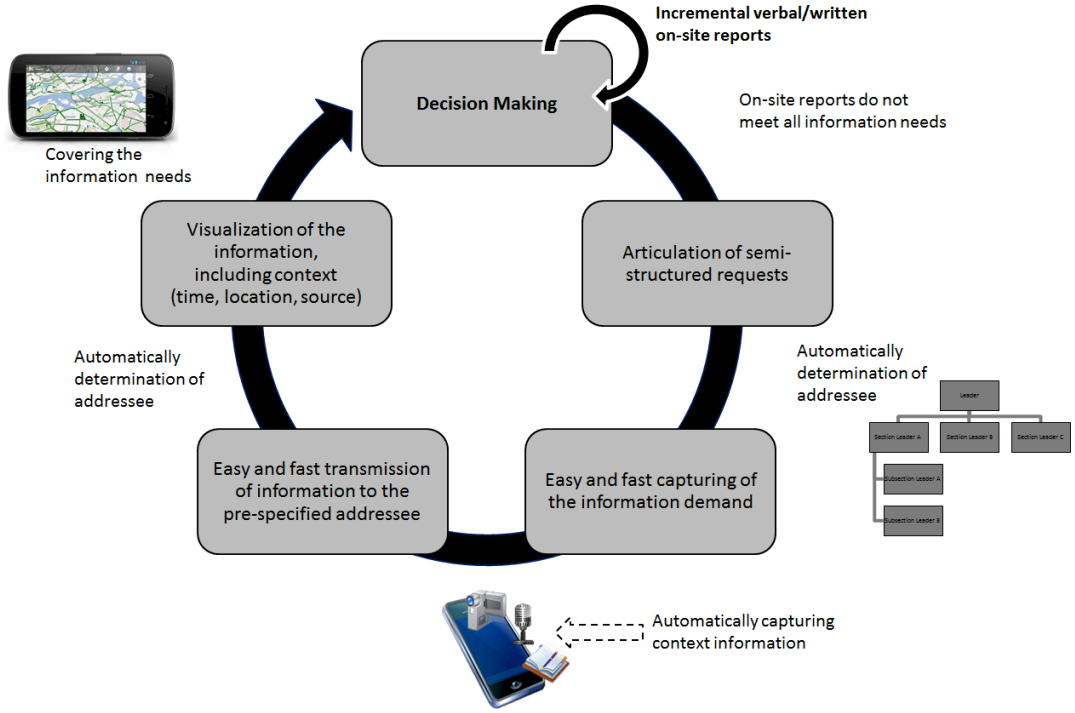

Figure 1: Supporting decision making through mobile semi-structured information requests

Determining addressees of requests needs to be possible by its location or role: Location-based requests give a location overview on all subordinates of which information can be requested, which enriches the awareness between the control centre and the on-site units. For role-based requests the addressee can be determined by its role (e.g. *sub section leader area 1)*. A supportive mechanism must be applied to smartphones as well as tablets to guarantee a proficient handling including following rights:

- *Requesting information* allows a response unit to fine-specify and articulate the kind of information needed. At this, transmitting a destination location for a remote-navigation of the unit and setting the priority for a more appropriate assessment of the task's urgency must be possible.
- The *independent sending of information* allows authorized units to send information, directly, without previous requests. For instance, this permission is relevant for section leaders, as their information does not have to be authorized anymore.
- *Sending information by previous request* allows a unit to send information by himself, but only as an answer to a previous request. This restriction should help to avoid ‚information overload' for decision makers due to information needs to be requested first.

Implementation of a Mobile Reporting Application (MoRep)

In order to verify the concept and research its effect we implemented a mobile application. By using Android 4 the application MoRep can be used on smartphones as well as tablets. The technical concept is based on REST architecture as form of the SOA-paradigm, where the services are implemented by HTTP-servlets. Using modern communication technologies, such as Google Cloud Messaging, innovative notification mechanisms are implemented that simplify communication and allow a parallel use to radio communication. In the following, the application MoRep will be briefly introduced.

Start up: After authentication, the user receives current information of his role and permissions. The main screen is designed according to these permissions. Figure 2 shows a user with all rights: Seeing reports, requesting reports from subordinates, answering requests made by superior as well as writing reports independent from previously request.

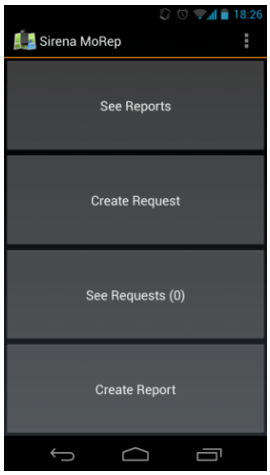

Figure 2: Main Screen

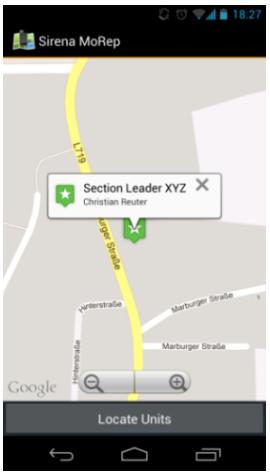

Figure 3: Localizing the response units

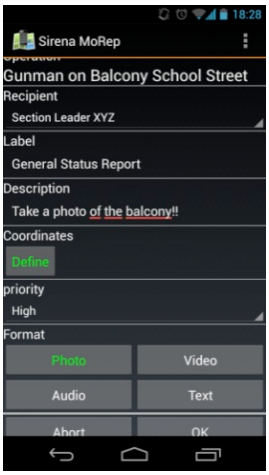

Figure 4: Request form

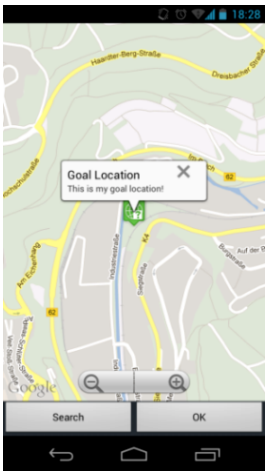

Figure 5: Determining the location

Requesting reports: When requesting reports, a location- and role-based determination of on-site units is possible. By the first option, the user can scan for subordinate response units (Figure 3), where the unit is displayed on the map characterized by role and name. By selecting the unit, the request form is opened (Figure 4). There the user has to enter specified characteristics and the desired format of a report. He has the option to define a destination location for the remote navigation (Figure 5). Afterwards the request can be sent. For role-based requests the recipient can be chosen from a combo box, where all the possible recipients are listed, from whom information can be requested, no matter what their location is.

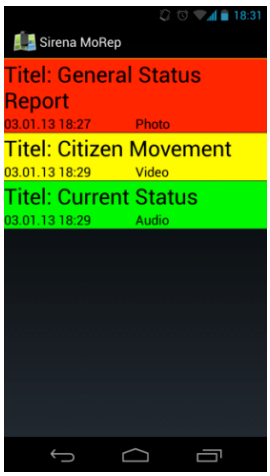

Figure 6: Request Overview

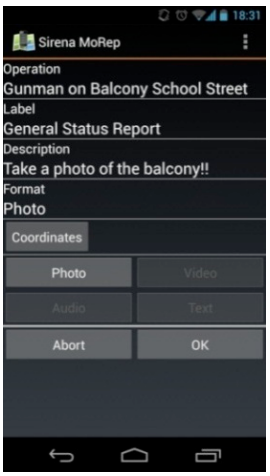

Figure 7: Report on Request (I)

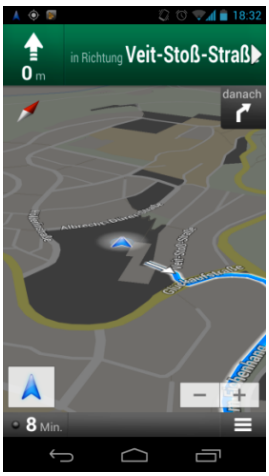

Figure 8: Target Navigation

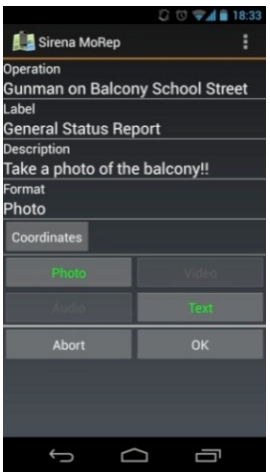

Figure 9: Report on Request (II)

See requests / creating report: In the request overview (Figure 6) open requests are displayed for the user sorted by priority and time. A request can directly be answered with a report, where a form (Figure 7) appears, in which the text fields have already been pre-determined by the creator of the request. If a target location was transmitted, the coordinates-button will be shown that offers the possibility of navigating to that location (Figure 8). By entering the format button, the standard application for generating files is opened; subsequent the text button is activated to make an optional text input (Figure 9). A report that is not based on a request can also be created from the main screen. In that form the recipient is immediately determined as the next superior unit.

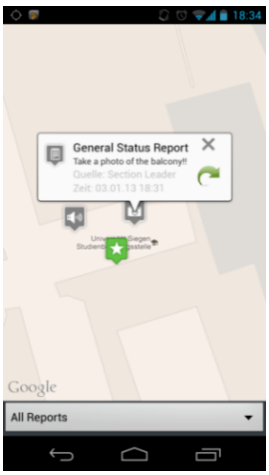

Figure 10: See Reports

Figure 11: Content of Report

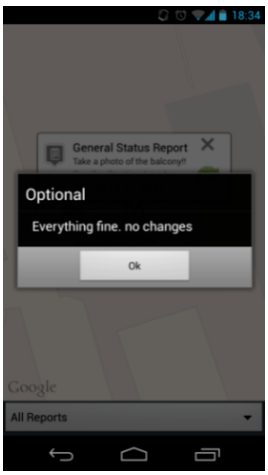

Figure 12: Additional Text

See reports: The main element is a Google Maps map (Figure 10), on which previously created reports are shown with icons that indicate the data format. The user can view all reports or only those he requested. It is also possible to add this view to any Geographical Information System using Web Map Services. In the information window

the source and time are displayed that, in combination with the geo-location, meet the criteria specified for suitable information (IM05). If it is entered, the content will show (Figure 11).The text symbol on the left side of the window indicates an additional text (Figure 12) the arrow symbol creates an easy forwarding of information to the superior.

Evaluation

Although our system had been fully implemented, IT security regulations and privacy and documentation concerns of the emergency response organisations prevented us from having an in-use evaluation. We evaluated with practitioners in police and fire stations how mobile dynamic semi-structured requests can support current decision processes by providing a high-quality information basis and avoiding ‚information overload' as well as ‚lack of information'. In order to evaluate the findings, concepts and our supporting tool related to the work practices we evaluated the prototype in a scenario-based walkthrough and following interviews. Again the participants were members of the police and fire department, but this time also volunteer emergency forces were included, due to these are potential end users as well (IM01, IM02). The evaluation sessions lasted in average 45 minutes and eleven persons from police and (professional and volunteer) fire departments participated in different sessions. With this selection of interview partners the impressions and experiences of communication partners on different levels within the chain of command could be gathered and evaluated.

Within each evaluation MoRep was introduced functionally and it was demonstrated how it could support in different situations by referring to operations mentioned by the interviewees in the empirical study. The demonstration was an interactive session, where the users directly explored the application. The participants were asked to make remarks using „thinking aloud" (Nielsen, 1993). After the demonstration, the participants were asked questions regarding the practice-oriented use, e.g.: What are possible implications of using semi-structured requests in emergency response? Under what conditions can the concept and application support current working practices? What are limitations concerning the usage? The workshops were recorded and later transcribed.

No.	County	Organization	Role	Control Centre	On-Site Leader	On-Site Other
IM06	A	Police Department	Head of Control Centre	X		
IM07	A	Police Department	Head of Section	X	X	
IM08	A	Police Department	Head of Section		X	X
IM09	A	Police Department	Executive Staff			X
IM10	A	Police Department	Executive Staff			X
IM11	A	Fire Department	Fire Chief, Administrator Control Centre	X	X	
IM12	A	Fire Department	Municipal Fire Inspector		X	
IM13	A	Fire Department	Volunteer Fire Chief		X	
IM14	A	Fire Department	Volunteer Workmanship			X
IM15	A	Fire Department	Volunteer Workmanship			X
IM16	A	Fire Department	Volunteer Workmanship			X

Table 3: Interviewees of the empirical study (phase 3): evaluation of the collaboration tool

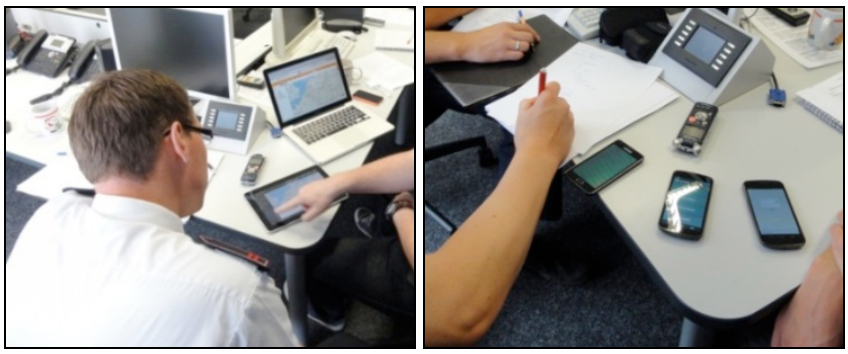

Figure 13: Evaluation of the mobile application in the fire department

Results

Using our design we were able to derive the impact of mobile dynamic semi-structured requests on improvisation work practices of decision makers and on-site units.

Extending articulation work with semi-structured mobile requests

The concept of semi-specified mobile reports as a consequence of dynamic, semi-structured information requests cannot cover major emergencies over their entire time, but it can easily be used for "*basic information and a common understanding of the situation*" (IM08). In contrast to phone calls, it is an additional way of communication and articulation, which can enrich reports with visual data (IM09). The mechanism of fine-specifying and requesting report demands was seen as very useful in case of insufficient reports. Therefore the decision makers have the option to enhance the routine reporting structure and informally request information. The on-site units have the duty to answer those requests (IM04). Requesting information by the units' localization as well as their role were important aspects to establish awareness between the spatially distributed units and to get an overview of the situation assignment of the units (IM07). By being able to determine units by their role was regarded as stress reducing, because the actors did not have to think about the correct addressee (IM08). Another important feature of applications that support the communication between on-site units and the control centre is the fast transmitting and forwarding of information. Being able to forward information to the superior was regarded as being one of the most important functionalities, which enriches the entire information flow (IM06, IM08).

Improving situation awareness through semi-structured requests

The handling of semi-structured information requests as one of the core concepts has two supportive dimensions: First, it supports local volunteer fire fighters that indeed know the location of the incident place, but do not necessarily have the experience in judging the importance of information for the control centre respectively the officer-in-charge and which information needs to be reported (IM06). Therefore semi-structured information requests provide and foster training effects. Second, semi-structured information requests

support professional units from other counties, who assess the importance of information better than volunteer units do, but who often – especially in large-scale emergencies – do not know the location. Therefore, the requests foster situational awareness of the units. For example, the head of the studied police station mentioned that they will have new recruits starting very soon and the majority of them are not familiar with the region. Thus, they will use their smartphones to navigate which is why transmitting locations is very important (IM06). They are already using GoogleMaps on private smartphones (IM10), wherefore "*introducing something different makes no sense, because everyone knows and uses GoogleMaps and it is up to date*" (IM11).

Taking organizational specifics and improvisational practice into account

The different leading structures of the police ("from the behind") and the fire department ("from the front") have an important impact on using the concept in the work practices during emergencies. At the police department, the control centre has the entire responsibility for an operation. For this purpose it maintains software, which manages the included actors and their dynamically assigned roles. Through this matching they have always an overview of the command and reporting flow (IM06), wherefore an automatic connection between those control centre systems and the mobile applications could easily be implemented to guarantee up-to-date role assignments and correct command- and reporting flows in the applications like MoRep. In contrast to the police departments, the fire departments in our study do not maintain such software systems. The officer-in-charge on-site has the entire responsibility for an operation and the control centre has just supportive task to the officer-in-charge. The control centre has the problem „*if I send him coordinates, then it is a process, where I directly influence the operation and you need to decide if that makes sense and on which level you have the permission to do that"* (IM11). It's not the control centre, but the officer-in-charge would use such mobile systems to support the communication between the on-site units, because he stays at a location while the other units are distributed around the incident site (IM11).

Enhancing debriefing with multimedia-based documentation

After an emergency the automatically saved requests and transmitted information can be used for the documentation *"where I need the timestamp and the content what happened. Right now there is no standard"* (IM03). This documentation could be the basis for debriefing of the past operations: *"Currently we use internet videos of photographers and information of journalists from the incident place for debriefing afterwards"* (IM11), because, except written reports, no other data for documentation or training exist.

Predefined communication path vs. improvisation work

Even though it was mentioned as very useful, that communication paths are predefined by the application, there were still doubts whether the on-site units will utilize this feature (IM07). Through the predefined command and reporting structure the concept is currently too static to cover all improvisational activities during emergencies. While on the one

hand the hierarchy of the police could be easily adapted to the mobile applications, on the other hand, there are still open issues and a need for action to the technical implementation and to maintain the actuality of the organisational structure of the fire department. But all participants were aware that mobile applications like MoRep only *"support an additional way of communication and that in case of emergencies you can still make a call"* (IM09), to guarantee options for high-flexible extensive improvisation activities.

Discussion and Conclusion

In emergencies, gathering the necessary information to generate a situation overview is crucial for emergency services to make informed decisions. The interplay between control centres and on-site units is an important information chain that is shaped by legal regulations (e.g. on notification and documentation duties) and professional conventions (e.g. reporting agreements). But in crises, the routines connected with these regulations and conventions do not cover all information needs: Situational aspects connected with the crisis require stakeholders to improvise and to engage in articulation work about information needs and resources that emerge as the crisis goes on.

There has been previous research on the technical support of response units on-site to share reports with control centres including multimedia data. But in some situations those reports were ignored (Bergstrand & Landgren, 2011) or disregarded, simply due to the sheer amount of incoming notifications (Wu et al., 2011). Applications such as DIADEM (Winterboer et al., 2011) or diretto (Erb et al., 2011) enabled the control centres to actively articulate information needs and request needed information. The requests were described by short text messages, which still left plenty of room for misunderstandings as with voice transmission.

In this paper, we explore the practice and necessities of articulation work with regard to the ad-hoc gathering of information in emergencies, and suggest and evaluate an interaction concept involving semi-structured multimedia reports. In our empirical study on current work practices of emergency services with regard to collaboration in situation assessment and decision-making activities, we could establish that the spontaneity and volatility of emerging information needs on all sides pose a significant challenge to communicate them accurately as well as to provide accurate feedback. Existing practices show that, in order to cope with requirements like time-criticalness of feedback or reliability of information, a set of framing conditions needs to be addressed when developing technological support:

- *Targeted requests:* The missing information in a decision situation is often very specific to a location, a critical infrastructure or another situational aspect. These specifics of information needs have to be articulated and understood.
- *Trusted reports:* Decisions in the control centre may affect lives of crisis victims and may have legal consequences. Therefore, staff members require high quality information for the specific decision in-situ, which cannot be secured in terms of

technical information quality only, but also in terms of trust, which is established through the professional expertise of the source creating the information.

- *Documented action:* To enable debriefing and provide material for training purposes the requests as well as the reports have to be documented.

It is important to note that these framing conditions may lead to conflicting information quality requirements in a concrete situation: The faster reports may come from an information source with a lower expertise, and the report from a trusted information source may not be available fast enough to inform the decision-maker at hand. As a result, not only time, location and content type of information are important metadata for requests as well as report interactions allowing an easy interpretation and assessment of the content, but also role, contact data, location and experience of the person providing the feedback. Documentation and interpretation needs may be addressed by establishing a content structure for request and report messages that relates to professional signs and languages of the emergency response service and that allows free comments. The interpretation of information in the context of a specific decision may turn out to be a collaborative effort requiring additional interactions.

We developed, implemented and evaluated an interaction concept using semi-structured request and reports based on Android devices, and allowing location-triggered as well as role-triggered interactions (MoRep). The feedback we got from practitioners using the prototype confirmed that the suggested content and metadata structures would improve the expected information accuracy and quality. But it also revealed further side aspects of organising this interaction, for instance the material that would be gathered may help improving debriefing processes and educational initiatives.

In particular, the organisational structures and coordination strategies influence information needs and interaction details. In some cases it is required to delegate and forward information requests to people who are even closer to the site of interest in a documented, traceable way. The police with their ‘leading from behind’ coordination strategy has a more static role and responsibility structure and the direction of the main information flow is towards the control centre, whereas fire fighters with their ‘leading from the front’ coordination strategy have changing roles and responsibilities on-site, and an information flow directed mainly to the on-site coordination. Request and report strategies of our prototype need to adapt to these differences by maintaining the organisational and information structure. In the long run, these predefined information structures also carry a notion of potential information needs to all forces involved in the interactions and may also raise the general awareness on information necessities.

Our research efforts described here are part of a larger research initiative to improve the *collaborative resilience* (Goldstein, 2011) of and in critical infrastructures. In contrast to many crisis management approaches in the field of IS and HCI, we do not aim to further capture and refine holistic process representations or to extend sensor data collection and visualization to be better prepared for crises, but rather to improve improvisation capacities in crises by addressing smaller ad-hoc collaborations we found to be important to practitioners. We believe to have found an interesting one here, and would now further explore its integration into new emerging technological and

organisational infrastructures like the German emergency service digital radio network ('BOS-Digitalfunk') or recent inter-organisational infrastructures for coordinating regional crisis management work (Ley et al., 2012).

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