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Jobst Löffler
Markus Klann (Eds.)

Mobile Response

First International Workshop on Mobile Information Technology for Emergency Response, Mobile Response 2007
Sankt Augustin, Germany, February 2007
Revised Selected Papers

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Volume Editors

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Preface

The interest in mobile information technology for emergency response (ER) comes from the simple fact that an important part of this work is done in the field. With little or no infrastructure to rely on, ER operatives have to make do with the tools they bring along. Of course, ER organizations build, invest in and do rely on infrastructure for their operations and this includes sophisticated stationary information technology. The systems used for dispatching ER units are a good example for this. While such systems are very important to support strategic planning and decision making, the effects of emergency response work eventually have to be created on site. And this includes both obtaining the information required for taking informed decisions as well as implementing decisions through targeted actions in the field. All of this is of course not new. The trade-off between responding quickly with the available resources to the situation at hand and responding with more deliberation to strategic goals and constraints is not inherent to the use of information technology but to responding to emergencies in general. What is new is that current and foreseeable innovations in mobile information technology have the potential to offer substantially better support for emergency response field work, resulting in better solutions for this trade-off. By providing better gathering, communication and processing of relevant information between all actors involved, we believe that mobile information technology can be a valuable tool in the hands of ER professionals to increase the speed, precision, efficiency and effectiveness of their operations.

But we are also aware that new technologies not only solve problems but frequently create new ones. Examples in this case are reliability, dependency, and the need for adapted operational procedures, to name but a few. So it is because of this double characteristic, the great potential benefit that usable mobile IT could yield in the domain of emergency response and the specific design challenges for such technologies in this particularly unforgiving domain, that we decided to create a new venue for researchers and practitioners from different disciplines and backgrounds; a venue for a focussed exchange on how mobile information technology can be effectively used to the benefit of ER.

The call for papers for the first Mobile Response workshop attracted over 30 submissions from 13 different countries, including international submissions from Australia, Brazil, Japan, Korea and Russia. An international Program Committee with experts on mobile information technology, ER, and ER equipment selected 16 submissions for presentation during the workshop, which was held February 22–23 at Schloss Birlinghoven in Sankt Augustin, Germany. These presentations offered not only an interesting overview of how different disciplines address the design of mobile IT, but also provided insights into the perspectives from different countries as well as the different perspectives of scientists, industrial representatives and practitioners.

The workshop was concluded by a panel discussion on some of the points that had been raised during the presentations, three of which we would like to briefly present here. Firstly, the relation between standardization and innovation was discussed. It was pointed out that standardization might help in building solutions from well-proven technologies and that it would also foster interoperability which is of particular importance for international cooperation as well as for creating bigger markets. On the other hand, it was stressed that standardization can become a severe obstacle to innovation. Especially for a quickly developing field like mobile IT it is important to maintain sufficient space for innovation. Secondly, the question of how all the information that might be obtained from mobile information technology could be made accessible and usable in something like a joint operational picture was discussed. It was stressed that not all the information is needed by everybody, but that specific actors need information that is relevant for their current task, corresponding more to a common relevant operational picture. It was pointed out that the concept of situational awareness is likely to be helpful in understanding what information is actually needed. Thirdly, the importance of understanding and designing for the actual work of emergency response professionals was stressed. This includes considering everyday problems and informal processes that might not be visible at first glance. Jokingly, one ER professional remarked that it is insufficient to paint some system red to turn it into a solution for fire services. On a more serious note it was stressed that empirical studies to understand the actual work and needs of ER professionals is one of the weak points of current research and development that needs to be extended.

We would like to thank the members of the Program Committee who were very helpful in attracting attention to the event and reviewing the submissions. We would like to thank everybody who was involved in the preparation of the event, particularly our colleagues from Fraunhofer IAIS and Fraunhofer FIT. Most importantly we would like to thank everybody who submitted papers to Mobile Response 2007, all the presenters and all the participants who contributed to a lively and intriguing exchange during the event. Special thanks go to our keynote presenter Kees Nieuwenhuis, who not only gave a most interesting talk, but was also kind enough to promote our event in the ISCRAM community. Finally, we would like to thank the European Commission for their support to the EU projects Share and wearIT@work and for providing us with the context to organize this event. We plan to continue with Mobile Response in 2008 and would like to invite everybody interested to check www.mobile-response.de for announcements on this event.

March 2007

Jobst Löffler
Markus Klann

Organization

Mobile Response 2007 was organized by the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS and the Fraunhofer Institute for Applied Information Technology FIT.

Organizational Committee

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Team Support

Geospatial Information

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Abstract. Improving our knowledge of and capabilities to handle disasters and crises is not simply a matter of more information processing and more reliable communication and computation. It needs the exchange of information between many different scientific and technology disciplines and a much better understanding of engineering complex C4I systems-of-systems. This discussion paper will address the need for and purpose of an international community and how to obtain focus and transfer of scientific results.

Keywords: Decision Support, Crisis Response and Management, crisis taxonomy.

1 Introduction

Even without understanding any of the details behind terms like disaster management, crisis management, crisis response and command & control, most people can claim to have some basic understanding of what managing a disaster or a crisis may encompass. They would be able to explain that managing for example a major road accident or airplane crash is a process which involves many different organizations, working together with some common intent and that there is a need to share information and, based on that information, decide on something to do with the purpose of improving a situation that got out of control.

In 2003 a number of scientists from different organizations decided to set up an international community to stimulate the exchange of views and information on the design and use of information systems for crisis response and management. It was appropriately entitled the ISCRAM Community. Muray Turoff and Roxanne Hiltz from the New Jersey Institute of Technology, Bartel Van De Walle from Tilburg University and Benny Carlé from the Belgium Nuclear Research Centre were among the initiators. Already working together with researchers and professionals from many institutions and for many years, the realization that more and continuous communication over a broad range of scientific and technology disciplines and with the professionals of disaster prevention, response and rehabilitation, translated into establishing the ISCRAM Community. ISCRAM is (to be) for scientists what TIEMS (The International Emergency Management Society) is for professionals in the field of disaster and crisis management, but with a focus on Information Systems aspects.

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1.1 Purpose of the Community

ISCRAM wants to promote research in all relevant scientific fields, from computer science, information science, economics, business administration, cognitive science and many more. But the purpose of the ISCRAM community is to apply a context or focus by formulating and addressing question from a particular application domain, namely disaster and crisis management. At the same time, we also want to promote the development and deployment of information systems that use the results of the research and discuss the experiences of the professionals that use these applications. Feed back from the field is of vital importance and can help us direct future research in multiple areas of knowledge and technology.

The community is also the mechanism to facilitate and promote cooperation between scientists, the institutions that they work for and the researcher from for example industrial research departments and technology providers. And of course across the globe. It will allow people with similar interest to collaborate but it will also facilitate the much needed multi-disciplinary approach.

And last but not least, because the community also counts solution providers and end-users among its members we explicitly address dissemination and establishing a conduit from research-to-market. Which helps us to show that there are clear societal and economic benefits form the scientific labor that is put in research in many different disciplines.

1.2 Organizing Exchange, Dissemination and Transfer

To promote and facilitate research and the exchange of information between scientists and professionals, the ISCRAM community deploys several methods and tools.

The yearly International ISCRAM Conference is probably the most noticeable tool at the moment. It started in 2003 with a 2-day workshop in Brussels, but already the following year obtained its status as an international scientific conference. The predicate ‘scientific’ is important, especially since the domain of disaster and crisis management is not a field of science. Care is taken that the yearly conference, traveling between Europe and the United States, is a recognized platform for young and experienced scientists to present their best work and get it published in the proceedings. However, the conference also wants to provide a platform for professionals and their contributions via papers and presentations in which their experiences and needs are presented to the academic researchers.

Other tools are the workshops and special Emergency Management sessions at other conferences. They address the need for in-depth study of specific topics or special parts of the user community.

Also a yearly event is the ISCRAM-TIEMS Summer School that targets young researchers, PhD students in particular from various disciplines. The Summer School offers them the chance to learn about the field of disaster and crisis management from experienced researchers and professionals and learn how their own research can contribute to solving problems in this domain.

Finally, the web-based environment www.iscram.org offers community members access to its members list, proceedings and papers, book reviews and a mailing list. It helps to establish contacts, by acting as ‘who-is-who’ and collaboration.

2 The ISCRAM Community

Membership is open to all that have an interest in studying disaster and crisis management from different angles. From 2003 to 2006, membership has grown to more than 800 people, from graduate and PhD students, to senior researchers but also including professionals such as fire fighters, police, medical emergency staff and government officials. Therefore, the community is not only a scientific community but also a community of practice. As indicated in figure 1, members are spread across the globe and their number is still growing.

Fig. 1. Distribution of ISCRAM community members over the globe

Apart from disseminating the results of scientific research and experiences with the application of these results, an important goal is to help define further programs and projects and action plans on a national and international scale, for scientific and technology research, and stimulate collaboration between researchers of different disciplines. The aim is to get a better grip on both the impacts of disasters and crises on society and the specific context or circumstances in which they need to be managed. And because of the many different disciplines involved, we need to develop a 'common understanding' that helps us to communicate across disciplines and specializations.

2.1 A Simple Crises Taxonomy

For many experts from many different fields and expertise areas to communicate effectively and exchange information and views, some form of common understanding is necessary, at least within the ISCRAM community. One way of starting a discussion on the subject of a common understanding, is to define and share a simple and fairly abstract crisis taxonomy.

The three main structural elements proposed here are to differentiate between man-made disasters, natural disasters and pandemic disasters. The reason for putting pandemic disasters in a class of their own is because in contrast to the other two, they will not allow us to restore the before-disaster situation. And thus, while the response is in progress, we need to plan ahead for a new society.

Describing their differences in terms of a number of features will help us to understand them as context for our problem definitions and problem solving. The purpose of this classification is therefore not an analytical one, but to define the scope of the problems that we need to focus on, the information system requirements that we need to address and the context in which solutions for (perceived) problems can be validated. As indicated in figure 2, the use of such a taxonomy should allow for specific incidents to fall in two or even all categories, i.e. develop different characteristics while they evolve.

A first set of differentiators could be the following:

- **Predictability and risk assessment:** The models and the reasoning techniques that are available and their reflection on the information systems for the phases of the management process
- **Organization infrastructure:** The organization infrastructure availability, reliability and robustness during the phases of the management process
- **Communication infrastructure:** The communication infrastructure availability, reliability and robustness during the phases of the management process
- **Information infrastructure:** The same for the information infrastructure.
- **Management goals and 'commanders intent':** Depending on the sort of crisis, the management objectives are different and impact the so-called 'commanders intent' which in turn impacts the requirements for the information systems and the context in which they have to operate.

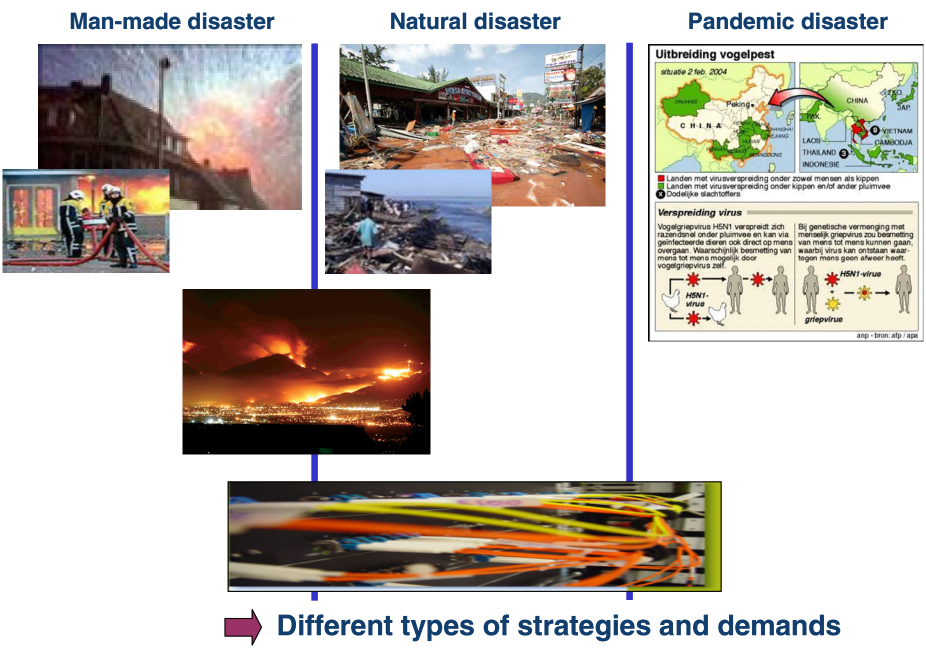

Fig. 2. A simple crisis taxonomy to structure discussions

As stated in the beginning, the views presented here are aimed at starting a discussion within the community and can thus be defined as 'work in progress' on the foundations of ISCRAM. They have nothing to do with scientific research on disasters themselves.

2.2 Common Concerns

From an operational view, the disaster and crisis management process is often described in a sequential way by a number of steps that impose their own specific requirements on the information systems for their support. This process description is common to all three elements of the taxonomy introduced.

A step-wise process description that is often used in the ISCRAM community is the following:

- **Detection:** the process concerned with searching the environment for key features of an incident of a particular nature
- **Assessment:** the process of building situation awareness and trying to classify and quantify an observed incident
- **Alerting:** planning for a step-wise increase in detection and assessment with the aim to respond
- **Mitigation:** planning the first response and the necessary scaling up
- **Response:** scheduling (and re-planning) to actually engage resources to contain the incident under severe time-constraints and uncertainty
- **Recovery:** planning and scheduling for rehabilitation

One process step that does not fit well with the step-wise approach explained before, but which is vital for the quality of all these process steps, is

- Training.

Training at the operational, tactical and strategic level focuses on the preparedness of the humans involved in the overall process. It has two important links with the information systems that are the main concern of the ISCRAM community: first, for training we need specialized information systems and, secondly, training involves the use of the information systems that we need for the different steps described above. Therefore, training also needs to be addressed as a common concern.

2.3 Disciplines Involved

As for the scientific and technology disciplines involved in further investigating and elaborating on ISCRAM, a projection of the background of present ISCRAM community members already includes: computer science and technology (from computational techniques to AI), communication science and technology (from telecommunication to information distribution and security), information science and technology (from information modeling to knowledge extraction), the human sciences (from psychology, sociology, anthropology to cognition), operational research and business science etcetera.

The list can be made longer, but already indicates that advances in the domain of disaster and crisis management are, by necessity, based on a cross-disciplinary approach rather than a mono-disciplinary one. Still, the well known methods of research: fundamental research, applied research and empirical research, apply. In fundamental research we can distinguish two basic approaches: a theoretical or model based approach and an experimental one. In the first we calculate and analyse and in the second we capture and analyze. In Applied research we can distinguish between the use of controlled experiments and prototyping or simulating (and capture and analyze the data). The use of these two methods is well embedded in the ISCRAM community. The third method, empirical research, is also well known in this domain. Here we can distinguish between controlled reality experiments and dedicated exercises. Not withstanding the excellent research projects in which this method is used, I would argue that it is under-valued especially by the professionals in the field. There are many good reasons for not using this method, especially political and practical ones, but there are also excellent reasons for its use and work to overcome the difficulties associated with it. And to name the one that is most important in the authors view: research in now-time can be used for demand articulation.

3 Some Thoughts on a System Architecture

Looking at the disaster management and crisis management process in the real world, it is clear that it involves two sorts of information processing entities: the humans and the computer based systems. This is also clearly reflected in the research that is presented by members of the ISCRAM community. However, in most discussions, we are still stuck with the traditional view on information systems as the ‘silicon based’ and engineered partition that is ‘used by’ humans.

It is time to shift gears and to redefine the notion of an information system so that it can include also humans and thus forces us to investigate the use of for example human cognitive capabilities with as much vigor as the use of AI-techniques, in the context of crisis management. This implies that we define a new paradigm from which to derive requirements for new architectures for information systems for crisis response and management. The paradigm proposed is that of Actor-Agent Communities. The actors refer to the human (or carbon-based) information processing entities or systems. And the agents refer to the software (or silicon-based) entities. The use of the word ‘communities’ reflects the notion that an information system for crisis response and management is, at any given moment in time, a dynamic configuration of collaborating and therefore interacting entities of the two sorts, but with emergent properties that are not all defined at design-time.

A number of issues emerge from this paradigm that must be addressed at the architecture level, such as communication, shared awareness, collaborative decision making, the construction of systems-of-systems, the construction of organizations-of-organisations and coordination and autonomy. This list is not complete, future research will set the scope by adding more issues that need to be addressed in a multi-disciplinary way.

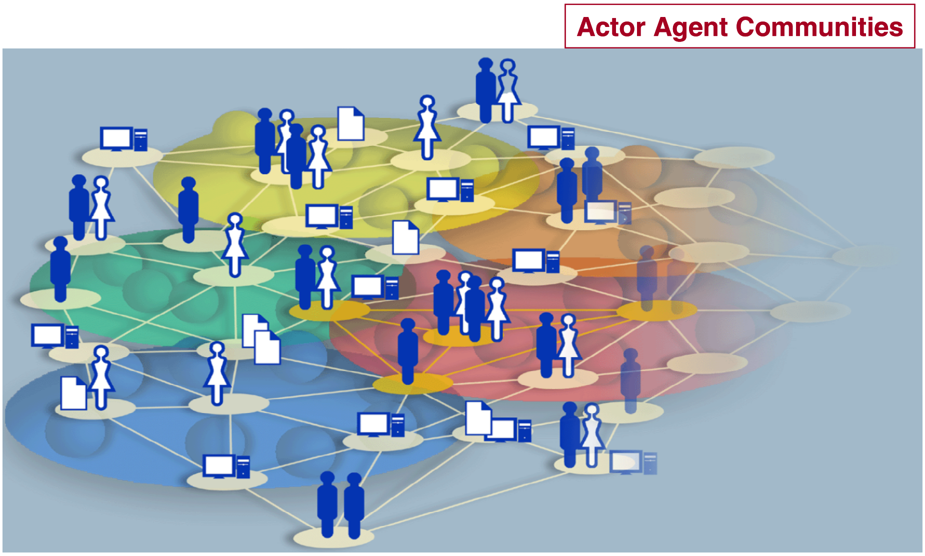

Fig. 3. A new paradigm for complex information systems, including human processing

4 Conclusions

As stated in the abstract, this discussion paper is not scientific in nature. It does not elaborate on a theoretical model or tries to validate a scientifically interesting hypothesis. It reports on a number of ideas to improve the transfer of scientific results in multiple fields to a particular application domain: disaster and crisis management.

The paper presents the ISCRAM community as a viable method to increase the use and rate of transfer of better concepts and technology from the domain of science to the domain of application. It presents a case for a new system paradigm, as a starting point for the investigation of new information systems architectures for use in the particular complex and demanding use domain of crisis management. It also presents a simple crisis taxonomy as a tool to guide cross-disciplinary communication and collaboration.

Future work will focus on elaborating on the taxonomy and its practical application and how to measure the effectiveness. And on providing the scientific foundations for the AAC paradigm. The paradigm defines a complex information system as a network of autonomous information processing entities that collaborate. Two types of entities are distinguished, the humans, often referred to as the-people-in-the-loop, and the agents or engineered information processing systems. The collaboration context is named community to indicate that the system properties come from both designed-in and emergent behavior through interaction of the entities. The paradigm prompts for the investigation of a whole new string of multi-disciplinary research activities and technologies and techniques to be developed, such as how to interface and connect human and AI-based decision making processes and algorithms, and how to transform existing software based information systems into autonomous software agents and what system architectures are suitable to support the construction and use of AACs.

And what (supervisory) control methods and techniques do we need to constrain the function, performance and operational behavior of a dynamic AAC-type system?

In support of the relevance of those and other questions, consider for example that in the domain of the software based information systems the use of the OODA loop (or derivatives thereof) is generally accepted and appears also in newer concepts such as Network Centric Systems and Network Enabled Capabilities. In humans however, recent literature on for example Naturalistic Decision Making makes more and more reference is to a different cycle in humans and human decision making which can be paraphrased as Observe-Match-Act. Not only is the Observe used in the context of OODA not similar to the Observe used in connection with humans, because human observation is subject to a filter at the input ('we see what our thoughts allow us to see'), whereas in engineered information systems we typically apply the filtering at the output of the observation. But the whole structures and meaning of the steps in these two loops are not at all similar. An implication is that in an AAC we simply cannot rely on superficial similarities between humans as sensors and sensors that transform some physical signal into a stream of digits.

And than there is the question of design methodology and accompanying methods and tools to design, build and operate AACs. And the business models, infrastructures and standards that we need, if only to mitigate the risks involved in building and using such systems. In short, the paradigm is the doorstep that leads us to the next level of the use of Information Technology for complex information systems that have to operate reliably in chaotic environments, but the place that it gives access to is still mostly uncharted.

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Aspects of Anatomical and Chronological Sequence Diagrams in Software-Supported Emergency Care Patient Report Forms

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Abstract. Across Europe emergency physicians are still using paper-based emergency report forms to document medical procedure at accident scenes. The forms are quite similar, but they differ in certain parameters or attributes. There are ongoing endeavours to combine the paper-based protocols and then transfer this new protocol standard into a software-based Emergency Patient Care Report Form (EPCRF). However during the transformation from a paper-based to an electronic solution, many problems occur. To keep the users' acceptance of the emergency medical services personnel, it is crucial that electronic EPCRF supports the central process efficiently. Therefore key elements within the emergency report form are the anatomical diagrams and the chronological sequence diagrams. These diagrams allow the emergency physician to track and record patient's parameters in a very fast and understandable and user friendly way.

Keywords: Emergency patient report forms, chronological sequence diagram, emergency, patient record.

1 Introduction

In the last decade, more and more countries have made an effort to change the way of logging and recording data in medical emergency situations. The intention is to create a new European standard with a common record set to ease the documentation evaluation, and processing of the medical emergency patient data and to replace the paper-based emergency patient report forms with software-based solutions running on rugged hardware setups.

For example the 'European Emergency Data Project' (EED) [1] is a research project supported by the European Union (Twelve participants; Belgium, Denmark, Germany, France, Finland, Great Britain, Ireland, Italy, Portugal, Sweden, Spain and Austria). The project aims to filter similarities between the different European medical emergency systems with the intention to make them comparable. The 'Hesculaep Project' [2], another project supported by the European Union, works on the standardisation and coordination of European medical emergency systems to increase the quality of medical procedures in emergency situations [3]. Both projects have in common that they homogenize medical emergency procedures and quality

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assurance of documentation. Due to critical time schedule of emergency situations and the above mentioned goals, the use of information technology is absolutely necessary to ensure that data is being recorded and processed in time.

This paper presents a general survey of graphical elements used in medical emergency report forms and the advantages of their software-based equivalent. These elements (graphical controls) implemented in a software system represent a major leap forward regarding the quality as well as the usability and acceptability of these reports. To conduct a thorough evaluation of the report forms being used in Europe, report forms of 23 European countries (73 organisations) were collected and now a collection of 49 different protocols are available within the Collection of European Emergency Protocols (CEEP)[4]. The evaluation has shown that in a high number of report forms anatomical and sequence diagrams are central elements supporting the workflow.

2 CANIS

The goal of the research project CANIS [5] - Carinthian Notarzt (emergency physician) information system - is the establishment and optimization of the information stream between the emergency rescue vehicle (ERV) / emergency rescue helicopter (ERH) and the receiving hospital. CANIS is to be realized through the development of an emergency-relevant, mobile and standardized protocolling of all medical relevant events. This includes all clinically vital parameters that vary from the norm at the scene of the accident as well as during the transport to the emergency room.

Table 1. Rugged devices

Device	Hammerhead RT	Toughbook CF-18	Gotive H42
			
Dimens.	280 x 210 x 41 mm	271 x 49 x 216 mm	230 x 94 x 34 mm
Weight	2,17 kg incl.batteries	2,1 kg incl. batteries	580g
Display	1024 x 768 (XGA) 10.4” transmissive active matrix colour TFT with Touch-screen (Digitizer or pressure sensitive)	1024 x 768 XGA 10.4” trans-missive, anti-reflective and outdoor-viewable active matrix colour TFT with Touchscreen (Digitizer or pressure sensitive)	640 x 240(HVGA)6.2” Touchscreen(Stylus-Pen)
Ports	USB, PCMCIA Type III	USB, PC Card Type II / III Secure Digital Card (SD)	USB, SD Card Slot, CF Card Type II Slot
Wireless	Wireless LAN, GPS, GPRS, Bluetooth	Wireless LAN, GPS, GPRS	GSM/GPRS, GPS, Wireless LAN, Bluetooth

Within CANIS an evaluation process of feasible hardware setups has been carried out. Because of the possibly rough working environment, the hardware for an electronic EPCRF system has to meet certain requirements, e.g. standards such as the IP Rating, Military Standard (MIL-STD), Military Specification (MIL-SPEC), or the National Electrical Manufacturer Association (NEMA). When working in a medical environment, the minimum requirement is an IP Rating of IP54 which means the device has to be resistant against water, dust, shocks and vibrations, a so called ‘rugged’ device. It should be able to integrate the devices into either the emergency rescue vehicles or into a special medical suit for the physician.

Three different devices have met the rugged environment requirements and represent the best possible solution at this time (Table 1). There are two Tablet-PCs (Walkabout Hammerhead RT, Panasonic Toughbook CF-18) and a Windows Mobile 5 Device (Gotive H42).

The Gotive H42 is available with features like Bar Code Reader, Smart Card Reader or Finger Print Reader (interesting from a security point of view).

When considering ‘wearable computing’ the Gotive H42, as well as some other PDAs can be integrated into a special environment suit for the medical personnel. As an extension for such a suit, a head-up display can be used to visualize the display content of the PDA (Fig. 1). Another extension could be the integration of speech recognition to navigate and control the program. This would be a hands-free approach and could be an advantage for the physician.

Fig. 1. Integrated medical suit with head-up display

3 Emergency Report Form Evaluation

3.1 Collection of European Emergency Protocols

Almost every country in Europe has its own paper-based EPCRF. They are all quite similar and show a structural compliance, but they differ immensely in certain details. All evaluated forms refer to the following hierarchical information structure with a depth of 3 (Fig. 2).

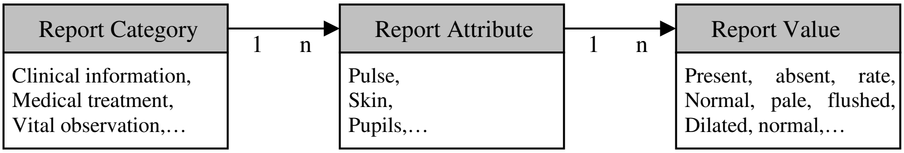


Fig. 2. Report category hierarchy

Table 2. Report categories

	Report category	Report attribute
1	Mission related data	Administration data, insurance data, statistical data
2	Incident information	Date of call, time of call, incident location
3	Clinical information/vital observation	GCS (Glasgow Coma Scale), pupils, skin
4	Medical treatment/measurements	Defibrillation, medication
5	Results and transfer data	Injury assessment on handover

The evaluation has identified strong correlations within the report categories, which are listed with examples below:

The most important part of the EPCRF is the medical treatment/measurement section. All measures taken have to be recorded in this section. The condition of the patient, measured values, pharmaceuticals, complications and many more are recorded chronologically.

3.2 Anatomical Diagrams

Injuries are an important part of the patient's state of health and need to be documented. To achieve this in a clear and easy way, graphical elements or areas (e.g. draw of a human body) are provided inside the forms. The various injuries are represented by characters (Fig. 3, 4), free text description fields (Fig. 5), or symbols (Fig. 6).

The visualization of an injury allows a very fast overview of existing injuries. The physician is able to evaluate the injuries by taking a look at the graphical presentation. In 22 of 49 protocols graphical elements to illustrate injuries are already implemented. However the existence of graphical elements does not automatically improve the quality of the information. In some report forms there are, for example, no segmentations of the anatomical figure or no symbols for certain kinds of injuries and most of the symbols are not used consistently. The ⊗ - symbol, for example, is used for fractures, wounds and burns. The standardisation of these symbols is essential for the establishment of a European EPCRF.

Table 3 shows a possible recommendation for the consistent usage of symbols for the illustration of injuries. When creating symbols it is important to have in mind that the symbols are interpreted differently by different cultures (with the exception of the burn symbol).

Table 3. Injury symbols

Characteristic	Symbol	Description
Fracture	//	Fracture includes both open and closed fractures.
Burn	🔥	Damaged tissue, as a result of impact of heat (burn) or impact of cold (frostbite).
Wound	⊗	This category includes all types of wounds, surface injuries and fissures.
Pain	●	The category pain describes injuries like embossments, tumours, contusions and luxations.
Amputation	~	Separation of a part of the body.
Acroanaesthesia	□	

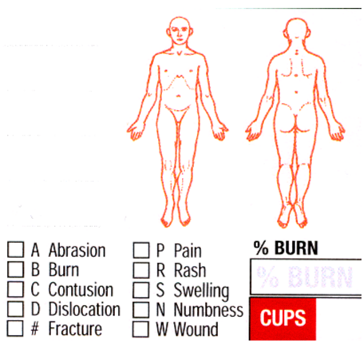


Fig. 3. Illustration of injuries (Pre-Hospital Emergency Care Council, Ireland)

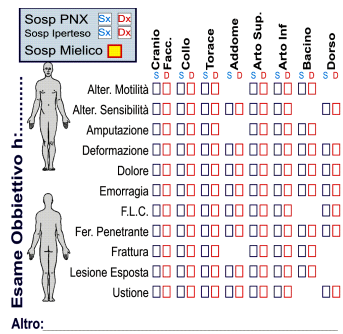


Fig. 4. Illustration of injuries (Soccorso Sanitario Regione Lombardia, Italy)

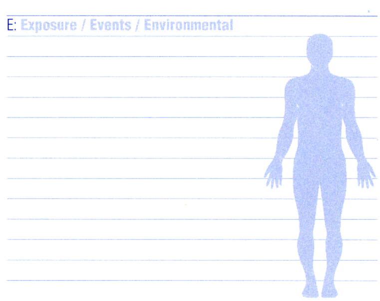


Fig. 5. Illustration of injuries (Ambulancezorg Limburg, The Netherlands)

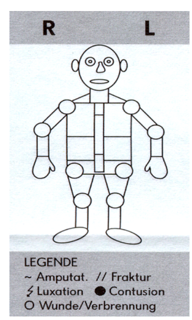


Fig. 6. Illustration of injuries (Red Cross Austria, Vorarlberg, Austria)

An example screenshot of an anatomical graphical control (part of a software-based emergency system, developed within the research project CANIS) is shown in Fig. 7. It demonstrates a topographical illustration to document injuries used with either Tablet PCs or Windows Mobile-based Pocket PCs. Six different categories of injuries can be described by a simple drag-and-drop of symbols to the appropriate regions. Additionally a differentiation between the front and the back of the bodyisavailable. Overall there are 52 regions available, which mean that there are 6^{52}

combinations possible. Even with detailed classification and multiple regions it is relatively easy to get a quick overview of the situation.

The following features have to be implemented:

- Different symbols for either different visualizations (Tablet-PC or PDA) or different countries.
- Gender-neutral illustration
- Different possible segmentations/granularity
- Drag-and-drop functionality
- Speech recognition support

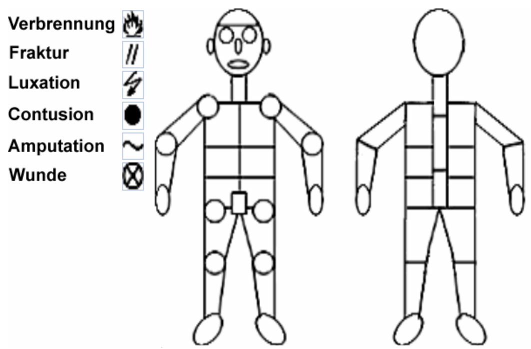


Fig. 7. Illustration of injuries, available body regions (CANIS, Austria)

3.3 Usability of Anatomical Diagrams

An important factor of an anatomical diagram is the way the illustration of the human body is done. It should be clear and well-structured and therefore intuitive to use. Every detail of the illustration has to be large enough to ensure that a selection either by finger or by pen is possible. The selection of the symbols should be capable by “select and use” and by “drag-and-drop”. To ensure a clearly arranged body illustration, the clickable regions should be bigger than the symbols.

Of course, the acceptance of such a control element depends on the screen size and resolution of the device. On a Tablet-PC it is absolutely easy to use just by using your finger, whereas on a mobile device the user has to use a stylus to hit the designated areas.

3.4 Sequence Diagrams

Another important aspect within the EPCRF is to increase the usability and to simplify the recording process of the chronological sequences of medical treatments and/or the administration of medicine. A sequence diagram allows the physician to record parameters like medical treatments, complications or vital parameters. This is quite a good method to observe the patient’s health condition during medical treatment even if it lasts for a longer period of time.

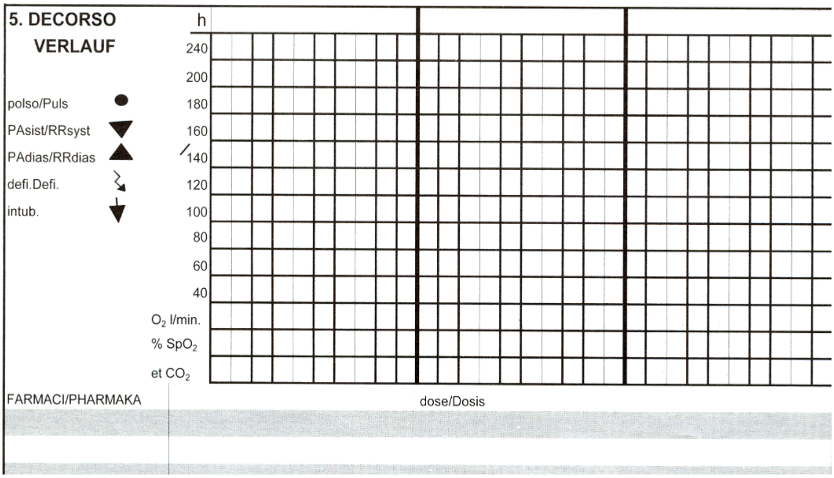


Fig. 8. Sequence diagram (White cross, Italy)

Table 4. Sequence diagram symbols

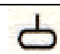
Characteristic	Symbol	#	Occurrence
Pulse	○ ● X	4 8 1	**13**
Blood pressure	∨ ∧	12	**12**
Defibrillation	↯	9	**9**
Intubation	↓ T	7 1	**8**
Cardiac massage	 ♥	6 1	**7**
Transport	T-T	5	**5**
Controlled (artificial) respiration	● I/\/\/\/I ○/\/\/\/○	1 1 1	**3**
Extubation	↑	3	**3**
SpO_2	●	1	**1**
Breath frequency	○	1	**1**
assisted respiration	⦿	1	**1**
Take over	X-	1	**1**
Transfer	-X	1	**1**
Exitus Letalis	+	1	**1**

Fig. 8 shows an example of a paper-based sequence diagram. On the left hand side of the sheet the available symbols are listed, whereas on the right hand side the physician is able to record for example the administered medicine. Further notes can be taken in the pharmacy section below.

But with the growing number of symbols and values during medical treatment, the sequence diagram on the paper becomes more and more complex and therefore less useful.

Unlike the symbols for injuries, the sequential diagram symbols are quite standardised (e.g. the symbol for blood pressure). A list of all symbols of the available European protocols is shown in Table 4 sorted by frequency of occurrence.

A software sequence diagram control allows the user to adapt the timeline and therefore allows the user to zoom in and out to keep the details in view. Fig. 9 shows an electronic sequence diagram which meets the following requirements:

- **Triggered events:** For example the system could fire a trigger every ten minutes to remind the physician of a certain task, e.g. measurement of blood pressure.
- **Constraints and rules:** The system ensures that the entered values are within the allowed range. Every parameter can be defined with min/max values. Also rules can be defined to ensure that specific parameters are entered in the correct order.
- Drag-and-drop functionality and support for different hardware platforms
- Predefined adaptive filter for viewing (mask out certain symbols)
- **Speech recognition support:** To increase the efficiency of the user interface, a speech recognition system can be used as well.

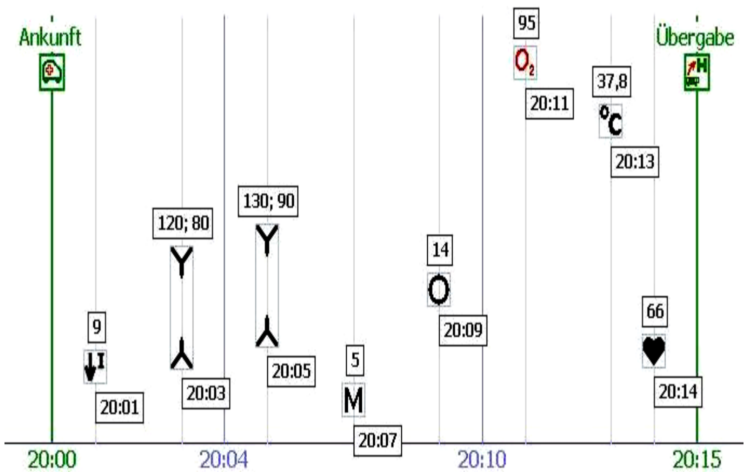


Fig. 9. Software-based sequence diagram (CANIS, Austria)

3.5 Usability of Sequence Diagrams

The user is able to fill in data directly by clicking into the diagram, but it can also be done by using the buttons below it. Because of the direct data input, the sequence diagram is highly interactive. This method speeds up the whole input process, but the user has to learn how to deal with this control element.

An important factor is the size of the icons. On one hand they should be big enough to allow a proper selection by using finger input, on the other hand small enough to keep the diagram clear and easy to read. The symbols can be placed using drag-and-drop functionality. Time and measurement values are pre-filled by using the chosen position and have to be validated or modified by the physician using sliders or the special adapted input panel for figures.

4 Interface Design Considerations

Instead of the classical GUI approach with a multitude of menus, tabs and buttons, the anatomical and sequence diagrams could be used as the central part of the software. This approach would change the way how the user interacts with the application. At the moment the GUI follows the paper-based protocol, and is divided in many menus and tabs to flatten the learning curve for the personnel.

To increase the efficiency and quality of documentation of the system, different sensors for measurement or surveillance could be integrated into the application. It is also possible to connect different devices to the system which deliver measurement values like blood pressure or electrocardiogram (ECG) automatically. Defibrillator devices could also provide valuable information which is important to be documented in the application.

5 User Acceptance and Social Benefits

After a 2-month pilot installation of CANIS (LKH Graz, Austria) was successfully tested, the involved medical personnel were able to work with the system within a very short period of time without training on the software, because the design of the user interface follows the similar structure as the conventional paper version. After a few weeks, the personnel got used to the anatomical and sequence diagram and preferred this way of direct data input.

The social benefits of an electronic EPCRF are for example:

- Quality assurance for medical personnel (because of the complete documentation)
- Insurance companies could be integrated into the data flow
- Educational aspects
- Quality Management for better patient care

6 Conclusion

Though paper-based EPCRFs are widely used all over Europe, the next years will lead to a change and more and more countries will probably move on to an electronic solution to increase the quality of documentation and therefore the quality of medical treatments of the patients. The anatomical and chronological documentation are the central elements within electronic EPCRFs, in contrast to the paper-based report forms. Referring to the shown aspects for implementing such graphical objects is crucial for high user acceptance and usability [6].

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Mobile Devices in Emergency Medical Services: User Evaluation of a PDA-Based Interface for Ambulance Run Reporting

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Abstract. The design of easy-to-use mobile systems for collecting and handling emergency medical care data in the field can significantly improve the effectiveness of rescue operations. In particular, this paper focuses on the design and evaluation of a mobile application that replaces ambulance run paper sheets. First, we discuss the limitations of traditional ambulance run paper sheets. Then, we present the PDA-based system we have developed. Finally, we discuss in detail the usability study we have carried out with first responders.

1 Introduction

In emergency medicine, prompt, accurate recording and communication of patient data can make the difference between life and death [1]. Traditional information collection in the field and communication to the next level of care is often inaccurate. For example, during interviews conducted by [1], medics reported that typically 40 percent of the fields on an ambulance run sheet for a trauma incident are either left blank or filled in erroneously.

The design of easy-to-use systems for collecting and handling emergency medical care data can significantly improve the effectiveness of rescue operations by satisfying first responders' needs such as: (i) enhancing operations timeliness by allowing to efficiently record and communicate data between on-site teams and headquarters; (ii) being able to efficiently perform on-site patient classification using severity color coding (*triage*), by rapidly applying a set of criteria (*triage protocol*); (iii) being able to get information from medical databases that could help in choosing a proper course of action in the field; (iv) getting real-time information about nearby hospitals and/or medical care facilities, checking their availability and therapeutic capabilities, and communicating data to them. Moreover, digital reports can be stored

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in databases and enhance knowledge management capabilities of emergency services (e.g., automatic assessment of quality of service).

This paper focuses on the design and evaluation of a mobile application that replaces the traditional ambulance run paper sheets. While other researchers pursued this goal by using full PCs installed on ambulances [2] or using belt computers, speech recognition technologies and tablet handhelds [1], we focus on smaller, lightweight devices, and aim at a data entry style that has to be unaffected by environmental noise and as similar as possible to traditional paper sheet filling to be familiar and quickly adoptable by first responders.

2 The Proposed System

In this section, we illustrate some of the main features of the system that is being jointly developed by the Human-Computer Interaction Lab of the University of Udine and the Emergency Medical Service of the Hospital of Udine, Italy. Besides replacing current paper sheets, the system aims at introducing new functionalities that are not supported by paper sheets and is developed following a user-centered methodology.

2.1 The Traditional Ambulance Run Sheet and Its Limitations

Medical teams on ambulance trucks and helicopters typically record data about the rescue operation on the so-called *ambulance run sheet*, i.e. a paper sheet where they write down information about the incident, patient conditions, actions taken, and rescue team members.

The contents of a typical ambulance run sheet are split up in sections. The specific ambulance run sheet we considered is organized into 9 sections: *Evaluation*, *Treatment*, *Pharmacologic Therapy*, *Anamnestic Data*, *Home Therapy*, *Diagnosis*, *Outcome-Transport-Alerts*, *Mission Data*. These sections are usually filled in the reported sequence, but the first responder is free to follow a different order.

Using paper for information recording has clear limitations, both in data entry and information representation. When a user miswrites something, corrections result in reports that are hard to read and revise. Moreover, a paper sheet is a passive information container that is not able neither to warn the user of inconsistencies in the data nor to highlight critical situations by analyzing the entered values.

During the initial interviews with target users, it clearly came out that the layout of sections on the ambulance run sheet was designed to get the most out of the space available on a A4-sized sheet, and the arrangement of fields does not take into account neither the logical order followed by medics in filling out the report nor the classic conventions for maximizing readability in forms.

2.2 The Mobile Prototype

The proposed application aims at overcoming the above summarized limitations of the ambulance run sheet as well as augmenting it with functionalities that were previously unavailable. It has been developed in C#, represents data in XML format, and runs on a Pocket PC platform. Pocket PCs were preferred to Tablet PCs after initial users' interviews strongly pointed out the need for a lightweight device that can be carried in a pocket of the protective suit. *Ruggedized* versions of PDAs are particularly interesting for the considered application, because they can be washed after manipulating them with dirty protective gloves.

Due to the limited size of Pocket PC displays, the original ambulance run sheet cannot be fully displayed in a single screen. We thus organized the original contents in logical parts (*sections* and *subsections*). The general structure of the user interface is shown in Figure 1 and is divided in three main parts.

The *Navigation Bar* allows one to navigate sequentially among sections and subsections, informs the user about which part of the ambulance run report is being edited, and provides further information on where the user is in the navigation structure by indicating which parts of the report precede and follow the current one. The name of the currently displayed report section (in upper case) and subsection (in lower case) is shown in the lower center of the navigation bar. Arrow buttons on the left and right of the bar can be used to navigate backward and forward as if the user were browsing the pages of a book. The labels on the arrows indicate which section and subsection the user can reach by tapping on the buttons. When there is no previous or next subsection, the corresponding arrow button is not shown.

The central part of the screen shows the contents of the *Current Subsection*. The user can visually inspect the current values of all the fields and change them.

The *Application Menu* at the bottom of the screen allows one to carry out typical file operations such as load and save through a *File* menu, and to rapidly jump to any desired section through a *Sections* menu.

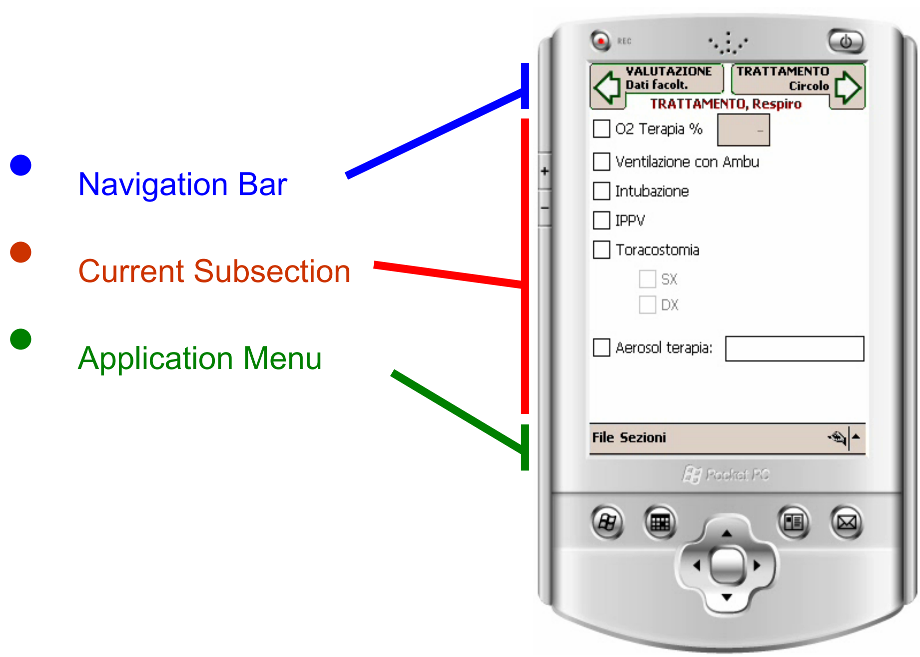

Fig. 1. General organization of the user interface

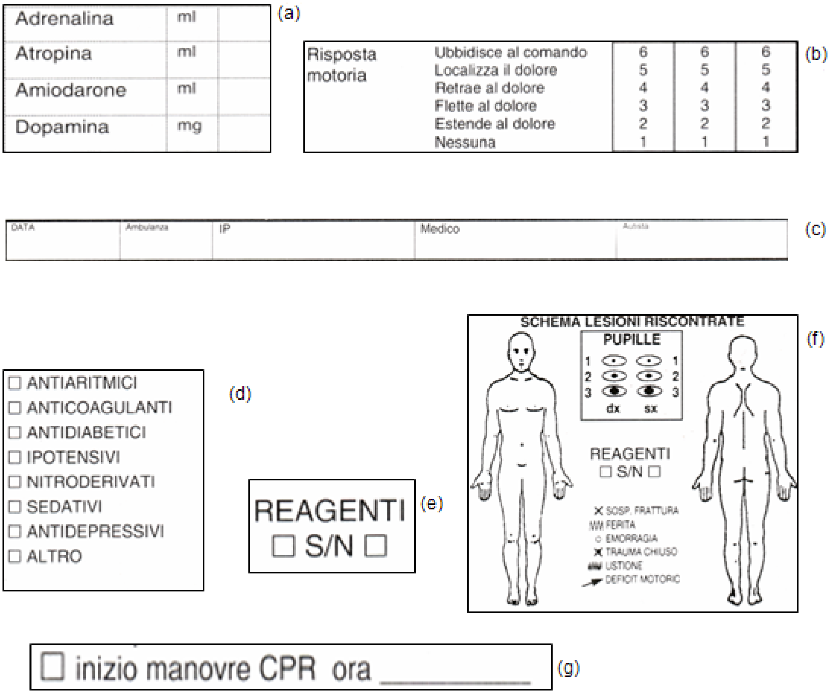

Fig. 2. Examples of fields in a traditional ambulance run sheet: (a) free numeric field, (b) pre-printed numeric field, (c) textual field, (d) multiple-choice field, (e) mutually-exclusive choice field, (f) graphic field, (g) mixed-type field

The different types of input fields found on a ambulance run sheet (see examples in Figure 2) can be classified in six categories: (i) *numeric fields*, that can be divided in two subcategories: *free numeric fields* (white fields where the user is supposed to write a number) and *pre-printed numeric fields* (fields with pre-printed values that the user has to mark); (ii) *textual fields*: white space the user can fill with text (e.g., patient's name, ambulance ID, brief description of the rescue operation,…); (iii) *multiple-choice fields*: groups of checkboxes where the user can check more than one box; (iv) *mutually-exclusive choice fields*: groups of checkboxes where the user must check only one box, (v) *graphical fields:* areas on which the user can draw symbols (e.g., representing different types of injuries on a body picture to describe how and where the patient is injured); (vi) *mixed-type fields:* combinations of previously described fields (e.g., a textual field that should be filled only when a corresponding checkbox has been ticked).

For each kind of field, we developed an electronic counterpart that aims at: (i) preventing possible errors made by the user (e.g., values that are out of physically possible ranges), (ii) taking into account, where possible, the typical usage of the original ambulance run sheet, to make data entry easier and more familiar for the target users; (iii) allowing for quick editing of information, (iv) preventing erroneous or arbitrary use of the fields (that was instead possible with the paper sheet),

(iv) improving the way data is visualized on the mobile device [3], e.g., we introduced automatic color coding of the fields based on the entered values to give a quick idea of how close/far the values are from normality and also provide further feedback to highlight possible input errors. Figure 3 shows an example of the graphical interface for visually describing patient's injuries: only two taps on the screen are needed to place the proper injury symbol in the right position on the patient's body schematic. For filling textual fields, we explored a handwriting recognition approach as well as a on-screen virtual keyboard with automatic word completion. Speech recognition was not considered because the initial interviews highlighted that environmental noise in ambulance trucks and helicopters often seriously affected even human recognition capabilities when communicating with headquarters.

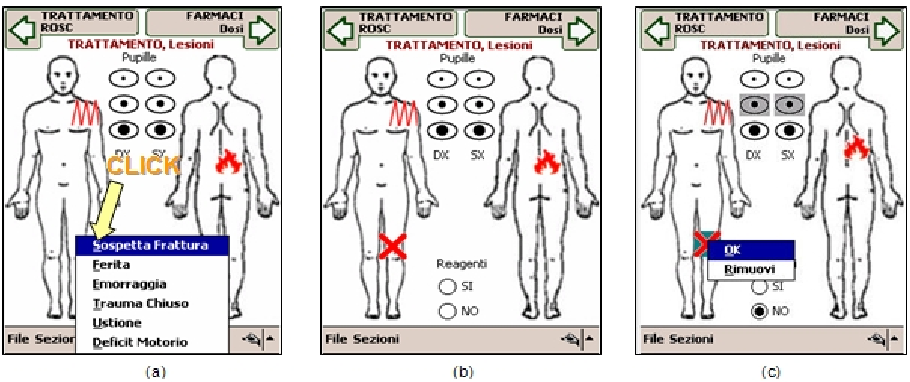

Fig. 3. To visually enter injuries, the user first taps on the injury location, then a pop-up menu lists the available types of injury and the user taps on the desired one (a), and the icon of the chosen type of injury is drawn by the system in the chosen location (b). Tapping on a injury icon allows instead to remove it or drag it to a more precise position (c).

3 User Evaluation

The usability testing of the completed prototype took place with 6 first responders (4 male, 2 female) of the emergency service involved in this project. Their age ranged from 23 to 50, averaging at 37.5. Since we were particularly interested in the reactions of users who are not familiar with the employed technology, none of the recruited first responders had ever used a PDA before. All users had instead some familiarity (very low for two of them) with desktop PCs. The prototype was tested in the real places where traditional ambulance run sheets are usually filled by first responders, i.e. in the ambulances (see Figure 4) as well as in the emergency services rooms. More specifically, half of the users tested the system in an ambulance, half in a emergency service room. In the following, we describe in detail the task, the testing procedure and the obtained results.

3.1 Task and Procedure

Before the test started, users were briefly taught the basic concepts needed to operate the system. More specifically, they were briefly instructed about: (i) the touch screen and stylus, (ii) the organization of the user interface in three main parts, (iii) a few tips about how to enter text using handwriting recognition software, e.g. drawing clear capital letters inside the reference grid on the screen, (iv) how to use the automatic word completion feature of the on-screen virtual keyboard. Since we were interested also in evaluating how quickly the details of the interface could be understood, no other information was given, but users were free to ask any question in case of difficulties so that we could pinpoint aspects that were possibly difficult to understand.

The task users had to carry out concerned a scenario describing a real rescue operation and was specifically written by a emergency physician to test every part of the system. Users were given an A4 sheet with the textual description of the operation, and a photograph (part of which is shown in Figure 5) shot on a real rescue mission, illustrating the scene of the accident (an hiker's fall from a mountain trail), including the patient and the equipment employed by first responders. The textual description included all the necessary clinical data needed to fill an ambulance run report. Users were asked to read the description and then fill the report using the PDA.

Fig. 4. One of the first responders using our application inside an ambulance

A 624Mhz PocketPC with a 3.5” display and QVGA (320x240) resolution was employed for the test. Textual data entry was handled through a commercial software (Phatware Calligrapher [4]), in the handwriting recognition mode (recognition of entire written words) as well as virtual keyboard mode (with automatic word completion), both configured to recognize Italian words. To test both textual data entry options, the textual field describing the accident was filled by users through handwriting recognition, while the textual field for clinical notes was filled by users through the virtual keyboard. The description of the accident for this scenario was about 7 words long, while the clinical notes were about 26 words long.

After users completed the task, we employed a questionnaire to collect their subjective opinions concerning the usability of the system. The questionnaire included 5 open-ended questions and 21 statements that had to be rated by users on a numeric scale ranging from 0 to 9. The 5 questions concerned which features the user liked and disliked, possible advantages and drawbacks of the system with respect to the paper run report, and suggestions on how to improve the application. The 21 statements were taken or adapted from the standard QUIS (Questionnaire for User Interaction Satisfaction) [5], and divided in five groups, each one dealing with a different aspect of the user experience: Overall reactions to the software, Screen, System information, Learning and System capabilities. The statements, as well as means and variances for the collected answers are reported in Figure 6. After completing the questionnaire, we freely discussed with users to possibly get more feedback from them about the system.

Fig. 5. Part of the photograph illustrating the scene of the accident

3.2 Evaluation Results

In general, the results of the evaluation were much more positive than we expected. Although they had never used a PDA before, all 6 first responders quickly learned how to effectively operate the system and expressed willingness to employ such technology in their daily practice. All but one of the 21 statements in the questionnaire received very good ratings, and most of them with a small variance.

	Mean	Var.
Overall reactions to the system		
The system is (0=Difficult, 9=Easy)	8.5	0.3
The system is (0=Uncomfortable, 9=Comfortable)	7.3	1.5
The system is (0=Rigid, 9=Flexible)	7.2	2.2
The system is (0=Dull, 9=Stimulating)	8.0	0.8
Screen		
Characters on the PDA screen are (0=Hard to read, 9=Easy to read)	7.5	1.1
Organization of information on screen is (0=Confusing, 9=Clear)	8.3	0.3
Sequence of screens is (0=Confusing, 9=Clear)	8.5	0.3
Use of color for data representation is (0=Useless, 9=Useful)	8.7	0.3
System information		
[In case the system showed you error messages] Error messages are (0=Unhelpful, 9=Helpful)	8.0	2.0
Learning		
Learning to operate the system is (0=Difficult, 9=Easy)	8.2	0.2
Exploring new features by trial and error is (0=Difficult, 9=Easy)	8.7	0.3
Remembering names and use of commands is (0=Difficult, 9=Easy)	8.2	0.6
Tasks can be performed in a straightforward manner (0=Never, 9=Always)	7.7	0.3
System capabilities		
System speed is (0=Too slow, 9=Fast Enough)	8.3	0.7
System reliability is (0=Low, 9=High)	8.0	0.8
Entering numeric values is (0=Hard, 9=Easy)	8.7	0.3
Writing text using handwriting recognition is (0=Hard, 9=Easy)	3.8	6.6
Writing text using the on-screen virtual keyboard is (0=Hard, 9=Easy)	7.2	1.8
Using the graphical injury diagram is (0=Hard, 9=Easy)	8.2	0.6
Entering other kinds of data is (0=Hard, 9=Easy)	8.2	0.6
[In case you have corrected errors] Correcting errors is (0=Hard, 9=Easy)	8.0	0.5

Fig. 6. Results for the statements in user questionnaire

Users had no problems in understanding and navigating the sections/subsections structure. Some of them even stressed how they felt such an organization of content was useful because it suggested a well defined way of filling up the report: they felt that displaying data fields in a logically ordered sequence of screens made them take into account every part of the report, reducing the possibility of leaving relevant fields blank because they have not been viewed or considered. Entering and editing the data fields was also considered to be very simple. Users were able to rapidly understand how to handle the different types of data fields and the corresponding input technique. They were also positively impressed by the new features of the PDA-based report, such as criticality color coding or graphical interaction with standard symbols automatically and clearly drawn by the software in the injury subsection.

The rating of the statement about handwriting recognition indicates a usability problem. Results obtained by the considered users with handwriting recognition were not satisfactory: most of their written words were not correctly recognized, and they had trouble following the writing tips suggested at the beginning of the test, because it felt unnatural to them. The high variance of this rating is due to the fact that although all users were dissatisfied with the results, two of them did not rate negatively the feature because they felt the input method could perform better with practice. Two users reported that the available screen space was insufficient for them to write a long word entirely. Moreover, three users expressed concern about the effectiveness of this method when used on a moving ambulance.

The virtual keyboard led to better results and the word completion feature was able to suggest also some medical terms. However, letter-by-letter typing was time consuming for all users. This was seen as an advantage by one user, who reported that using the keyboard forced him to be more concise in writing textual descriptions on the report. An interesting comment that came from another user was that she would be writing faster using a T9-like input system tailored to medical terms and abbreviations. She pointed out the fact that she and her colleagues are very familiar with typing SMS messages on cell phones. Four users reported that keyboard keys were too small, and hard to read and use. We further elaborate on textual data entry in the next section.

Some users remarked that sending the data through a PDA could improve communication between them and their headquarter in terms of speed and reliability, since today they communicate much information by voice through mobile phones or radios from noisy environments. Electronic reports were also perceived by first responders as a more secure way of recording data, since paper sheets can be torn, soiled or lost.

4 Conclusions and Future Work

The informal evaluation showed that first responders who are completely unfamiliar with PDAs can quickly learn how to use the proposed ambulance run reporting application, without the need for a particular training.

We are currently working at the handwriting recognition issue that came out during the evaluation, and we plan to consider different options to offer an easy-to-use and efficient text input method to the target users. One possibility would be to implement a T9-like input system relying on a medical dictionary. Users could be presented with an on-screen phone-like keyboard, possibly with larger keys and more convenient controls for symbols and punctuation. Considering the widespread usage of cell phones, this technique could be a good choice also for people who are not familiar with the QWERTY layout. It would also eliminate the problem of having a full keyboard squeezed into the PocketPC screen, that forces the size of the keys to be very small. Another option could be to use a format such as UNIPEN [6] or InkML [7] to represent digital ink information. Such data can then be processed by a recognition software (most likely running on a server rather than the PDA) to translate handwriting into text. For example, LipiTK [8,9] is an open source generic toolkit that supports the UNIPEN format natively, can support different recognition algorithms and is meant for the development of online handwriting recognition engines. We are also considering the possibility of limiting the need for handwriting as much as possible through a mechanism for assembling the text by selecting sentences or words from pre-compiled lists specific to the ambulance run domain.

Another interesting development of the system could concern functionalities for receiving data directly from monitoring devices, such as the ECG monitor, that are available onboard ambulances.

Moreover, we have also started working at an adaptive version of the user interface with the aim of (i) automatically proposing the next most appropriate fields to fill based on the information previously entered in the report, (ii) guiding first responders to comply with the correct medical protocols in accordance with the clinical scenario they are dealing with, by introducing into the system an advisory capability based on medical knowledge.

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Feasible Hardware Setups for Emergency Reporting Systems

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Abstract. The main priorities of emergency medicine are to rescue lives and to limit the damage to life and limb of the patient as much as possible. The emergency physician analyzes the situation at the accident scene and chooses the appropriate first aid methods as well as the follow-on medical techniques at the hospital. The goal of CANIS - the Carinthian Notarzt (emergency physician) Information System - aims at the establishment and optimization of the information stream between the emergency rescue vehicle (ERV) or emergency rescue helicopter (ERH), and/or the receiving hospital. To achieve this, a feasible hardware setup must be established which meets the challenging requirements of an emergency situation.

Keywords: Emergency Systems, Emergency Patient Care Report Form, Hardware, Setup, Speech Recognition, Digital Pen, Optical Character Recognition (OCR), Wireless Data Transmission, Mobile and Wearable Devices.

1 Introduction

Documenting medical emergency events in Austria - as presumably in most European countries - involves largely the paper-based application of an Emergency Patient Care Report Form (EPCRF). After the arrival of the emergency physician at the accident site, this paper-based form is used to document and to report the assessments and emergency treatments performed. Together with the patient, this information arrives at the dispatching hospital where both are handed over to the emergency department simultaneously. Obviously, immediate electronic transmission of patient data and diagnoses would put the receiving institution in a more favorable position, since admitting the expected patients could be prepared much better in advance due to the improved state of knowledge. However, introducing an electronic emergency response information system into extreme environments such as an accident scene, considerable analyses must be accomplished in order to employ suitable data recording and transmission devices. After all, the major responsibility of emergency physicians is to save the lives of

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their patients, which must not be hampered by the important, but subordinate task of data entry into a mobile device [1].

2 Motivation

This paper focuses on suitable mobile devices, to support data entry for electronic emergency medical response systems with the emergency physician on-site as the primary actor. In addition, non-standard data acquisition technologies as an alternative will also be evaluated. Our research is part of the CANIS project, and concentrates on the analysis of the current state of the emergency medical response system in the province of Carinthia (Austria), as well as the development and implementation of an electronic Emergency Patient Care Report Form (eEPCRF), which relies on mobile clients for on-site data acquisition and wireless data transmission to the receiving hospital. The project employs portable clients which consist of rugged Tablet PCs as well as smaller and handier Personal Digital Assistants (PDAs). Additionally, a combination of both in order to optimally support the emergency physician in any potential working scenario is provided.

As far as the project is concerned, the problems listed below occur in the deployment of the current paper-based EPCRF. Moreover, the outcomes which result from these problems as well as the primary project goals are described.

Problems:

- Non-structured, (mostly spoken) sequential disclosure of information
- Basic knowledge (diagnosis, therapies, medications) about the patient at the accident site is lacking
- No suitable tool/device for quality assurance of documentation
- An error-free accident protocol is very hard to realize, but is required by law

Results:

- Best possible preparations to receive the incoming patient at the receiving hospital is very limited
- Potential delay of essential life-saving medical measures, and as such
- A possible reduction of the quality of care for the patient, which results in
- The neglect of the medical protocol requirement

Project Goals:

- Simple, fast and mobile data acquisition corresponding to usability criteria and following the fire & forget principle
- Data collection simultaneous to first aid measures via voice recognition
- Utilizing the Austrian electronic health insurance card (eCard) or introducing an RFID solution to identify the patient
- GPS-localization of the emergency physician
- Contactless identification of the emergency physician (RFID) as well as the patient

All recorded entries should be time-stamped in order to afterwards guarantee an accurate traceability of all events. Other features like an automatic GPS determination of the accident location, or even the capability of reading out data from the patients eCard, represent important privacy issues and concerns, and will therefore be handled with care.

3 System Architecture

Interoperability with other predefined components in the healthcare sector is a major demand for the CANIS application. Figure 1 illustrates the communication flow within CANIS as well as all the components involved. On the one hand, these components are independent systems, which are integrated in the overall IT management of a hospital (e.g. Hospital Information System - HIS, and Management Information System - MIS), or medical devices which are operated by the emergency rescue team (e.g. electrocardiogram - ECG, or blood pressure meter).

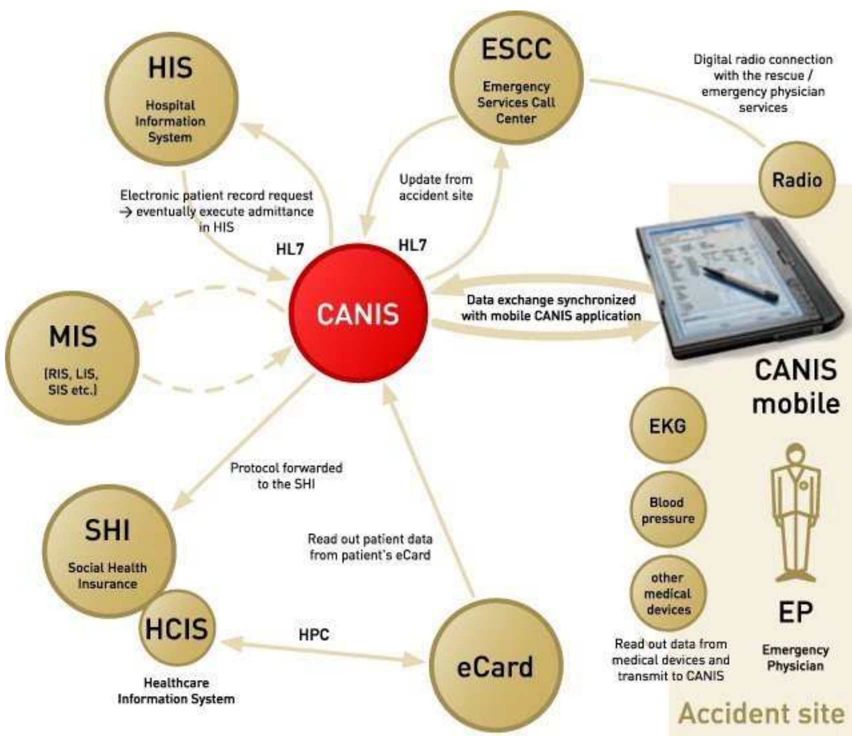

Fig. 1. CANIS Communication flow and the important components of a Medical Emergency Event

On the other hand, the CANIS communication architecture consists of co-dependent as well as independent institutions, like the Emergency Services Call Center (ESCC), or the Social Health Insurance (SHI). The ESCC, for example, is the component where the emergency call is received and that then distributes the best suitable medical emergency team. Furthermore, the ESCC provides important information at the accident site. Thus, during the transport, all required resources - like operating rooms, medical equipment, surgical teams - can be allocated. The Social Health Insurance (SHI) institute is another interesting communication partner for CANIS. Largely relevant for billing scenarios, the SHI institute can gather patient-related data for the accounting department. Austria's eCard is an optional component for the future, when eCard holders can store their individual medical information on the card itself. This concept is currently not realistic, because of the sensitive nature of patient's data and the legal restrictions concerning data security and protection.

The communication between the existing clinical systems will be provided by a standardized open interface called Health Level 7 (HL7).

Table 1. Data Acquisition Modalities

HCI/GUI	**Standard Input**	**Voice Input**
		
TabletPC, PDA with stylus and finger	Digital Pen	Speech Dictation/ Understanding/ Recognition

In order to ensure that the system remains open for a variety of accident/ emergency rescue scenarios as well as for the requirements of emergency physicians, many different hardware combinations for an emergency rescue implementation have been identified. Table 1 illustrates three possible data acquisition modalities. The Human-Computer-Interaction (HCI) could be performed via Tablet PC and PDA, however, both displays need to be sensitive to stylus and finger touch. Standard data acquisition includes the digital pen, whereas voice input can be divided into three categories: speech dictation, speech understanding, and speech recognition. Possible options that are being developed include a speech recognition component for both mobile platforms (Tablet PC, PDA) as well as a device for the digital capture of handwritten notes (Digital Pen). Using the voice input device, emergency physicians will be able to record data easily with their hands remaining free. The digital pen on the other hand allows doctors to fill in their standard handwritten protocols while simultaneously transmitting the digitally captured data to the server via Bluetooth and the current cellular technology. In addition, the digital pen could be an attractive product to become familiarized to digital data acquisition, and to enhance the users acceptance of electronic data acquisition. [1]. With the feature of digital data capture, a variety of potential legal problems that arise without the corresponding Health Professional Card (HPC) can be solved (e.g. handwritten signature).

4 Hardware

Regardless of the numerous features that electronic devices nowadays have to offer, the requirements of the potential user - the emergency physician - need to be kept in mind, as well as the specific features that are absolutely necessary for devices used in medical emergency settings. Analyzing these events, the device has to cope with constantly changing environmental conditions and to withstand rather rough handling.

4.1 Requirements

The following hardware requirements have been identified in order to optimally support the user.

Display. Thinking of small and handy PDAs, their display size might be just as small, which put the user in a non favorable position when trying to interact with the application using his or her fingertips, not to mention wearing rubber gloves, as emergency physicians wear in general. Touch screen sizes of regular PDA's range from 2.8" to a maximum of 3.6", and hence do not provide an accurate user interface. Also, daylight readability for Tablet PCs and PDAs is required in order to appropriately use both devices outdoor.

Weight. Another important requirement when thinking of a mobile device is the weight factor. How satisfied would an emergency physician be, when in addition to the mental stress the physical stress accrues by carrying around a 4 kg mobile computer? A PDA is handy and light-weight and barely noticeable while being carried around. A Tablet PC is not as heavy as 4 kg either, but it depends on the brand and type selected.

Audio. The requirements for the audio component of the device focus primarily on wireless headsets that are needed in order to acquire data via voice in the mobile context. Therefore, the Bluetooth service needs to be integrated and provided by the headset.

Protection and Operating Condition. The fact that emergency physicians are wearing rubber gloves while performing lifesaving measurements as well as the more or less constant presence of blood and other fluids already strongly demands the use of a more sturdy and feasible design. Rugged devices seem therefore to optimally fit the working environment of an emergency physician, and it seems obvious that these devices should belong to the target group. Special coatings and sealants - internal as well as external - contribute to the specific design of rugged devices, in order be able to exposure the device to extreme temperatures, humidity, dust and vibration.

In order to determine which rugged mobile device is most suitable for the application field of emergency events, specifications and ratings for rugged devices that have been established by several government agencies, industry organizations, and also independent laboratories needed to be examined. The most common standards and ratings are the following three [2].

- IP Rating (Ingress Protection), defined by the International Electrotechnical Commission (IEC),
- National Electrical Manufacturer Association (NEMA), defined by the IEC,
- Military Standard (MIL-STD) or Military Specification (MIL-SPEC), established by the U.S. Department of Defence,

The minimum requested protection level for devices integrated in the medical emergency process is an IP rating of IP54 (dust, limited ingress, water sprays from all directions) and MIL-STD 810F (shock and vibrations), which also include a possible operating temperature of -15 °C and +60 °C [1].

Power Supply. Battery life has to last at least up to eight hours (regular work shift). Features like "hot swappable" or being able to charge the device inside the car is a possible alternative, although, for this amount of time the device is bound to the car which limits its mobility.

Connections. The device is requested to provide sufficient components to connect to networks as well as other devices, in order to retrieve and process emergency or patient-relevant information.

Table 2. Requirements for Tablet PCs for the Application Field of Medical Emergency Events (*optional)

Characteristics	**Requirements Tablet PC**	**Requirements PDA**
Weight	below 2 kg	below 0.8 kg
Display	1024x768, daylight readable, touch screen - pen and finger sensitive, transmissive	640x240, daylight readable, touch screen - pen and finger sensitive
Audio	speakers/ microphone	speakers/ microphone
Power Supply	"hot swappable"	"hot swappable"
Connection	Ethernet, GSM/GPRS, Bluetooth, WLAN 802.11*, USB	GSM/GPRS, Bluetooth or WLAN 802.11, USB
Operating Condition	-15 °C and +60 °C	-15 °C and +60 °C
Protection	min. IP54, MIL-STD 810F	min. IP54, MIL-STD 810F

Table 2 provides an overall view of the requirements that are absolutely necessary for feasible Tablet PCs and PDAs in the context of medical emergency events.

Depending on the range of capabilities and cost structure, emergency physicians can determine the ideal IT support combination for their work settings. Four different hardware setup combinations have been established, as can be seen in Figure 2. [illegible] is a combination of both, Tablet PC and PDA, whereas the Tablet PC is mounted stationary in the ERV, and the emergency physician is

Fig. 2. Four feasible hardware setup combinations (*optional)

equipped with a PDA. , on the other hand, provides a Tablet PC inside the ERV, which is connected with the emergency physician at the accident site via voice. However, this setup does not provide visual feedback to the emergency physician. focuses on the PDA device including speech recognition, and is again a combination of Tablet PC and PDA, plus digital pen and optional speech recognition. In order to gain an optimal support for their working environment, emergency physicians are now able to select any given setup.

4.2 Devices

After having tested numerous different hardware platforms and devices, it was determined that the following devices would optimally fit the requirements imposed by the project. The chosen tablet PC devices are the Walkabout Hammerhead RT, the Panasonic Toughbook CF-18, and as handheld version the Gotive H42 was selected. Table 3 displays the major characteristics of all three devices [1,3,4].

5 HCI Aspects

The following Human-Computer-Interaction aspects need to be kept in mind.

GUI. Touch screen and stylus allow direct manipulation of data, which, in the context of emergency events, is more than favorable. The intended user may enter patient-related data easily and fast with his fingers or with the help of the provided stylus. As the use of touch screens is a form of direct manipulation, the hand-eye coordination is much easier than with mice and

Table 3. Features of Hammerhead XT, Toughbook CF-18,and Gotive H42 (*optional) [1,3,4]

Features	**Hammerhead RT**	**Toughbook CF-18**	**GOTIVE H42**
Processor	Intel Pentium M III (933 MHz)	Intel Pentium M (1,2 GHz)	Intel Bulverde PXA (270 - 520 MHz)
Main Memory	512 MB SO DIMM	512MB SDRAM (DDR2)	1 GB non-volatile Flash memory, 128 MB RAM
Hard Disk Drive	yes	yes	no HDD
Dimensions	280 x 210 x 41 mm	271 x 49 x 216 mm	230 x 94 x 34 mm
Weight	2.17 kg (incl. battery)	2.1 kg (incl. battery)	580 g (incl. battery)
Display	10.4" 1024 x 768 (XGA) transmissive, daylight-readable TFT Active Matrix Color LCD, (Digitizer, Touch)	10.4" 1024 x 768 (XGA) transmissive, daylight-readable TFT Active Matrix Color LCD, (Digitizer, Touch)	6,2" 640 x 240 (HVGA), 65 536 Colors, Integrated Touch screen (Digitizer, Touch)
Audio	integrated speaker, microphone	integrated speaker, microphone	integrated speaker, microphone
Battery Life	4 hours, hot swappable	4-6 hours	hot-swappable
Connection	WLAN 802.11, GSM/GPRS, Bluetooth*, USB 2.0, PCMCIA Type III Slot	Ethernet, WLAN 802.11, Bluetooth, GSM/GPRS, GPS*, USB 2.0, PC Card Type III Slot, SD Card Slot	WLAN 802.11, Bluetooth, GSM/GPRS*, GPS*, USB 2.0, SD Card Slot, CF Card Type II Slot
Operating Condition	-15 °C to +60 °C	-10 °C to +60 °C	-10 °C to +60 °C
Protection	IP-64, MIL-STD-810F	IP54, MIL-STD-810F	IP-54
Others	Smart Card Reader via PCMCIA	Smart Card Reader via PCMCIA	Bar Code Reader, Smart Card Reader, Fingerprint Reader

keyboards, which again supports the learning process [6]. However, as the devices mentioned so far, in particular the PDA, provide limited display sizes, an adapted GUI is essential. If the icons or buttons are too small or too close to each other, using the fingertips may hamper the ability to click on the correct icon or button.

Speech Recognition. The speech-based prototype is developed using Nuance's speech recognition system VoCon 3200. After having tested several recognizers of various manufacturers, VoCon 3200 was selected in order to act as a speech server which communicates with the Graphical User Interface (GUI) of the eEPCRF via TCP. The system architecture has been designed in order to meet the requirement of an independent speech recognizer that could be easily exchanged if necessary. The following characteristics [5] need to be kept in mind in order to gain beneficial results when employing speech recognition in medical emergency events.

– [illegible]: multiple emergency physicians use the application
– [illegible]: support of a natural way of interaction
– [illegible]: standard EPCRF contains about 400 words
– [illegible]: to fill in the eEPCRF, complex grammar is not needed
– [illegible]: to ensure a high recognition rate

The results of several usability tests concerning speech recognition can be divided into three main categories: speech instruction set, vocabulary, and general design preferences. In order not to narrow the user's speech instruction set, the gained results showed that multiple instruction choices for one action should be offered. Furthermore, additional manual data acquisition is demanded by a high percentage of the test candidates.

Digital Pen Input. The digital pen model that has been selected for the CANIS project is NOKIA's Digital Pen SU-1B, which provides data transmission via Bluetooth.

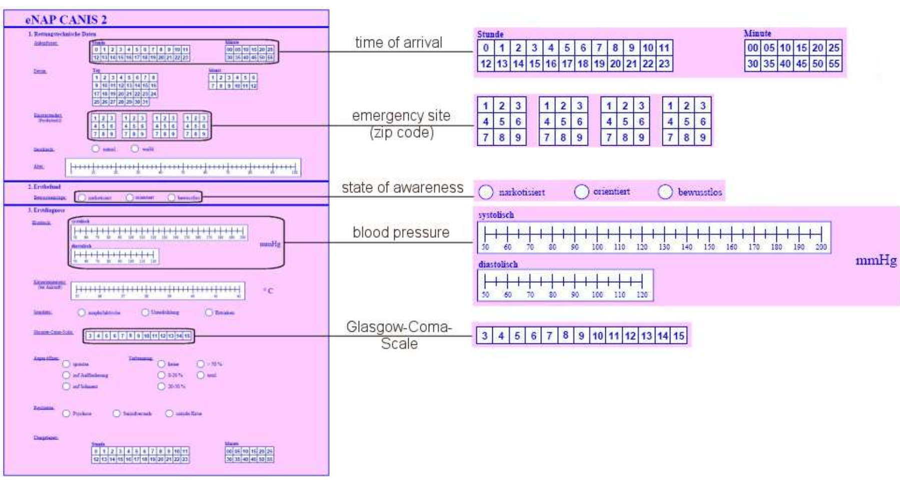

Fig. 3. Design of digital pen form without OCR/handwriting recognition [1]

The digital pen enabled paper has been developed by the Swedish company Anoto (www.anoto.com). It holds the license and ensures the compatibility of the digital pens from the various manufacturers with the forms and software products. After having accomplished and evaluated several usability tests, the decision was made not to integrate either Optical Character Recognition (OCR), nor handwriting recognition. Therefore, the form needed to be designed without any free text areas. As the use of checkboxes does not require the need for an OCR or handwriting recognition, this feature was adopted when replacing free text areas by checkbox-alike components as can be seen in Figure 3.

6 Conclusion

The environmental setting of medical emergency events is not neat nor are the working conditions simple. The main actor concerned in this paper is the emergency physician, who performs his/her time-dependent tasks under constant mental and physical stress. An electronic Emergency Patient Care Report Form (eEPCRF) in combination with a feasible hardware setup can support the emergency physician in this very sensitive environment. Key factors for the optimal teamwork of user and device are in this context, on the one hand a feasible device, which, in regard to its weight, display features, power supply, connecting options, protection and operating conditions, has to be adapted to the emergency physician's needs. On the other hand a user friendly GUI is requested, as one major goal is it to additionally support the user while providing extensive features and by no means to hamper his/her work.

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Supporting Implicit Coordination Between Distributed Teams in Disaster Management

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Abstract. In this paper we consider disaster management as the coordination of resources in space and time, and contrast this with the Joint Operational Picture (JOP) used in military planning. The basic premise is that the processes involved in the collection and management of information could interfere with the priorities of dealing with immediate demands on 'rescuers' and their managers. Thus, we explore ways in which collaboration could be made as implicit as possible. The paper includes small-scale user trials of prototypes to highlight potential benefits and shortcomings. The paper concludes with consideration of how brokering approaches to coordination could be realized using the prototypes described in this paper.

Keywords: Wearable computers, Collaborative Technology, Digital Annotation.

1 Technology for Disaster Management

In 2005, the U.S. National Research Council (NRC) convened a panel to consider the role of information technology to enhance disaster management. The resulting report (NRC, 2005) addresses three broad areas: 'the critical and evolving role of information technology to disaster management'; 'research directions for information technology in disaster management'; and 'collaboration, coordination and interoperability'. The report is grounded in the experiences and problems of contemporary disaster management and places much emphasis of the social, cultural, organisational and technical demands and constraints on operations that are conducted in inhospitable environments by many different agencies. This raises significant challenges for the design of future technologies to support disaster management (Meissner et al., 2002).

Many of the concerns raised in NRC (2005) address immediate problems relating to communications network coverage and interoperability of different working practices and technologies. However, the report also hinted at future directions for research, and we pick up on the following (emphasis added):

i. "...***reliable voice communications***…will continue to be the unequivocal highest priority for the public safety community";

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ii. "***strategic planning*** on a multi-jurisdiction, cross-agency basis eases the burden on individual jurisdictions and agencies by giving them a common framework...";

iii. "systems that allow data to be ***accessed from the field*** are valuable in a number of settings";

iv. "***visual data*** such as pictures, video and maps are increasingly complementing and being integrated with voice and text data";

v. "The importance of better ***situational awareness*** is illustrated by the observation that responders run the risk of becoming casualties themselves...";

vi. "***Context*** (including a user's location, task load, and environment) is critical to decision support and situational awareness".

The first point indicates that, for the near future at least, any new technologies are likely to be seen as adjunct to voice communications. NRC (2005) makes clear that there remain significant problems in using voice in areas that have been affected by disaster. In terms of network management, there is consideration of the use of 'cognitive radio' (Fette, 2006) to better manage dense communications across fragile networks.

We also note that, by and large, disaster management is concerned with managing resources in space and time, albeit in a 'space' that is hostile and risky, and under time pressure to remove survivors and victims. Before elaborating this idea, it is worth considering what we might mean by 'collaboration' in disaster management. To this end, we take a specific activity involved in disaster management, the identification of victims. Figure one shows some of the agencies that could be involved in the activities related to disaster victim identification (DVI) in the U.K. Once a body has been recovered, it needs to be properly and formally identified before it can be returned to its home country and family. Mistakes in DVI can have distressing consequences. Thus, there is a need to ensure accuracy in identification, which requires liaison between agencies working on site and agencies holding ante-mortem records, such as medical or dental records. From this one can begin to appreciate the NRC (2005) argument for the need for a 'common semantics' to support sharing of information. One can also begin to appreciate that 'collaboration' need not entail direct contact between all agencies at all times, but can involve exchange of information through a number of different routes.

Talks at the *Managing Disasters 2006* conference highlighted how competition between demands can come from different working practices, e.g., differences in collecting samples to perform dental analysis for DVI have implications for the management of work, and the preservation of bodies. Obtaining material and comparing this with patient records requires access to ante-mortem information (dental records); as a result of this activity, the body can be identified positively, and there is a need to track both the body and anything removed from it during the rest of the DVI process. During the tsunami that hit Thailand, there was some success in making such records available, in pdf, over secure web-access (Sweet, 2006). Thus, the digitization and exchange of ante-mortem information is being established in disaster management.

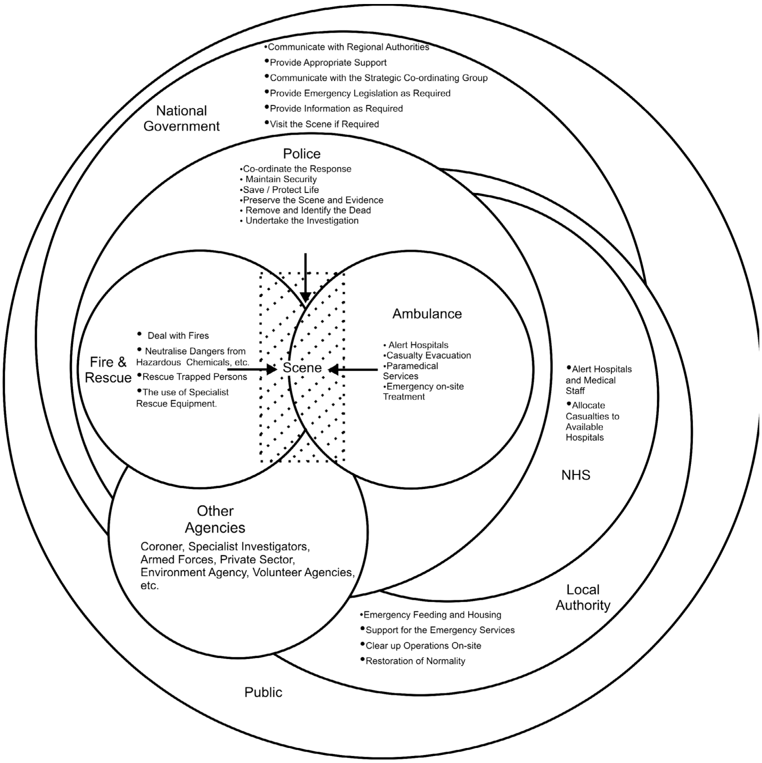

Fig. 1. Agencies involved in Disaster Victim Identification

2 Collecting Data in the Field

We agree that a fruitful line of enquiry can be found in the development of novel concepts in mobile and wearable technology to support disaster management in the field (Aldunate et al., 2006). As noted above, there is a need to provide some form of identification of material recovered and the body itself as it moves through the DVI process. There is growing interest in the use of radio frequency identification (RFID) for disaster victim identification (DVI). An RFID tag can be fitted to the body, and the tag updated with information as it becomes available. The RFID would most likely be placed inside the body (Meyer et al., 2006) or in the teeth (Thevissen et al., 2006) so as not to be either dislodged or damaged in processing or storage. Extending this notion a little, it becomes feasible for the RFID tags to also provide links to other information for the investigators, e.g., activation of a tag might call up a photograph of the body *in situ* prior to recovery.

As Raskar et al. (2005) suggest, placing RFID tags on artefacts in the world can support augmented reality in a manner that requires minimal interaction between person and computer. This will require additional descriptors of the data. A key descriptor of data collected in the field is its location. The obvious choice to support labelling of data in terms of location would be Global Positioning Satellite (GPS) systems. Often these data are combined with aerial views on GIS systems in order to support coordination of search and rescue teams.

In addition to sending data about location and artifacts, it can also be useful to provide some images from the scene. For example, in managing floods in the early 1990s in Leicestershire in the UK, a police officer said that he felt hampered by not having a view of the scene; if there had been video footage in the Silver Command Post, it would have helped with evacuation decisions.

If people pass images from the field to a command post, then there could be a need to label items of particular interest or have some means of categorizing incoming images. Wilhem et al. (2004) describe how mobile multimedia metadata (MMM) can be used to tag photographs taken with a camera phone. The MMM consisted of CellID (to indicate location), date, time, and UserName. This provides a basic metadata set that can be used to describe some aspects of the image. In our work, we use GPS (for location of the observer) together with the bearing of the object (from a digital compass). In addition to these data, we also provide an opportunity for the observer to provide simple coding of the image, e.g., in the form of selection from a pie-menu (Cross et al., 2005). Thus, annotation becomes partially automated through the use of sensors on the image-capture device (see figure two).

Fig. 2. View through the SmartScope Display

3 Implicit Collaboration

We have outlined a high-level view of disaster management, as the coordination of resources in space. From this point of view, it is not surprising that there is much work on adapting and extending Geographical Information Systems (GIS) concepts to disaster management. As Johnson (2000) noted, there are numerous uses of GIS to support planning, mitigation, preparedness, response, recovery, e.g., “A GIS can work in concert with GPS to locate each damaged facility, identify the type and amount of damage, and begin to establish priorities for action (triage).” (p.9).

Fig. 3. Digital Support for Joint Operational Picture[1]

This necessitates a system that maps the location, activity, capabilities, and movement of resources to be onto an accurate representation of the environment. In military terms, such a representation can take the form of a Joint Operational Picture (JOP). Figure Three shows an example of a JOP detailing scheme of manoeuvre and location of hostile and friendly assets, superimposed on a map of the terrain. The InfoOps Staff would update this JOP as information becomes available and to modify it in the light of new commands. The process of updating this display is, typically, manual.

One key difference between the actual role of the JOP in military operations and the possible role of such a 'shared view' in Emergency Response lies in the nature of the work being coordinated. One can assume that the JOP is often used to provide a shared view of the environment in order to effect some agreed upon action, e.g., move Forces into specific locations to defeat an enemy. This implies a 'Command Intent' that is shared by all Forces. In Emergency Response, it is feasible that there may be several 'Command Intents' (for each of the Services involved) and that, in some instances, these might conflict or, at least, might involve different interpretations of the environment. Thus, it is unlikely that a *single* JOP could be suitable for Emergency Response. However, it might be possible to provide different *views* on a JOP, i.e., such that each Service can view their own operations individually, but can also view the operations, locations etc. of other Services. This could provide both a means of overviewing the operations and also some support for implicit collaboration.

In disaster management, it is unlikely that people would (as yet) fill a specialist InfoOps role, and that most of the people on the ground would (initially at least) see themselves as 'rescuers'. This implies that action would involve local decision-making to deal with immediate threat or opportunities, and that providing reports of terrain, conditions, etc. could be some way from the first priority. Thus, we see a potential conflict between the needs to act swiftly and appropriately at the scene of the disaster, and the need to provide sufficient information to allow high-level coordination and management. Our research has been to develop devices that, on the one hand, provide intuitive, easy-to-use, rapid reporting capability in the field and, on the other hand, support strategic command of activity.

[1] http://www.defense-update.com/features/du-3-05/c4i-6.htm

4 Coordinating Search Activity

In terms of the sort of information that might need to be collected at a disaster scene, figure four shows the site of an air crash. The area is girded and the various parts of the aeroplane marked. Having a SmartScope in this context could provide a means of rapidly acquiring this information. The inspectors would take a photograph of parts *in situ*, and using the rotary menu to categorise the parts. This information (converted to XML) is passed to a control post and combined to provide an overview of the site. Inspection of this overview can be performed either globally or in terms of specific categories, e.g., all items classified as 'cabin seating'.

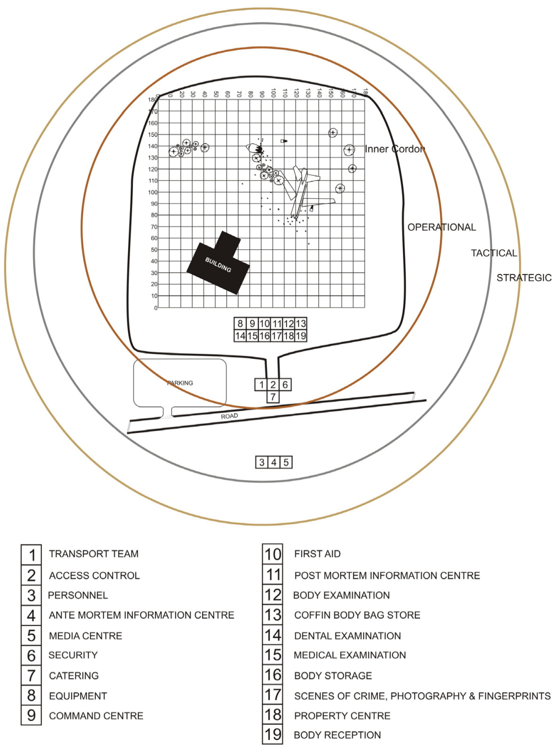

Fig. 4. Performa report for aircraft accident investigation (Adapted from Interpol, 1997)

In order to construct figure four, one needs to define the environment in terms of a search grid, to allocate areas to searchers, to record finds as accurately as possible against the grid and to determine areas that might require special search efforts. In a 'traditional', i.e., non-technological approach, this process might involve briefings at which searchers are gathered to receive instructions or to report back. This can be a time-consuming process and one which could benefit from real-time sharing of information. However, having people provide information to a command post whilst they are searching could prove disruptive and irritating. Thus, we suggest that it could be useful to have some means by which salient data can be collected without distraction from the search and recovery tasks.

An analogy with the use of 'data link' between aircraft pilots and Air Traffic Controllers (Acts); much of the communication between ATC and aircraft can be seen in terms of reporting location and bearing. Using data link to automate this exchange frees the communication channels in what can be a very busy network for more important communications. Figure Five shows an application in which a person in the field uses sensors to conduct an initial search (in this case, we use a simple system comprising a metal detector coupled with Global Positioning System to indicate finds and their location). Results of user trials with this equipment showed that, in well-defined search tasks conducted in stable environments, the datalink led to significantly superior performance over speech communications, but that as either the search task become more ambiguous or the environment more complex, the advantages of datalink were reduced (Baber et al., 2005).

Fig. 5. Searching for Targets using metal detector and GPS linked via WLAN to command post

4.1 Defining Search Patterns

Having established the path that search activity can take, it is possible to allow the commander to interact with this search by drawing paths on a whiteboard in the command post (see figure six). Interactive whiteboards are receiving increasingly serious consideration across a range of emergency services (see figure seven). For the most part, their use tends to be on the recording of data and manipulation of images on the display. In our work, a path drawn (by hand or with a pen) is converted into coordinates and used to compare the actual movement of agents in the field (defined by GPS) against this desired path. Deviation from the path are flagged up and converted into simple messages to the searchers. The messages are not unlike those used in car navigation systems, but their origin lies not in the computer planning a route but in the intention of the search coordinator.

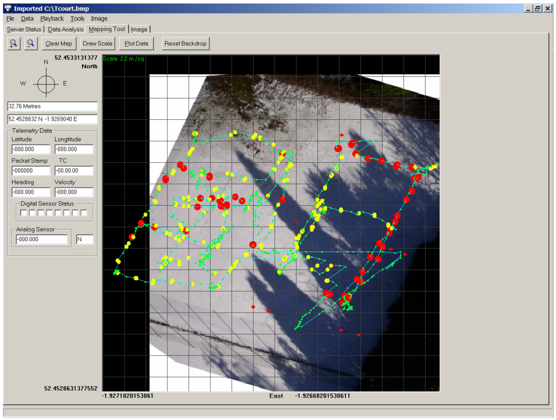

Fig. 6. Commander's view of the search activity. The figure shows the path being followed, together with search actions (light dots) and identified objects (dark dots).

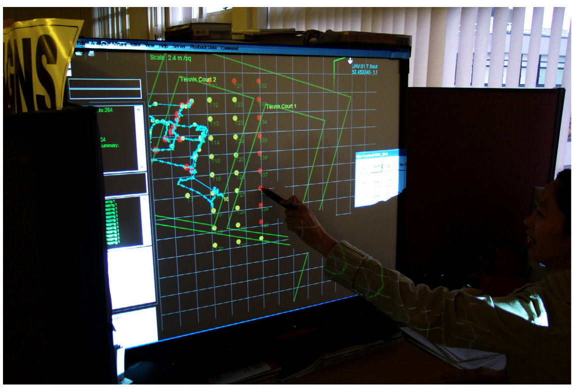

Fig. 7. Defining a search path for agents in the field

5 Collaboration Through Annotation

So far, we have considered ideas of providing images with some meta-data tags, or sketches on images to manage activity. This provides some capability to annotate the image, albeit in a basic manner. However, as Boujut (2003) notes, the practice of annotation is often subordinate to verbal discussion, especially in desktop systems. For example, an annotation is used to point to a feature that the person is talking about, or speech is used to explain the nature of a given annotation. If annotation of images collected at the scene is to be used to support coordination, then a better understanding of the manner in which these practices arise and are used is needed. Boujut (2003) suggests that, over time, the annotations form a ‘shared repertoire’ within a given community of practice. The use of standardized annotations on images could also provide additional support to organizations that use a variety of different languages.

Previous work has demonstrated that providing participants with a tablet-PC and software that allows images to be annotated can improve performance on the recording of archaeological finds (Cross et al. 2003). In this work, images were captured and then layers of annotation added to define different categories of interest. The results suggested that people found it quicker and easier to annotate a photograph than to produce sketches. However, this raises two associated questions for the use of annotation to support collaboration: (i.) was there a difference in the usefulness and accuracy of the resulting drawings? and (ii.) was it possible to use the drawings to support collaboration? In order to explore these questions, we developed a system that ran on Wireless Local Area Network (WLAN) and that allowed the observer in the field to capture an image, annotate it and send the annotated image back to a command post. The commander could then view the annotated image and, if necessary, provide additional annotation or comment. Figure eight shows the user interface at the command post. This shows (from left to right) a set of command options, the annotated image and a text box containing details or chat, the original image and a map showing the location at which the image was captured.

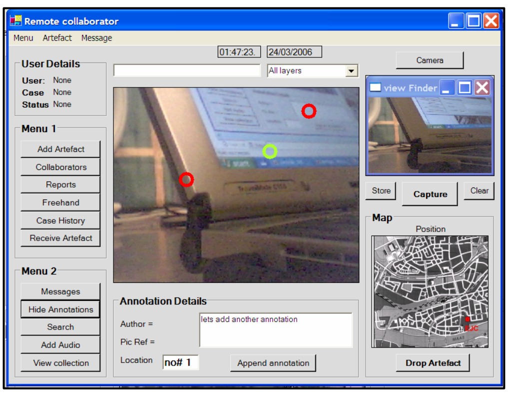

Fig. 8. User Interface on Server

A user trial was undertaken to explore elementary usability issues associated with the use of a networked annotation tool. In this trial twelve students of engineering were required to visit five specified locations, capture an image at each location and add annotation to the images in order to answer specific questions. Their performance was measured in terms of time to complete the tasks and in terms of subjective rating of the ‘accuracy’ and ‘usefulness’ of the annotations. The study compared performance using the computer-tool with similar activity using paper.

The results of the study show that the initial collection of the image was significantly faster when using the computer than when using paper [$F(1,4) = 52.337$, $p<0.001$], which is primarily due to the difference between taking a photograph and producing a sketch. However, (interestingly) there was no difference in time to complete the annotations on the computer or on paper (although this involved very different activities in the two conditions). Finally, the transfer of information from the field was faster with the computer, because the annotated image could be sent over the wireless local area network whereas the paper needed to be transported to the laboratory. Thus, the general pattern of performance results fits that of previous studies in showing that the use of the computer leads to faster performance. However, we also considered the usefulness of the resulting images and annotations and found that the rating for usefulness was no different for the computer and paper conditions, but that the paper condition produced higher ratings of accuracy than the computer [$F(1,4) = 10.631$, $p< 0.001$]. This latter finding could relate to the degree of level of detail that the user could add with the pen-based computer, particularly in terms of hand-written notes and labels, but would probably improve with higher resolution displays. Finally, participants were asked to rate their subjective workload using the NASA-TLX and it was found that the paper condition lead to higher ratings for temporal demands, effort and frustration. This is illustrated by figure nine.

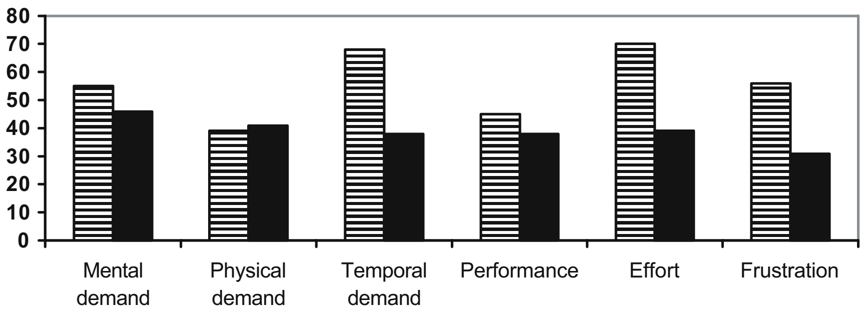

Fig. 9. Workload ratings from NASA-TLX (paper as horizontal stripes; tablet as solid blocks) [NB Lower rating is better]

6 Discussion

If much of the management in a disaster involves the coordination of resources in space, then having some concept of how coordination is performed and can be supported would be useful. In recent years, ‘coordination theory’ has been proposed as way of conceptualizing some of these issues (Malone, 1988). For example, Malone and Crowston (1994) define coordination as the process of “…managing dependencies...” This is an interesting perspective in its focus on dependencies between activities or resources or agents, rather than simply the matter of ‘arranging people to perform functions’. One implication is that these dependencies can be organized hierarchically, e.g., goals decompose to strategic objectives; inventory decomposes to components.

In a useful analogy, Malone (1988) likens coordination processes to the use of contracts in business: an announcement for specific work is made; agents bid to undertake that work (on the basis, say of their skill sets, their availability, their location etc.); a decision is made to award the work to specific agents and the work is performed; the result of the work is reported. In terms of coordination of mobile response, this analogy can be applied almost intact. At a disaster scene, there is likely to be an influx of people willing to provide help during rescue and recovery operations, and this requires some means of coordination to ensure that not only all aspects of the work are appropriately resourced but that any potential conflicts are resolved as smoothly as possible. The suggestion is that agents ought to be in a position to recognize those dependencies that most affect them and seek to organize activity through constraint satisfaction. While this might sound implausibly democratic, there remains a need to exercise higher-level command in order to optimize constraints for the good of the overall system rather than for each clique.

In this paper, we have considered disaster management in terms of the coordination of resource in space, and suggested that developments in technologies that can be carried, or worn, and used in the field, could provide enhancements to coordination and collaboration. Our intention is to highlight ways in which new technologies can provoke new ways of thinking about the process of inter-agency collaboration and the many organizational challenges facing disaster management. We suggest that one way of thinking about the 'common semantics' requested by NRC (2005) is to think about ways in which GIS technologies can be supported by mobile and wearable devices in a way that support implicit collaboration between agents in the field.

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AMIRA: Advanced Multi-modal Intelligence for Remote Assistance

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Abstract. AMIRA provides a multi-modal solution that significantly improves the accessibility and resources available for supporting urgent and critical decisions that must be taken by mobile workers, operating individually or in multi-discipline collaborations, at their point of intervention in an event. By integrating reusable search components and collaboration methods, the AMIRA platform has been used to create various multi-modal applications for use by mobile workers operating in safety or business critical situations in the field. The analysis of proof-of-concept applications tested in the field produced evidence demonstrating that AMIRA added value to the decision making process by providing information that is not currently available through existing support mechanisms.

Keywords: Search, collaboration, multi-modal environment.

1 Introduction

AMIRA is a pan-European research and technology development project with the aim of providing rapid, relevant and reliable time-critical information to support urgent and critical diagnostics and decisions that must be taken by 'mobile workers' (such as incident commanders or vehicle repairers) at the point where they are undertaking their work.

Such a mobile worker may have to diagnose the source of a problem. It may be a rarely experienced problem, or at least something not seen before in either training or experience. The criticality of the situation may range from simply one of time, to a life-threatening emergency. In order to identify and resolve the problem encountered, such a person needs access to multiple sources of information, provided in a meaningful way via a mobile processing and communications device with at least speech input and possibly a hands-free kit to connect to an interactive system. Today, such an intelligent, intuitive system does not exist. The overall goal of AMIRA is to provide just such a solution.

Four proof-of-concept applications have been tested in real situations during several months: vehicular road-side assistance for the Transport Engineering Works of West Midlands Fire and the Civil Defence Authority (business-critical environment) and support for incident commanders within various UK and Swedish emergency fire services (safety-critical environment).

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This paper introduces the AMIRA vision and technologies, and presents an analysis of the trials performed on selected end-users' applications.

2 The AMIRA Vision

The AMIRA vision incorporates agent technologies for supporting mobile workers: Case-Based Reasoning (CBR [2], [3]) and full-text search [5] – representing the ‘information agents’; CSCW (Computer Support for Co-operative Work [6]) – representing the ‘moderator agent’; and Speech [4] or Graphical Dialogue – representing the ‘user agents’. Whereas the reasoning and search components deliver the intelligence of the system, the speech/graphics components provide the end-user interface - enabling the mobile worker to access the information and knowledge retrieved by the 'intelligent' components of the system. Through agent technology, the CSCW component acts as a hub, providing support for collaboration between components, between users and components, and between users and users.

The various components do not act separately from each other. One of the key aspects of AMIRA lies in the development of integration methods sufficiently powerful to reconcile the incompatibilities in data types and representations between the different reasoning and search components, and to use the incoming/outgoing user agents.

3 Technology Description

3.1 High-Level Architecture

AMIRA does not deliver a specific application but a library of loosely coupled reusable components (see [1] for a more detailed presentation of the underlying technologies and their integration). The backbone of the AMIRA platform integrates four key technologies: case-based reasoning, free text search, speech dialogue and collaborative agent's technologies. AMIRA combines the various components to enable the creation of diagnostic and decision support applications, focusing on processes and solutions for the management of critical incidents, emergencies or disasters.

The term 'loosely coupled' means that the individual components – CBR, search, user dialogue or collaborative working – are not tightly bound together as an inseparable whole, but rather can be used in a mix-and-match manner offering a great diversity of application and solution potential, for example:

- By coupling speech dialogue with search and reasoning technologies, structural CBR drives the intelligence behind the dialogue, generating the questions to be automatically answered.
- By coupling CBR and free text search, the AMIRA platform can deal with both structured and unstructured information repository, optimise the retrieval accuracy of free text search, and minimize the effort required for building the initial model.

The overall AMIRA architecture, illustrated below, shows the interaction between the users of the AMIRA platform. Acting as moderator, the CSCW component manages the user's input and interactions and provide them the adequate information from the various search engines.

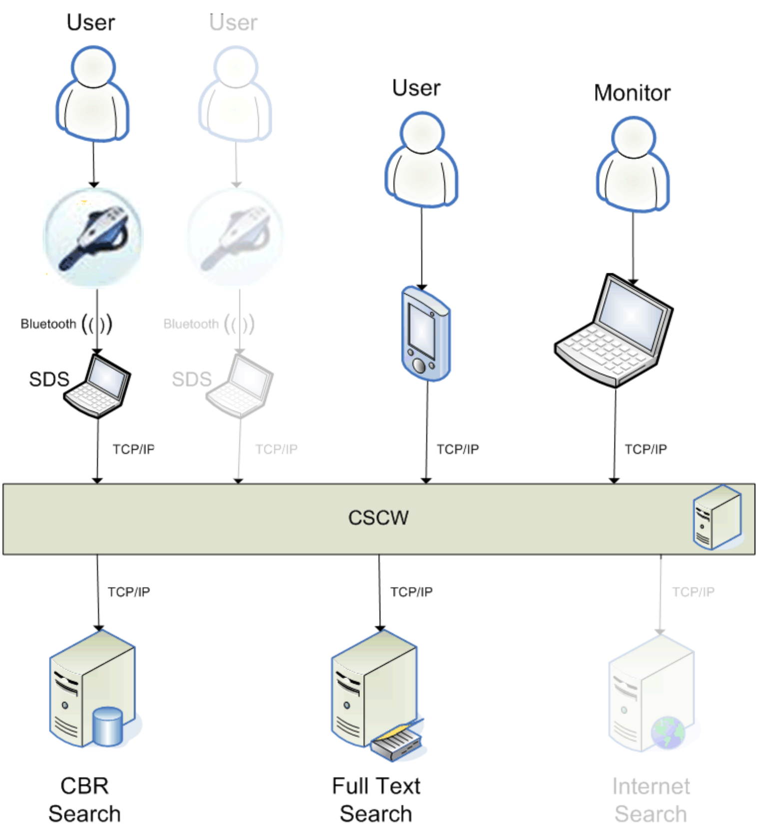

Fig. 1. High-level architecture of the AMIRA platform

The mandatory components for this architecture are:

- The CBR engine, which is used to build, maintain and retrieve information inside the knowledge base;
- The search engine, which aims at building, maintaining and indexing the corpus of textual information;
- The client agents (speech dialog system or dedicated GUIs for PDAs, laptops or mobile phones), which provides access to the knowledge resources to the mobile users;
- The collaborative workflow environment, which triggers the end-users queries to the various knowledge sources through collaboration patterns.

The usage of these components is detailed in the next section.

3.2 Component Library

CBR is a knowledge-based technique that reasons from prior experience, trying to answer the question: “has anyone ever seen a similar case before, and if so what decision was made?” Traditional CBR technology requires that information be structured (using a domain model or ontology). AMIRA has developed semantically-based and context-aware systems that can acquire, organise, share and reuse knowledge in structured and unstructured format. The extended CBR engine has the ability to process trends in data, in order to be able to identify and recall cases with similar parameter shifts. In addition to these enhancements, AMIRA has coupled CBR with search techniques in several aspects so that the combination will benefit from the best aspects of both techniques. AMIRA has also coupled CBR with grammar-based speech dialogue to enable speech ‘self-service’. While the platform provides speech dialogue, the task of creating a ‘decision-tree’ like structure to drive the dialogue is very important. CBR in AMIRA drives the intelligence behind the dialogue and automatically generates the questions to be answered.

State-of-the-art in industrial strength, the *search* component is characterised by data scalability, real-time indexing, linguistic analysis in a wide range of languages and highly expressive relevance models. To widen the applicability of these advanced search technologies, AMIRA has developed analysis and correlation techniques for advanced searches in real-time based on scaleable CBR principles. AMIRA has also applied, configured and validated these techniques using a wide variety of information sources from the selected scenarios: AMIRA-TEW (the truck repair casebase) and AMIRA-FIRE (the fire incidents casebase). This is in order to build an index of the documents based on their respective domain model.

Although many commercially available *speech dialogue* techniques exist today, in general the dialogue is reactive, insomuch as it is driven by human responses to questions rather than being proactive in using past experience intelligence to drive the dialogue. To enable such a proactive, intelligence-driven dialogue, AMIRA has created semantic space matching surface expression semantics with underlying task specific descriptions. This approach not only allows for a wide variety of acceptable user expressions, it also makes the system largely language independent in the sense that surface language for both input and output can be changed irrespective of the internal representations. In addition, AMIRA has implemented dynamic dialogue strategies allowing for appropriate dialogue behaviour for different levels of expertise, co-operation and environmental conditions, from noise levels to transmission problems. In the open field, robustness at all levels is crucial for usability. The dialogue system runs exemplary dialogues in two domains: The AMIRA Fire domain and the TEW domain. It is worthwhile to stress that these different dialogue models and their different behaviours all run under the same system. It is sufficient to re-start the local speech dialog system client using different initialisation files to switch from one domain to the other. AMIRA has also implemented other client systems, ranging from a standard HTML GUI to specific GUI dedicated to PDAs and mobile phones.

Surrounding the three key technology strands of AMIRA (speech, reasoning and search) is the moderator support for sharing information and communicating effectively. The CSCW provides technological support for implementing workflows, sharing information and communicating effectively. AMIRA has seamlessly integrated knowledge technologies into the collaborative work, thereby adding a knowledge layer with new intelligent services on top of the agent infrastructure. AMIRA has also expanded collaboration beyond the co-operation of humans, by including proactive services (based on CBR and search technology) that feed knowledge relevant to the current work context from heterogeneous sources. Introducing knowledge-based technologies optimises collaboration patterns (as discussed in the next section) and workflow in general, through reuse of best-practice experience. The AMIRA CSCW component is realised through a Collaborative Agent-based Knowledge Engine (CAKE). CAKE is a general domain-independent architecture that can be used for developing a wide range of applications. It provides a very general data and process model that can be expanded by domain-specific data classes and processes, leading to domain specific ontologies. Therefore, an editor, the CAKE Editor, is available that allows users/knowledge engineers to create, edit and to view the domain model.

3.3 Collaboration Patterns

In order to support the working processes of the mobile workers, AMIRA delivers a dynamic pool of agents whose interaction is managed by the CSCW system. Two specific types of agent are necessary to handle the dynamicity of the targeted scenarios: User-agents and information-agents. User-agents are the technical interface to humans such as mobile workers (including, for example, incident commanders and vehicle repairers). Conceptually, the humans are part of their corresponding user-agent; consequently, they can log in and log out dynamically so that the pool of agents is not fixed, but highly dynamic. Information-agents provide contextual information about the application domain, such as the CBR or search engines. The knowledge containers that they use are part of the information-agent. Technically, each agent consists of a technology component, such as a speech dialogue system in a user-agent or a CBR/Search engine in an information-agent, and a CSCW-Wrapper that realises the connection between the CSCW system and the technology component's specific interfaces. Additionally, a reporting-engine acts as an additional information-agent. The CSCW system acts as a moderator and information router among all agents and supports the communication between them. The choice of an adequate combination of agents is performed dynamically through a set of so-called competence profiles organised in various collaboration patterns. The CSCW uses the CBR engine for searching the collaboration patterns that matches best the current context of the targeted scenario.

The following figure offers a generic idea of the different types of information agents that are available for the AMIRA scenarios:

- *CBR 1* is working on one database;
- *CBR 2* and *Search 2* are using the same database;
- *Search 1* is working on one database;
- *Experts* represent internal fire fighters or officers who are logged in the AMIRA system and who can be requested for information;
- All available *external experts* are also represented by competence profiles.

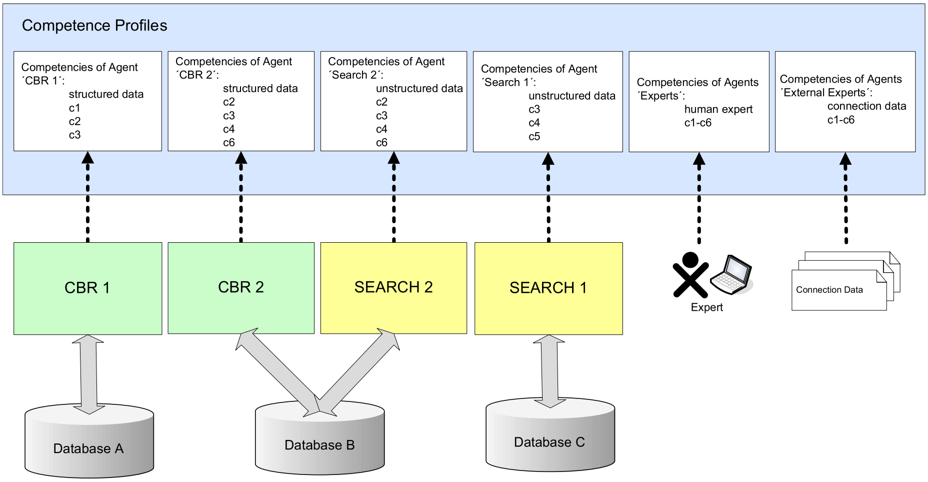

Fig. 2. Best collaboration patterns are dynamically constructed by selecting available competence profiles in order to support the working processes of the mobile workers

4 Results

4.1 Selected Scenarios

In order to assess the effectiveness of the AMIRA concept, two specific domains were selected to create and trial a proof-of-concept application. The application scenarios used to validate AMIRA were:

Safety-critical: Professional search and rescue operatives (fire-fighters) in the emergency services sector. Operatives work as part of a team, in often very dangerous situations, supported at the scene by incident command personnel and remotely by a command control station.

The *first selected application* scenario was based on a real-world incident that happened in early 2004, where many thousands of plastic crates were deliberately set alight by a gang of youths. The crates were made of polypropylene, which has very particular characteristics when ignited. If the blaze is not dealt with in the correct manner, then burning polypropylene will quickly get out of hand, increase in temperature and spread. Due to the lack of experience in the fire crew dealing with a polypropylene blaze, incorrect techniques were used in an attempt to extinguish the fire, resulting in very extensive property damage and the need to continually call for reinforcement fire tenders and crews, leaving the region with a much reduced service to deal with other emergency calls.

The *second scenario* selected involved a road traffic accident resulting in a vehicle fire on a major highway. Upon investigation by the fire service officers, the vehicle involved is found to contain explosives. Explosives are normally transported in well-controlled and regulated ways. However, no matter how good this regulation is, there will be occasions when the explosives will become an additional hazard, for example following a road accident or if the carrying vehicle catching fire. This scenario replicates a real world event some years ago where fire crews attended what appeared to be a simple vehicle fire. The vehicle carrying explosives was on fire and the resulting detonation killed one fire fighter and severely injured other members of the crew.

Business-critical: A field service technician in the transport sector who has to diagnose and remedy a vehicle fault at the roadside. This is a cost-related business critical situation as the vehicle must get back on the road as quickly as possible. The broken-down vehicle may also be creating a dangerous situation, increasing the criticality of a fast repair.

The *first scenario* selected involved a gearbox failure in a fire engine at the scene of an incident. In this scenario, a Dennis Sabre fire appliance has been engaged in pumping water at a fire. When the vehicle needs to be moved after the fire has been extinguished, the driver cannot engage a gear to drive the vehicle. The TEW technician is already in attendance at the incident because it is routine procedure to mobilise them to large incidents to provide technical support for the equipment. He attends the stricken vehicle and cannot diagnose the problem from knowledge he has already acquired during his limited experience. AMIRA is used to provide the diagnosis of the problem, to provide the guidance needed for the technician to repair the vehicle, thereby ensuring the vehicle is back on the road as quickly as possible, enabling it to respond to subsequent emergencies.

The *second scenario* selected involved the operational failure of the Holmatro cutting equipment used by the fire services to remove parts of a vehicle in order to rescue a person or persons trapped inside. In this scenario a user has reported slow operation and a strange noise coming from a cutting tool whilst in use. The repair technician has attended the station and again is unable to diagnose the problem from acquired knowledge. AMIRA is used in this scenario via a Graphical User Interface (GUI) to demonstrate an alternative user agent. AMIRA provides the diagnosis for this problem from service documentation and prior experience from other technicians.

4.2 On-Site Trials Methodology

The assessment of the proof-of-concept applications was based on user criteria determined in terms of usability; appropriateness to the operational need; innovation; efficiency and cost-effectiveness in comparison to existing methods.

The evaluation was performed through:

Debriefs – carried out at the end of each incident to gather the users' immediate feedback. The debrief followed a structured methodology. The debrief also include the crews/technicians at the incident, whose actions should have been informed by the outputs of the AMIRA system.

Interviews – on a one-to-one basis. Questions were designed to interrogate user needs and the value added context of the AMIRA system. When appropriate, questions were also used to capture new 'units of experience'.

Questionnaires - were used to collect information from users who are unavailable for structured interviews. A single question set was developed and used as the basis for all these methods of data collection. For the purposes of analysis, the various questions were grouped in categories, each category being related to one specific measurement criteria. The questions were scaled to enable the data to be analysed more easily.

Measurement – the evaluation of the data collected focused on the direct impact of the use of the AMIRA system, e.g.: did it help? How did it help? How did that inform your decision-making? What did you do differently because of the AMIRA system information given to you?

The trials were performed in the UK between February and May 2006, involving the Fire Service College, Avon, Gloucestershire and West Midlands Fire Services, WMFS Transport Engineering Works. Additional trials were performed in Stockholm at the Swedish Fire Service Academy. In total, some 1,350 person-hours were spent by the end users in trailing the AMIRA applications. This included the effort of 44 fire fighters, 6 control room staff, 6 repair technicians (from WMFS-TEW), and 30 Swedish fire officers.

4.3 Infrastructure and Organisation

In terms of infrastructure, effort and time spent, the most challenging scenarios were performed for testing the safety-critical scenarios by the fire fighters and fire officers. In summary, the physical infrastructure involved:

- An input device, that ranged from a standard web browser on a A4 size tablet PC, to more specific GUIs working on a mobile phone, a PDA, and even a PSP, and to a speech-enabled wireless headphone;
- A local software client depending on the input device;
- A local computer, connected through blue-tooth or WiFi to the input device. In practice during the trials, the local computer was installed in the fire fighters command vehicle, or directly in the repair shop for the TEW scenario;
- A GPRS link between the command vehicle and the CSCW server (installed in Germany). GPRS connection through a satellite dish is standard within the fire brigades who participated to the trials;
- A standard Internet connection between the CSCW server and the information servers (CBR server in France, search server in Norway).

A significant amount of time was spent during the early phases of the trials to specify and test the right hardware and communication environment so that the system could be used both securely (no loss of transmission), while preserving communication speed (maximum of 5 seconds for each interaction).

4.4 Evaluation

Since the trials were performed merely by fire fighters, the most feedback received was of a practical nature. The final results of the trials showed that:

- Trials in both simulated environments (through the Fire Service College) and in 'live' environments (through Avon Fire and Rescue Services & West Midlands Fire Services) produced evidence demonstrating that AMIRA added value to the decision making process by providing information that is not currently available through existing support mechanisms. Emergency responders indicated that this added to both their own safety and involved victims/assets protection as incidents are brought to resolution.

- The usability of the system was acceptable, but to make it more easily applicable to busy hands, busy eyes environment, the hardware used needs to be developed further to provide a more compact package which is better integrated.
- The needs of the operational environment were met appropriately by the provision of knowledge previously unknown to most, captured in the CBR component. This was further added to by augmenting the knowledge with appropriate information from the search component.
- The innovative approach taken by AMIRA added value to systems currently used by or in development by UK Fire Services by adding knowledge to the information, and by making this available directly to the incident commander, without the need to return to the vehicle.
- In summary, the results indicated that in the majority of cases, users thought that information provided by AMIRA would bring incidents to a more effective conclusion and provide for improved crew safety. This will increase efficiency and provide a more cost-effective service to the communities which they serve. Strategic managers saw this from a different perspective and were intrigued by the possibility of providing experiential knowledge and supporting information to ICs. They see the emergency response environment as one where organisations are exposed to corporate risk.

From the point of view of the industrial and scientific partners, the results demonstrated the capacity of complementary search techniques, both structured and unstructured, to collaborate in a unique framework, and to provide contextual and adequate support based on collaboration patterns. An important aspect was to deliver a "light" interaction of the various components of the library, rather than just a unique and rigid tight integration. Working with audio-to-text and text-to-audio technologies has allowed the acquisition of crucial experiences in building solutions that operate in combined audio and text environments. Finally, AMIRA enabled the evaluation of various technical and practical opportunities for designing and building decision support systems for the public safety market and to build real-size trial applications.

5 Conclusion

The business achievements of AMIRA are two-fold. For the industrial partners of the project, benefits include the improvement of the individual underlying technologies, opening new capabilities and new markets for their products. For the end-users, such as incident commanders and mechanics, the prototype applications developed in AMIRA are a first step towards the use of a new generation of intelligent, real-time diagnostic and decision support system, using multi-modal wireless devices such as earphone/microphone, PDA or UMTS telephone. For the fire services in particular, AMIRA is viewed as an essential solution to assist the first-on-the-scene incident commander, who may not have the experience or know-how to accurately assess a developing situation. Providing better, more accurate and timely information would help reduce incident escalation and subsequent human and economic loss.

AMIRA paves the way towards a new generation of wireless, user-friendly, intelligent, real-time diagnostic and decision support applications for mobile workers operating in safety or business critical situations anytime, anywhere, through a collaborative platform.

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SaR Resource Management Based on Description Logics

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Abstract. The management of resources is a great challenge for commanders in Search and Rescue operations and has a strong impact on all areas of operation control, as command-and-communication structure, geo-referenced information, and operational tasks are inter-connected with complex relations. During an operation these are subject to dynamic changes. For an efficient operation control commanders need access to up-to-date information in their mobile working environment. This paper presents a new approach to manage resources and their relations in an operation. It is based on ontologies to build a model of an operation and Description Logic reasoning to provide enhanced decision support.

1 Introduction

Search and Rescue (SaR) operations are characterised by well-established structures concerning command, control and communications, spanning the whole range of units and tasks involved in the operation. For a more descriptive scenario this paper focuses on fire brigade operations. As a result of national regulations a wide range of personnel is included in such operations. German fire brigades (professional and volunteer) and emergency medical service are organised on urban level and are under the same supervision and control. Rescue service and civil protection are overtaken by national or private organisations.

Under these circumstances the *Resource Management* in terms of control and organisation of heterogeneous personnel, vehicles and equipment within large scale operations means a great challenge. Resources must be managed by building formations, setting geo-references and assigning tasks with respect to qualification. Thus complex relations are created and dynamically re-arranged, e.g., depending on the size of the incident or its progress. Thereby information is implied which can enhance operation management and decision support.

This paper is organised as follows: It first introduces the structure of SaR operations of the German Fire Brigades and its modelling with Description Logics, a logic formalism for representing ontological Knowledge Bases. Subsequently, a

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logical and computational infrastructure to utilise Description Logic reasoning for operation resource management is presented. Based on the impact of resource management for SaR operations the application in the dynamic environment of operators and commanders is presented. The paper concludes with a discussion of the proposed system's advantages and shortcomings and a mention of possible improvements and extensions.

The work described here is part of the IST project *SHARE: Mobile Support for Rescue Forces, Integrating Multiple Modes of Interaction.* It is intended to offer an information and communication system to support emergency teams during large-scale rescue operations and disaster management.[1]

2 Search and Rescue Operations

The backbone of an operation is the communication between the forces and adequate information to support decision-making processes. Operation control can be cut down to the management of actions and the acting units, vehicles and persons. Therefore adequate techniques have to be utilised [1]. Nowadays radio messages and paper-based message exchange have obvious problems in information loss, time efficiency and documentation possibilities. Sets of maps and plans which are in most places still used in paper versions constrain the usage and information supply. Magnetic boards are used in order to place tactical symbols and draw additional notes and sketches. This established method often causes problems concerning clarity. For this manifold set of tools it is obvious that there is no chance to build up on a common data or knowledge base. Information is available in incompatible physical formats and spread over the different command cars and units. Although some stand alone ICT solutions exist for map application, messaging and documentation this problem is still not solved.

Explorations in the field of SaR show that there is a defined and very strong relation between communication and information [2]: communication is needed on the one hand by speech and forms, on the other hand by exchange of operational data. This leads to the needs in information support which can be divided to static data and dynamic information. Especially communication to provide this dynamic data to specific operating units is a foundation for efficient operation control. Thereby resources are one of the most important objectives, either referenced directly or indirectly. Operating officers are on the one hand part of the resources, on the other hand prospective system users. Thus their command levels have to be taken into account (see figure 1). In most cases a differentiation of three command levels is defined. The most common terms for the three command levels are *A–B–C Level* or *Gold–Silver–Bronze*, corresponding to the strategic, tactical, and operational level, respectively. The complex relations of resources to communication channels, geographical sectioning and task assignment build a high information potential which can hardly be utilised by currently used media.

[1] Please see `http://www.ist-share.org/` for more details about the SHARE project.

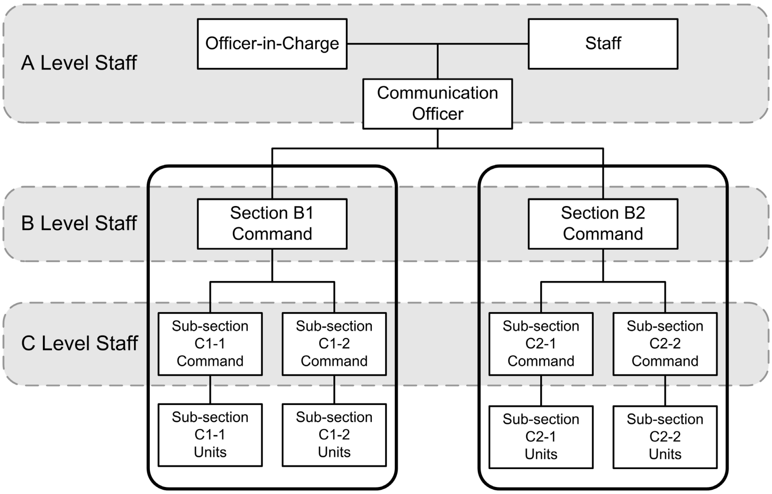

Fig. 1. The command-and-communication structure of a SaR operation

3 Logical and Computational Infrastructure

The resource management system described here relies on Semantic Web technologies in order to model the operation, derive inferences from the model, and provide for the interaction between the (inferred) model and the resource management application of the end-user.

The operation is modelled as an *ontology*, an abstract representation often used in the areas of Knowledge Representation, Artificial Intelligence and the Semantic Web as a way of structuring and representing knowledge. *Description Logic* reasoners are used to deduce knowledge that is implicit in the model; ontologies and Description Logics are two technologies that are developed in parallel. They are closely inter-dependent as the reasoner must be able to act upon the structures provided by the representation formalism and the latter must be able to represent the structures supported by the former.

Finally, the explicit model and the implicit (derived) knowledge is made available through a data service that exposes a web-service interface to the knowledge base. End-user applications access the web services over the SHARE system's mobile network infrastructure.

3.1 Ontology Representation

The elementary pieces of information in the ontology—corresponding to the individuals of the domain of discourse—are called *instances*. Instances are organised in a conceptual hierarchy (a taxonomy), where each *concept* (sometimes also called *class* or *frame*) groups together a set of conceptually similar instances.

Concepts are defined by the *properties* that their members must carry to be admitted as members. Such membership rules might be necessary but not sufficient to guarantee admittance, or they might be necessary and sufficient. Concepts with membership rules of the latter kind are called *defined concepts:* in these concepts, instances that are not explicitly included might be admitted through inference based on the concept's definition. Concepts, on the other hand, where explicit inclusion is the only ticket to admission are called *base concepts.*

The concept hierarchy is a *subsumption hierarchy*, where super-concepts include all instances of their sub-concepts and possibly some more. It is also an *inheritance hierarchy* where instances of sub-concepts have all the properties of their super-concepts, and possibly some more. Properties are either *relations* between two instances or *data properties* (or *attributes*) that link a single instance with a concrete value, like a number or a string. Relations can also be placed in a subsumption (inclusion) hierarchy.

It is a strong desideratum that ontology structure and instances be represented in a formalism that is both machine and human-readable. The most recent development in ontology representation is the Web Ontology Language (OWL) [3], defined within the Resource Description Framework (RDF) [4]. In short, RDF represents knowledge as triples which combine a pair of objects with a predicate. OWL is a series of increasingly expressive RDF languages: OWL Lite, OWL DL, and OWL Full. OWL Lite and OWL DL have the important property of being compatible with Description Logics (DL), a decidable fragment of First-Order Logic, which facilitates reasoning over the ontologies represented in either of these two formalisms.

The SHARE system uses OWL DL in order to ensure compatibility with DL reasoning engines. OWL Lite representation would have been advantageous from a computational point of view, but not applicable to SHARE, as it would omit important aspects of the operational model.

3.2 Description Logics

Description Logics (DL) are a family of formal logic formalisms for representing knowledge. The most fundamental common characteristic of all DLs is that they are dyadic first-order logics, i.e., they are within the fragment of first-order predicate logic expressible by up to two variables per clause. This very restrictive limitation makes DLs compatible with the RDF framework, which represents knowledge as predicate–object1–object2 triples. Furthermore, it has the important computational property of being decidable, where full first-order predicate logic is not.

A DL knowledge base typically comprises two components: the TBox and the ABox. The *TBox* contains the terminology of the domain in the form of declarations that describe general properties of concepts. The basic reasoning service of the TBox is subsumption, which is used to (a) check that a concept does not necessarily denote the empty concept (satisfiability) and (b) classify new concept expressions in the proper place in a taxonomic hierarchy of concepts.

The *ABbox* contains factual knowledge regarding the particular problem at hand and is specific to the individuals of the domain of discourse. The basic reasoning service of an ABox is instance checking, which decides whether a given individual is an instance of a specified concept. Instance checking is the underlying operator under a number of facilities, like *consistency checking* (i.e., verifying whether every concept in the knowledge base admits at least one individual) and *realisation* (i.e., identifying the most specific concept an individual is an instance of, based on the individual's properties).

3.3 SHARE Ontology Data Service

SHARE-ODS, the SHARE Ontology Data Service, is a comprehensive data and knowledge service for the SHARE system [5]. Explicit data about an operation and domain knowledge is represented in an OWL ontology as instances and axioms, respectively.

The model of the operation is organised as a number of sub-ontologies. Most central to the work described here is the SaR ontology, which holds all knowledge pertinent to the unit, command, and communication structure of the operation, personnel assignment, unit deployment, assignment of tasks and geographical areas of responsibility to units, etc. In addition to the SaR ontology there is a Multimedia ontology (communication objects exchanged during the operation), and the auxiliary Time and Space sub-ontologies that represent spatio-temporal references and actual geographical features (buildings, streets, etc) present at the theatre of the operation. All sub-ontologies are tightly integrated in a comprehensive model of the operation and extensively cross-linked.

Fire brigade rules and practices with respect to operational structure are encoded as ontological axioms in the SaR ontology. A particular operation's compliance is checked by a Description Logic reasoner. Access to the ontology and the reasoner's conclusions is provided though Web Services that use SOAP messaging [6] to export functionality to populate, update, and query the SHARE knowledge base.

4 Dynamic SaR Resources

The investigation of SaR resource management has to be based on the operational workflows. An emergency call defines parameters like the incident type, time and geographical information and affected human beings. Based on that an initial set of resources gets alarmed. Therefore two sources are utilised: Information about available units and a set of general rules, laws and regulations. During an operation the incident can change, units must be re-organised, personnel substituted after a certain duration and special forces deployed. These exemplary reasons require intelligent operation control support at the fire site. According to [7] the responsible instance is the Officer-in-Charge acting on-site in his mobile and dynamic environment.

4.1 Operational Impact of SaR Resource Management

For an efficient execution of firefighting tasks a *divide & conquer* approach is used: The fire site is divided into sections and sub-sections for functional or only geographical reasons. The initial command structure is built based on functional

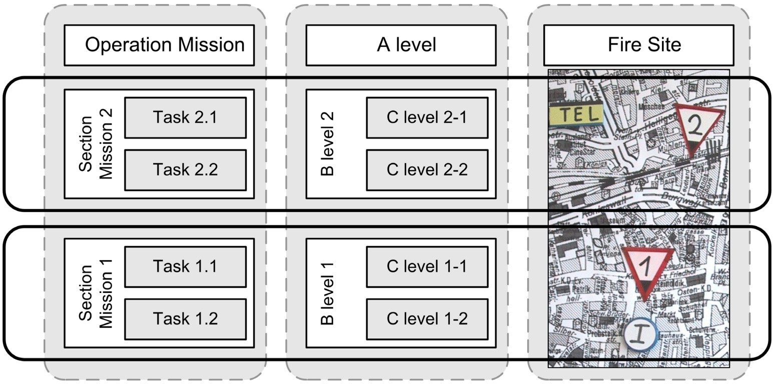

Fig. 2. Dependency between resources (e.g., B level staff), geographical sections and tasks

requirements. Thus this structure implies functional sectioning with regard to the incident and concerned danger averting measures, the available resources and regulations resp. laws. These functional sections have to be mapped to geographic references. Therefore input is given by characteristics of the incident, the scene (terrain, buildings, objects, dangerous goods, etc.) and the resources which provide special features. Figure 2 demonstrates the challenging relations between resources, tasks and geo-sectioning. They must be kept up to date during the highly dynamic changes within an operation.

These facts sketch a rough background for the requirements which they imply for a mobile ICT environment. Following a user-centred approach every officer must be provided a structural overview of the scene, mainly of the part of the hierarchy he is responsible for. Corresponding to the command levels a *Level Of Detail* of contents is reasonable. e.g., an operational commander has to be aware of very much details about his vehicles and firefighters while tactical or strategic commanders are interested in more general information. One parameter which only seems to be very simple is the manpower available at the fire site: currently it is very difficult to collect all needed figures using radio communication. Even more complex is the need to keep these figures up to date, but a bottom-up information collection and aggregation scheme distributes the necessary effort.

While the operation control centres in the back-end dispose resources the on-site operation control has to manage the units available on-site. Every officer is responsible for his sub-ordinated units. Thus rights and restrictions on rights have to be set accordingly for the functionality. The user interface must follow such requirements. Management of resources in this context means to move formations or vehicles within the structure, take elements out of operation and deploy new ones. In many professional fire departments alarm levels are predefined: They are increased when the incident becomes more complicated and decreased vice versa. Based on an alarm level the general structure of resources can be inferred. Therefore logical restrictions on types of resources and their relationships must be defined and proved when a change arises.

4.2 SHARE-ODS and Resource Management

The SaR sub-ontology models the objects that are related to the structure of the operation: the resources engaged in the operation, the command and communications structure, and the task and area of responsibility of each formation. SaR concepts include formation levels (A, B, or C level) and types (professional or volunteer fire-brigade, rescue service), operational roles and actual personnel, vehicle and equipment types, etc. Formations are also linked to the geographical area (section or subsection of the operation theatre) that they are responsible for, and the task they are expected to carry out within this area.

Formations and their units are linked together in a so called partology, and are also connected to operational roles they require (e.g. commander, dispatcher, etc) which, in their turn, are connected to the actual personnel members that fulfil each role. The knowledge base is explicitly populated with this information as the operation proceeds and units arrive to the theatre and are deployed.

Several characteristics of the operation's structure are inferred from this explicit information and the definitions in the ontology model, e.g., fire-brigade formations are defined as professional or auxiliary (volunteer), depending on the units and officers they are made up from; they are also defined as *full* or *base* formations depending on the number and type of sub-formations they subsume.

SaR operation regulations and practice have specifications regarding admissible operation structures, depending on the *alarm level*, i.e., the extend of the emergency. These specifications are formulated in terms of maximum and minimum numbers of full and base formations from each service (fire brigade or rescue service) that must be involved in an operation at each given alarm level. Generally speaking, as alarm levels rise operation structure gets 'fuller' and more populous.

The SHARE ontology models these specifications as defined concepts corresponding to well-structured formations of all three levels, for all alarm levels possible. For example, there is the concept of the well-structured C-Level Formation at alarm level 1, the concept of the well-structured C-Level Formation at alarm level 2, and so on, until all formation level and alarm level combinations are exhausted. SHARE-ODS uses instance checking to decide if the structure of an operation matches the specifications of a given alarm level, and also pinpoint the part of the operation structure that should be modified in case of a mismatch.

The Resource Management functionality is particularly useful when upgrading or downgrading the alarm level of an operation. Such an upgrade or downgrade can, for larger operations, require a significant number of unit deployment or disengagement actions to be performed. Thus such a tool can provide substantial help to the operation's command staff.

4.3 Application of Interactive Resource Management

The requirements of commanders are implemented in the Interactive Resource Management (IRM) application which is embedded to the SHARE client. This

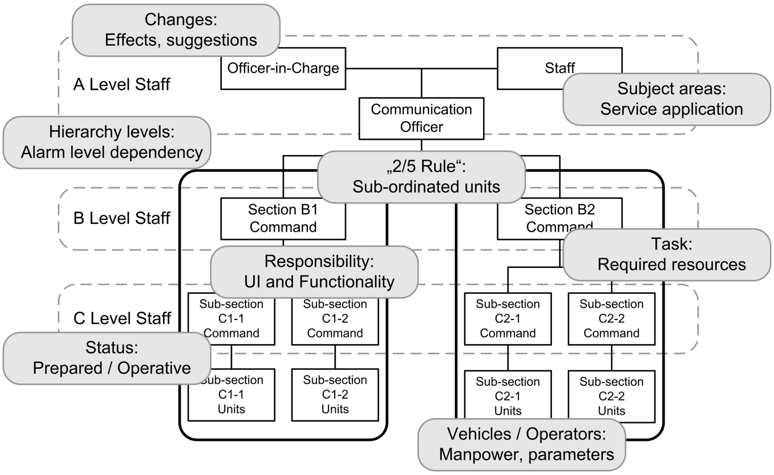

Fig. 3. Basic restrictions for the command and communication structure

client is designed following a thin client approach as it should be applied to mobile devices wearable in firefighting operations. The evaluation phase of the SHARE project brought out that Tablet PCs are the best solution for all command levels working either tactical or operational in the field. This is possible as the administrative parts of operational command are overtaken by assistents located inside command cars. For crucial input commanders themselves can handle a Tablet PC in short distance to the car. Plans for the usage of Handheld PCs were not favoured mainly because of their limited screen size. The GUI provides three different views to resource information: a) *view* resource information, b) *manage* resources at the fire site and c) *supervise* the connection between operation control centers in the backend and the operation scene.

The different use cases can be explained by the following example. Figure 3 highlights the relations and hierarchy elements which are affected by the described restrictions. A command structure with three hierarchy levels is presumed, called alarm level three. Staff members control certain subject areas, one is responsible for the management of resources. Commanders and staff communicate their status via analogue radio. Regarding this and processing information from the operation control center they supervise the operative and assembled units at the fire site. In this scenario he registers a pre-defined C level arriving at the assembly area consisting of a command car, three fire engines and concerned personnel. Thereby this unit gets visible to the IRM as a prepared resource available to be deployed. Commanders have access to their subordinated resources as well as all prepared resources. Because of a growing fire incident a B level officer orders the newly registered C level unit. This simple *drag & drop* action causes a command to the accessed unit, a preliminary change to the command and communication structure and the generation of a new operational rôle. With the arrival at the operation ground the C level officer overtakes this rôle by login and thereby finalizes the structural change. Corresponding log entries are stored. The officer-in-charge gets an information about this update. As the change affected the logical restrictions for alarm level 3 an exception is presented about a) the changed elements, b) the active operator and c) the suggestion to increase the alarm level. To decide on this the officer-in-charge retrieves information from the general view, e.g. about the type of vehicles that were added and the calculated new manpower. By his manage options he increases the alarm level. Additional upcoming inconsistencies regarding the new alarm level are highlighted.

The illustrative example presented some important aspect: The functionality behind the interface is designed user dependent whilst users are represented by the rôle they overtake. These rôles are command level related, except the supervisor rôle. The same applies for the view to resources. While officers want to view the overall structure, they only have to manage their subordinated formations for vehicles. The view to resources comprises the hierarchical structure, communication channels, defining characteristics and logistics information. Management of resources means the deployment, disengagement or structural movement of resources. This implies changes in the relations between resources defined in the SaR ontology. Every change is passed to the reasoning engine to check for inconsistencies. When existing a corresponding exception is thrown by the service. A package of special exception classes are modelled using inheritance to provide feedback as specific as possible. The interpretation of such messages informs about errors and suggest alternatives.

5 Conclusions and Future Work

We propose an ontological model that unifies SaR operation modelling with semantic annotation of documents, to offer an integrated model for an operation and all documents pertaining to it. Furthermore, we are putting together a set of tools for using the ontology at an actual SaR operation. These tools include the SHARE Ontology Data Service for updating and accessing the semantic data and the reasoning facilities that complete the original facts with inferred knowledge.

We are investigating various directions in which to extend the system. A major issue with SaR operations is data reliability: as an operation unfolds, the ontology gets populated by various sources, some reliable (e.g. GPS) and some not (e.g. information extraction modules). Faulty data can be caught (and, possibly, corrected) when creating logical inconsistencies, which can be resolved in favour of the more reliable source. In cases where multiple sources corroborate towards accepting or rejecting multiple pieces of information, the problem of deciding which to accept as most reliable becomes non-trivial. This problem has been approached in various domains, but not in the domain of responsibility distribution among multiple information extraction sources.

Another interesting direction we plan to pursue is temporal representation and reasoning for the purposes of *planning* (before and during an operation) and *evaluation* of past operations. At this stage, the SHARE ontology models only the current situation; a temporal model an reasoning engine will allow to track an operation's progress through time. Such an ontology will include a model of the task assigned to each formation, and reasoning over it will identify parts of the operation that are ahead of schedule or lagging behind. Such a model converges to a powerful decision support tool that not only checks the current operational status, but also offers helpful suggestions about resource reallocation, by identifying resources that are being under-used and sections that are under-resourced.

Finally, the system currently points out to the user aspects of the operation that are not conforming to some rule, without offering any indication of the gravity of the rule that is being broken. At a future system we plan to explore the possiblity of using weighted rules, so that suggestions to the user are accompanied by an 'importance' comment or colour-code. The weighted model can be computed by collecting situations of officers ignoring the official guidelines. Such situations will be compilied into a dataset, to be used to learn models of such exceptional decisions and the operational cirmustances that trigger them.

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Adding Space to Location in Mobile Emergency Response Technologies

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Abstract. In this paper, the potential of Mobile Spatial Interaction for Emergency Response Technologies is presented. The following basic advantages compared to traditional location awareness technologies have been identified: meaningful interaction with real-world objects, efficient selection and access, continuous interplay of virtual and spatial information, and accurate match with the user's task goals. The technical background for mobile spatial interaction as well as implications for further research are discussed.

1 Introduction

Mobile phones are increasingly used as a link between the physical and the digital world. A driving force here is the continuous integration of new features into mobile phones: standard camera-enabled devices can interpret visual codes posted on physical objects [6], near field communication [3] is currently inspiring the industry to new contactless applications such as ticketing and vending, and classical location-based services are reaching mass-market relevance. Meanwhile, web-based mapping and geo-browsing applications are starting to be transferred to mobile devices.

The idea of combining digital information with the user's direct surroundings is not new. In the late 90ies, Egenhofer [1] already predicted portable tools based on innovative interaction metaphors: 'Smart Compasses' pointing into the direction of interesting places, Smart Horizons allowing users to look beyond their real-world field of view or Geo-Wands – virtual geographic pointers for the selection of surrounding objects and attached services.

This form of 'Mobile Spatial Interaction' is getting more and more relevant in HCI research [2] and has many application potentials for the mobile mass-market, such as:

- Accessing background information about a certain historical building
- Searching (where is the next restaurant?)
- Access to information services (when does the next bus leave from THIS bus stop?)
- Advertisement (Point at a McDonalds restaurant to participate in a contest

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- Purchase (gather information about nearby specific real estates)
- Games (paper chases, etc.)
- Sharing (geotagging of photo collections, location-based blogging)

Of course, there are at least as many application areas for professional use. One of the most promising is the emergency domain, such as fire brigade operations, because much relevant information is inherently attached to places (and therefore inherently spatial). In the remainder of this paper, we will more deeply elaborate mobile spatial interaction in emergency situations. Based on a scenario (section 2), some advantages of mobile spatial interaction will be reflected (section 3). In section 4, we describe some important building blocks for mobile spatial interaction that are addressed in the project Point-to-Discover (p2d) at the Telecommunications Research Center, Vienna, Austria (www.ftw.at). We then draw some conclusions and future research issues that are especially related to the emergency application domain.

Fig. 1. Forms of mobile spatial interaction. Top: a 'geo-wand', bottom left: a 'smart compass', bottom right: 'augmented reality view'.

2 Mobile Spatial Interaction in Emergency Situations: A Scenario

It is Saturday evening. Thousands of visitors are watching a match of the 'Deutsche Bundesliga' in the sold-out Westfalen-Stadion in Dortmund. Somewhere in the middle of the second halftime the people in the southern part of the stadium start to panic – fire! A small part of the visitors in the southern segment of the stadium cannot escape because of the fire – they are trapped. Meanwhile, the Dortmund fire brigade a well as several hospitals receive an emergency call.

A short period of time later the first group of firemen arrives at the stadium. Using resQ on their spatially aware handhelds, they can explore an individualised visual 3D representation of their nearer surroundings. The visualisation informs them, in which direction fireplugs, power supply lines and gas pipes are located. The group moves towards the nearest emergency exit to rescue the trapped persons. As the firemen arrive at the exit, they see that it is blocked by parts of the stadium that have fallen down, with lots of smoke and dust around. Since there is no way to get through this barrier, they tag the exit as blocked by simply pointing at it and pressing a button. This information is immediately available for all units operating in this environment.

The firemen get into the stadium and up to the stand where they can see the dimension of the emergency. They can see which parts of the stand are blocked through the fire and therefore prevent the visitors for leaving the stadium. They also realise that parts of the roof have been destroyed and threaten to fall down directly onto the captured people. On their handhelds, a panoramic representation of the user's field of view helps them to tag the blocked and destroyed segments.

This critical, operation-related information does not only help the rescue forces on site but also persons who control the operation from "outside". The section leader uses a 3D map on his tablet PC to get a precise description of the situation and to support his tactical decisions. The 3D map features tools for moving and zooming as well as for setting tactical items and segments. He uses the map to analyse the structure of the building. He sees the tags from the first group that indicate a blocked emergency exit, the section which is affected by the fire and the roof which threatens to crash. Based on this information the section leader decides to request further support for cleaning the blocked exit. Moreover he can decide on how to position the additional units approaching the scene.

After some minutes, further fire fighting units from the surrounding fire departments arrive at the scene. They try to get into the stadium to treat the injured people. Thanks to tagging, they see on their handhelds that one entrance has been marked as blocked. Moreover, the best way to get to the injured people is highlighted by the operation commander based on the information and tags from the units which already have found their way into the stadium. After this operation, the data gathered by resQ is further analysed, assisting the emergency forces and facility management to improve their procedures and skills.

3 The Added Benefit of Mobile Spatial Interaction

The scenario depicted above shows several forms of mobile spatial interaction that promise to be more intuitive, efficient and useful than known from classical location-based services. The most important benefits are as follows:

- **Meaningful interaction with real-world objects:** In traditional location-based systems, the fundamental information consists of 2-dimensional position co-ordinates, which by themselves are not necessarily meaningful to the user. In the above example, information is more valuable if it is virtually attached to 3D objects or segments of a person's surroundings (such as labels directly combined with a visual representation of specific segments of the stadium roof).
- **Efficient selection and access:** Tagging a blocked stadium exit by pointing at it is a more intuitive and efficient act than selecting it from a map, let alone than describing it by means of written or spoken language. A pointing gesture is a very well known behaviour when communicating about objects in people's environments, thus it is arguable that it will also be accepted in distributed emergency systems. Furthermore, it is not based on the visual modality and thus also suitable in case of sight obstructions.
- **Continuous interplay of virtual and spatial information:** Probably one of the most promising interaction techniques is the overlay of virtual information over the user's field of view. Although location and orientation sensing inaccuracies will presumably not always allow for a perfect match between the real spatial environment and its virtual counterpart on a handheld, schematic representations are still a highly attractive basis for visualisation and interaction. In the scenario, the fire fighters benefit from selecting and tagging certain segments of the stadium by means of a panoramic visual representation corresponding to their field of view.
- **More accurate match with the users' tasks and goals:** Compared to standard location-based scenarios, selections with mobile spatial interaction can be much more fine-grained (e.g. pointing at only parts of the roof). Due to these active and targeted selections by users, the system reaction can be better matched with the user's goal (e.g. adding tags only to parts of the roof, instead of the whole roof).

4 Technical Building Blocks of Mobile Spatial Interaction

The Point to Discover (P2D) project at Telecommunications Research Center (ftw.) develops technical foundations for mobile spatial interaction: using satellite positioning and embedded orientation sensors, mobile phones function as pointing devices towards content that is „anchored“ virtually at geographic locations. Taking on a broad systematic approach, P2D addresses several research issues that are critical for next-generation mobile spatial information applications. Several aspects that are highly relevant in the context of emergency response are covered by the P2D system design principles:

- P2D builds on the idea of locally stored knowledge of the environment geometry: Segments of the environment model are stored in the mobile device in P2D's novel XML data format [5]. This way, P2D devices are not necessarily dependent on always-on connectivity, which is a crucial requirement in emergency situations.

- The P2D XML environment data model and user interface toolkit is designed to be agnostic of particular GUI metaphors and interaction types. Presentation can therefore be adapted for a wide range of mobile devices with vary ing form factors, screen resolutions, and navigation features sets. For example, rotating map views could be generated for location- and orientation aware devices with large screens, while stationary maps (or textual descriptions) can be produced for devices without orientation sensor hardware (or limited display capabilities, respectively). Potentially, the presentation can even be adapted on the fly in case of hardware failures: e.g. if compass or gy roscope sensors fail, or if external factors such as excessive heat or electromagnetic interference prohibit reliable operation of particular sensors.
- P2D is based on the concept of collaborative spatial annotation. Since P2D applications store fragments of the environment geometry locally, collaboration features do not necessarily require always-on connectivity: Synchronization with other team members can either occur as soon as connectivity with the network is re-established, or it can performed in a decentralized manner, by exchanging spatial knowledge stored on one device with other devices using close-range communication (e.g. Bluetooth). Potentially, this opens up the possibility of collaborative on-the-fly mapping, i.e. the collaborative generation and sharing of maps of previously unknown environment, provided that information can be shared among team members in reasonable time intervals.
- The P2D application platform has been designed to be open for different sources of environment model data and geo-spatial content. Open industry standards for the exchange of geographical vector data, as well as a state-of-the art open source spatial database ensure interoperability with GIS and commercial geographical datasets.

The first generation of P2D technologies is implemented and presentable: Since mobile devices that feature the necessary hardware components for P2D – such as embedded GPS receivers, compasses or tilt sensors – are only beginning to appear on the market, P2D develops custom prototype hardware to carry out function- and user-testing. The first hardware prototype is a Bluetooth accessory that features a digital compass and a 2-axis accelerometer-based tilt sensor. An advanced sensor module that combines orientation detection and satellite positioning has also been developed and is currently undergoing testing. A system trial in Spring 2007 with Austria's leading telecommunications provider mobilkom austria and Siemens Austria is under preparation.

5 Conclusions and Future Research Issues

In this paper, we advocated the addition of spatiality to location-based services has strong benefits. The attractive application potential for the domain of emergency response was illustrated by a scenario. Furthermore, we presented recent results from applied research clearly indicating the relevance and general feasibility of mobile spatial interaction.

It clearly has to be acknowledged that mobile emergency response is an area that poses important challenges for future research. First of all, sensor accuracy is a crucial factor for the reliability of outdoor- and indoor positioning methods. Mechanisms for the reliable identification of sensor errors should be investigated, e.g. concerning the identification of compass errors by comparing compass data with gyroscopic sensor data. Furthermore, strategies are needed for mitigating sensor inaccuracy by effect tively communicating it to the user, as well as for compensating errors using map -matching techniques. Finally it is important to prototype different modes of visualizing geospatial data and examine the usability and cognitive overhead of different presentation formats.

Acknowledgements

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Intelligent Cartographic Presentations for Emergency Situations

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Abstract. This paper describes ongoing work and research perspectives for integrating cartographic presentations into decision-support systems for crisis management and resource planning in emergency situations. The spatial visualizations shall improve the communication and analysis of the situation at different decision levels. The information has to be adequately prepared and presented according to the user's role, position and utilized device. The outstanding characteristics of the presented solution are (1) a context-dependent selection and visualization of data through location-based services and (2) a visualization of the situation at different perspectives. This reduces the amount of presented data and improves the understanding of the user's current environment. The paper describes an application prototype designed for the European project SHARE and outlines perspectives by introducing time as another information dimension.

Keywords: Visualization, visual communication, spatial decision support.

1 Introduction

Mechanisms for an efficient communication and analysis of risky and emergency situations are vital for the involved rescue personnel. Unreliable communication networks, fast changes in the environment and the management of rescue team members are non-trivial challenges for applying information and communication technologies (ICT) in dangerous operations. This may be the main reason why current systems are mostly based on archaic techniques such as walkie-talkie communications [7, 10]. In this paper we describe work and research connected to the cartographic module in the EU-funded project SHARE – Mobile support for rescue forces, integrating multiple modes of interaction[1]. The project aims at designing and prototyping a multimodal system to support emergency teams during large-scale rescue operations and disaster management. This paper focuses on the use of spatial services and visualizations appropriate for different operation contexts. The map module supports the operation management by providing an efficient description of the current situation taking into account the user's role, position and communication device.

[1] FP6 IST-004218, started in November 2004, duration 48 months, http://www.ist-share.org

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2 Related Work

The concept of "intelligent visualisations" relies on the presentation of data to give "everybody the right information at the right time and in the right way" [4]. Two main aspects have to be considered: the receiver of information (person or organization, called "actor") has to be supported on order to fulfil a specific task and the information has to be efficiently presented in order to be properly understand and used by the actor. The intelligence is given through the appropriate preparation and visual presentation of data to (1) reduce the information to the relevant level of detail, (2) use meaningful representations and (3) complain with the particular context (e.g. actor task, used medium, actor position). This can not be fulfilled for an abstract use cased, but has to involve the domain characteristics in which the system should be used.

The use of problem-oriented domain knowledge in time-critical applications as decision-centred visualization is presented on [5], but the concept does not include the use of visual presentation for communication purposes. Andrienko and Andrienko emphasise the importance of knowledge based technique for the structuring and transformation of spatio-temporal data for crisis management [3]. They also purpose the use of different symbols and styles according to the situation context (position, time, relevance of objects for the particular emergency situation, visualization goal and targeted medium). This knowledge is called "design modifiers" for the visual display. The separation of domain-independent data from the context specific representation is a main aspect to take into account when designing and developing user-centric spatial decision systems.

Luyen et al. [7] describe a context aware mobile system using the focus+context concept for the design of the role-driven user-interfaces for fire-brigades. As in our work different communication channels are provided to the user through the interface, which adapts the offered functionalities to the role on the rescue team and the used device. The system also integrates different data sources (spatial data, video, intervention plans) and presents geographic information dynamically by using services, which process the requirements and deliver detailed information according to the user interaction. For instance relationships between spatial entities can be requested and visualized or highlighted.

3 The SHARE Map Application for Emergency Situations

For emergency situations several factors play a crucial role in understanding the situation and taking appropriate decisions, notably operational data, data about the environment (e.g. streets, buildings, infrastructure, points of interest), and weather conditions. Specific requirements come from the difficult nature of the situation: the common network infrastructures may not work, the operation information has to be reliable, the situation changes continuously and the persons involved need a flexible and comprehensive access to data to react fast.

All these aspects must be considered for an ICT solution that allows the users to understand the situation at different perspectives. The Fire Department of Dortmund has been active involved as project partner for technical advises in the specific domain. They define the main user requirements and assess the quality of the system with the goal of integrating the results into their working environment. For the map module of the SHARE system the following design decisions were taken:

Secure and reliable information: All spatially related data is prepared and stored in a spatial database management system (PostGIS/ Oracle 10g), providing secure and fast transaction mechanisms. The data (Tele Atlas 2D-3D digital map) can be accessed through a map server (GeoServer[2]) with interoperable services, namely Web Map Services (WMS) and Web Feature Services (WFS) conforming to OGC[3]. Database and services are only accessible for an internal mobile network.

Support of different output devices: Different activities demand the use of devices with different capabilities. Therefore two map clients were developed: for PDAs and for notebooks or tablet PCs. Both applications were written on Java to run under different operating systems. The PDA application is a thin client using interactive mapping and feature querying services (both functions of the WMS). The application logic employs the standard WMS requests with additional style descriptions rules and constraints for data filtering. The PC application is a thick client using WMS and WFS for high interaction with vector data. At their PCs or laptops, operation managers shall be able to perform data transaction and request information quickly by moving the mouse over the map. Predefined features like street names and annotation data are displayed and can be interpreted by voice output. Data transactions are performed when a new project (a rescue operation) is defined and annotations are added by drawing sections or subsections and dragging tactical symbols onto the map. Once new annotations are received by the server, all devices get a signal to update their data. The PDAs always work on the server's data, so their project information is always up-to-date.

Support of customizable interfaces: The system demands a user authentication. Depending on the user's role the menu and map toolbar change (e.g. just A- and B-level leaders can define or select projects or rather make and edit annotations). Further, each client can be configured individually switching additional layers and visualizations on or off, and changing the styles for non operational data.

Use of domain knowledge to represent data and processes: The map application provides information on any changes of the operational data to an Ontology Data Service (ODS). The ODS is built up on the SHARE Ontology, which stores the data in a semantic structure, so that it can be requested for different purposes. An example would be a free text query "show me all water resources within 500 m from my position". The ODS processes the query and identifies the features (e.g. hydrants) and properties (geometry) that should be selected. A spatial filter (e.g. select only hydrants within a 500 m circle around the user's position) is then generated and submitted by the client with the WMS or WFS request. The client gets the results as a map or vector layer.

User centric access to information: The information obtained by the user depends on the situation context and the user's own position. The situation context is obtained from project management services in the form of a project with annotations. All users

[2] Open Source OGC compliant Map and Feature Server, http://www.geoserver.org
[3] Open Geospatial Consortium, http://www.opengeospatial.org

involved in a operation will just get the data (annotation, team members) for their role and communication device. Trough an integrated GPS sender the application logs the users' positions in the data base. Thus, all users can see all team members' positions on the map. The positions are differentiated by distinct icons according to the member's role and the team member name is printed next to the icon. Mobile Location-Based Services (LBS) provide the user with context information like points of interests (which are also fire extinguishers and emergency exits) in a certain surrounding distance from his position.

4 Intelligent Cartographic Visualization

Cartographic visualization means the generation of visually perceptible presentations for spatial information with the goal to support a user at his task. When a presentation involves complex processes and reacts to changes in the context or environment of its observer, we can speak of intelligent visualizations. The science of analytical reasoning supported by interactive visual presentations is defined as Visual Analytics. It synthesizes heterogeneous data sources and big amounts of data for effective communication and action [9].

As mentioned before, the management of rescue operations require tools applying intelligent visualization techniques to provide concise representations of complex information to support the reasoning and decision making process. The typical user of those tools is not habituated to work with geographic information systems (GIS). Still, the proliferation of Google Earth, Google Map and routing software has demonstrated that cartographic presentations can be used intuitively. Particularly realistic visualizations like 3D presentations and orthophotos enjoy a wide acceptance and are usefully for decisions on an emergency context. For instance the building height allows the recognition of landing places for helicopters.

This section summarizes requirements for visualization techniques that are in our opinion relevant for emergency tools. We refer to techniques already implemented in SHARE and visions or perspectives to extend them in future systems based on SHARE technology applying experiences from related projects.

Intuitive navigation: through the "space" is the basic feature for using map data. It can be facilitated by simultaneous views in 2D and 3D [1]. For SHARE, the 2D-3D Tele Atlas data model was used. There 2D data is enriched with additional feature information: the height of building and trees, façade descriptions and pictures, as well as information for constructing new features (lines of trees, street lamps and building roofs). This information is processed a priori in the database, allowing the fast access by the 3D-view to construct a 2½ scene from it. The use of landmarks is proved to increase orientation. The 3D view incorporates landmarks modelled as VRML objects in the map. Both views of data can be navigated with standard zooming and panning interfaces, which were enhanced with rotating and tilting (for 3D) functionalities. Each view can be maximized or minimized as needed by the user. Fig. 1 shows two different snapshots of the map module in SHARE.

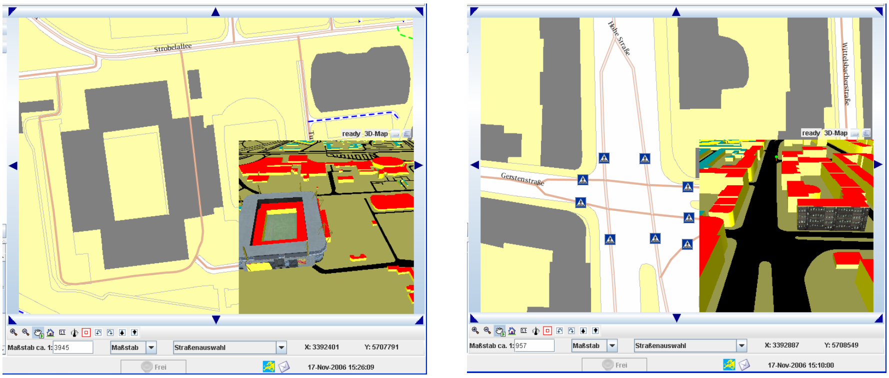

Fig. 1. (a) Map application with synchronized 2D and 3D views, using VRML landmarks and (b) showing pedestrian information and facades

Thematic visualization: GIS tools provide analysis support by offering a range of thematic visualization techniques based on attributes of spatial data, e.g. by coloring the map or situating calculated icons like bar-charts or pies on the geometries. Analogous, realistic presentations in 2½D or 3D can be combined with artificial presentations of thematic data [4, 6]. For instance, the objects can be colored according to any discrete attribute, e.g. buildings colors can be chosen according their utilization or their current degree of damage. Particularly this technique can provide a visual meaning to operation information. In the case of SHARE, a numeric attribute could, for instance, define the level of danger for each section. Each section can then be represented on the 3D view as a semi-transparently object, which color or height gives information about its state. The attribute value could be entered by the user through the edit mode for sections or it could be derived automatically from the knowledge base. Fig 2 shows an example visualizing a semi-transparent section in the 2D and 3D view.

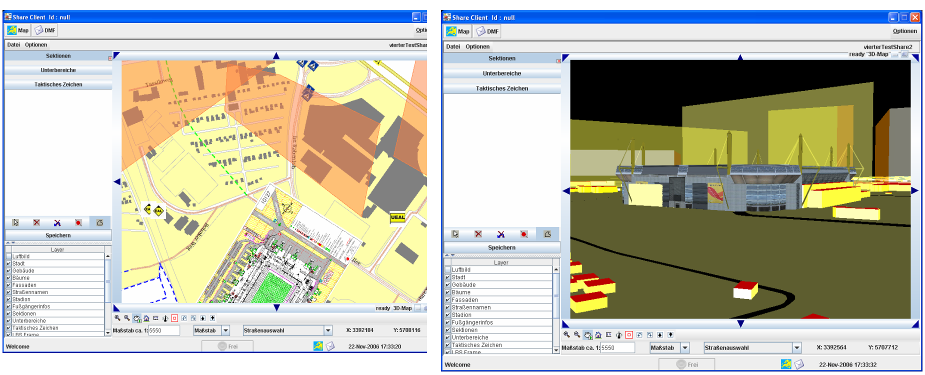

Fig. 2. Representation of operation sections on SHARE on 2D (a) and 3D (b), represented with different height according to their entry time

Consideration of temporal aspects: Time is an important aspect for disaster management [2], having a big impact on the situation evolution. When data refers to objects having geographic and temporal characteristics, then we speak from spatio-temporal data. Common visualization techniques of spatio-temporal data include map animations, multiple maps and 3D representations, which can facilitate the recognition of spatio-temporal coherences [4]. Currently the SHARE database contains time references for the creation of annotations (e.g. sections), projects and the tracking of team member positions. The ontology includes temporal concepts as time-points and intervals with temporal relationships [10]. This information is not used by the map application yet, but it could be exploited using the 3D view. Temporal information of "virtual objects", like annotations, can be projected into the z- or height-axis using a different scale as for representing the height of real existing objects, like buildings and trees. For instance, the chronological order of affected regions could be represented by lifting the 2D borders of virtual objects to a height, computed from the time interval since the section was created. By doing this, the fourth dimension (time) and the third dimension (elevation) would be represented in the same axis in the scene. Users can recognise which are real and which virtual objects and according to it interpret the visualized height differently. This can effectively expose the dissemination of the danger. Also, the paths traversed by team member could be shown in the 3D, where the height of a position point has been computed from the logging-time. Another form of representation of time is to project into the 2D plane, a time stamp, as a horizontal cut on the 3D map. The intersected path-points can immediately be compared, informing about the advances of the team members. The navigation on time could be done on the 3D map, defining which moment will be represented on the 2D. The examination of the situation for temporal aspects may be useful for post emergency analysis.

Domain knowledge for data selection and presentation: Intelligent visualization depends on the access to knowledge, especially domain knowledge [3, 5], which is indispensable for a decision-centred approach. Map applications should be linked to semantic information about data, for instance to a domain ontology, to represent the relevant domain notions and their relationships. On SHARE domain knowledge is applied by using adequate symbols and the ODS services for data querying as explained in the previous chapter. Context information is shown according to the specific user position, role and operation status. This feature can easily be extended to more specific tasks. An example is the presentation of pedestrian information. In SHARE the Tele Atlas data was interpreted to show POI's and different form of pathways according to their meaning for pedestrian. This information can be used for planning escape routes. An enhancement of the presentation could take into account the time of the day and signalize pedestrian paths, which are not illuminated (lacking of street lights), as dangerous pathways. Symbols can also change the size according to their meaning for a certain situation. Fig. 3a) and b) illustrate different visualizations of POI's, according to their importance for the rescue team on a dispersion of a dangerous gas plume. The plume is computed from the weather conditions and the display is updated correspondingly. Is the danger of explosive nature, mainly gas storages are shown (a) and, if the dangerous occur at a weekend, schools are not displayed, since children are not supposed to be there (b). The pictures are results of an ongoing work on the EU research project OASIS[4] [3].

[4] OASIS (IST-2003-004677).

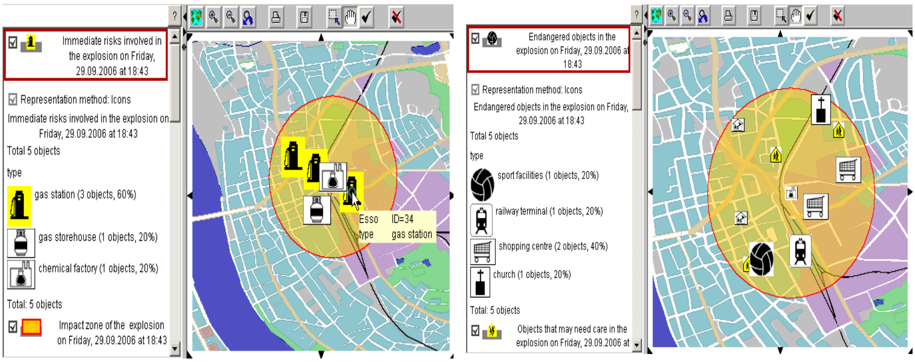

Fig. 3. Different representation of context in a dangerous situation according to the danger nature and the time of the event [3]

Interpretation of user intention: A proactive reasoning needs more sophisticated techniques involving predictive data mining and simulation algorithms. These analysis techniques are mostly time and resource consuming and can be hardly applied on runtime processes. For the SHARE project the ontology model is conceived to facilitate the application of such techniques, for instance to predict where a vehicle or team member will be in 5 minutes [10]. Another form of interpretation of user intention can make use of further devices to capture the user actions more precisely. A possible application example was originated by the project "Point to Discover"[5], where a device for the pointing of objects on the real world is been developed. When pointing with the device, the user's visual angle could be computed and used as a filter: more information is retrieved for objects in the visual angle, even, or especially, when they are hidden from direct view. A possible visualization of the user action could represent the visual angle and highlight the buildings affected by it (Fig 4).

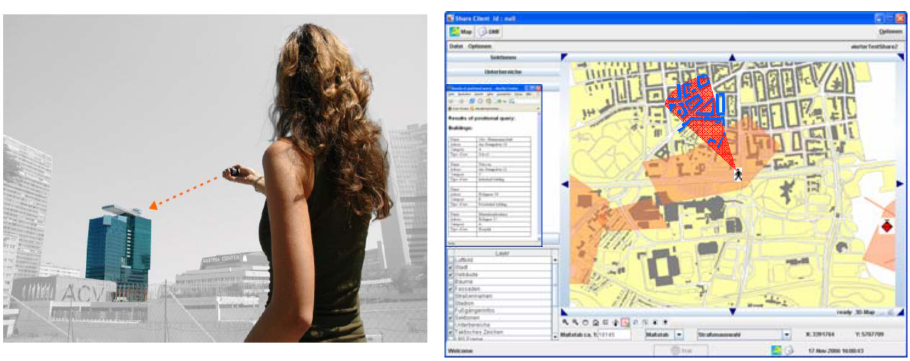

Fig. 4. Extension of LBS by using pointing devices: using the Point-To-Discover device (a) [8] and visualization on the map (b): The visible buildings are highlighted and the corresponding information is displayed

[5] http://p2d.ftw.at

5 Conclusion

This paper has presented our ongoing work on a map application for mobile communication in emergency situations in the SHARE project. It discusses the integration of the map application with the multi modal system using web services, different output devices and a user-centric data representation. Different visualization techniques to enhance the situation assessment of team members and the decision making of operation leaders have been suggested. New perspectives and enhancements are suggested by incorporating results of related projects.

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Hybrid Radio Frequency Identification System for Use in Disaster Relief as Positioning Source and Emergency Message Boards

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Abstract. We developed a system that uses radio frequency identification (RFID) tags both as the source of location information and as data storage units to record messages or information in disaster situations. Our system uses hybrid RFID tags, which consist of a passive (non-battery) tag and an active (battery-driven) tag. The system has been evaluated in disaster prevention trainings by local communities and rescue teams.

Keywords: RFID, Rescue, Disaster Relief, GIS, Triage, Ad-hoc Network.

1 Introduction

If a large-scale disaster strikes the telecommunication infrastructure, people will only be able to exchange information via "non-transmission" routes, that is, by "communication on the spot". In the aftermath of the Great Hanshin-Awaji Earthquake that hit Kobe in 1995, for example, paper bills were widely posted as a

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means of exchanging or distributing information in the disaster-afflicted area. Information about evacuations, residents' safety, and emergent risk assessments were directly posted on damaged buildings in Kobe. The disaster in Kobe highlighted the importance of establishing a system that can be used in rescue operations to rapidly collect and disseminate information throughout an affected area. Such a system might rely on manpower, rescue robots, or other elements independent of day-to-day means of telecommunication. This system would prove particularly important in the event of a large-scale disaster that would likely cripple the telecommunication infrastructure. Of course it is important to create a robust telecommunication infrastructure, but "communication on the spot" is the most reliable way of communicating. Therefore, research on information technology for "communication on the spot" is extremely important to emergency response information technology.

To develop electronic "communication on the spot," memory devices such as message boards and message uploading and downloading devices such as pens should be used. Uploading and downloading should be possible without devices having to make physical contact, that is, by wireless communication, e.g., HomeRF, Bluetooth, or ZigBee. However, memory devices for message boards should be inexpensive because they must be widely distributed in disaster-afflicted areas. Radio frequency identification (RFID) technology is both non-contact and inexpensive, making it ideal for such a system.

RFID tags are small devices that can store, input, and output data without coming into physical contact with other devices. In addition to their wide use in non-contact IC cards, RFID tags are on their way to becoming commercially feasible for attachment to merchandise and cargo in the logistics industry. In addition to logistics applications, a range of uses in other fields, including firefighting and disaster prevention, were recently highlighted in a report by a study group [1] organized by the Ministry of Internal Affairs and Communications of Japan.

This report describes development of an emergency communication system in which RFID tags are used as location indicators and as emergency message boards. The RFID reader-writer is designed to read or write rescue-related information to or from an RFID tag. Such a device could serve as an information resource for rescue work in a disaster area.

2 Discussion of RFID System Use in Emergency Response

The RFID system consists of a small tag that transmits ID information and a device that reads and writes ID. The passive (non-battery) RFID tag is supplied with electric power by the reader-writer via electromagnetic waves or induction. The passive tag is inexpensive and maintenance-free, so an enormous amount of tags can be distributed. The passive RFID system is superior to a barcode system because RFID tags have greater storage capacity and their functioning is not degraded when they become dirty. Moreover, IDs on tags in most passive RFID systems can be written and erased repeatedly. The problem with a passive RFID system is that the readable range between tag and reader-writer is quite short, so the reader-writer has to be relatively close to the tags to send or receive data. Moreover, the reader-writer has to radiate energy continuously in order to provide power to tags. Therefore, the reader-writer consumes a lot of power.

Active (battery-driven) RFID tags periodically transmit ID beacons. Most active RFID tags can transmit unchangeable ID, but stop transmitting when the battery fails. Most active RFID systems use the 300 MHz band. The advantage of an active RFID system is that the readable range between tag and reader is long. The active RFID reader can pick up an ID beacon from 10 to 100 meters away from the tag.

RFID systems have recently become popular in the field of personal identification and for retail and logistics point of sales (POS) systems. We believe that an emergency response RFID system should be different from such conventional RFID systems in the following two ways.

(1) In a conventional RFID system, reader-writers are installed in the target environment, and people or materials carry RFID tags. In contrast, in an emergency response system, simple RFID tags should be installed in the target environment, and people should carry reader-writers. Because a complicated system installed in a disaster environment might not function in a disaster situation. Of course, mobile tags should be used in case of RFID system for disaster victim identification.

(2) The RFID tags used in client-server systems are generally used only as identifiers, and the server retrieves information from an online database via a network using the ID in the tag as a key. However, an emergency response RFID system should be designed to use RFID tags for data storage, with all necessary information contained in each RFID tag. This is because, with client-server-based information sharing using a conventional telecommunication network, it may be impossible to call up and acquire information if a large-scale disaster leads to a breakdown of or congestion in the telecommunication network. In order to share collected information among the stand-alone RFID terminals, a self-organized telecommunication network, e.g. a wireless ad-hoc network, should be used.

Here, we discuss the advantages of a writable RFID system over handwritten messages in emergency situations. Handwritten messages are extremely cheap, easy to input and recognize, and require no special devices. Paper for the message can be obtained anywhere. However, handwritten messages are not easy to copy, deliver, and store. That means they’re not good for collecting and sharing large amounts of information in a short time, which would be necessary in a disaster situation. Moreover, it’s impossible to control access to handwritten messages. In other words, anyone, including malicious people, can read, replace, or overwrite them. Functions that set security levels or prioritize information are indispensable in leaving messages for specific people or in efficiently selecting important or relevant information from a huge number of messages. An RFID system will enable information to be quickly and accurately collected. RFID tags are much smaller than handbills with written messages. The information on tags is invisible, so security can be assured by using ciphers. Writers’ identities can be verified by authenticating their writing devices. Such a means of guaranteeing security is especially important in disaster situations. However, a special device is required to read or write messages. The time and effort needed to input data seems to be about equivalent to handwriting. Passive RFID tags have become cheaper, but they are not available everywhere now. Therefore, RFID tags must be stored in advance for use in disasters.

In an actual disaster, both message boards with handwritten paper messages and RFID tags should be used. Messages should be written in both media. At first only handwritten paper would be left and then later RFID tag messages could be stuck beside the paper. In such a way, handwritten messages can be easily delivered and stored.

To be effective in emergencies, RFID reader-writers must be popular and easy to carry. Therefore, reader-writers must be miniaturized and user friendly. Moreover, RFID tags should be applied both for emergency response and for other purposes. That is, the emergency response RFID system should be developed to be easy to use and to have applications other than emergencies.

3 Overview of RFID System Hardware

The proposed system consists of portable reader-writers and passive RFID tags that function as information-storage units. Information is remotely downloaded onto or uploaded from the tags by the reader-writers. As mentioned in the previous section, miniaturization of the reader-writer is important. Figure 1 shows how the reader-writers have become more compact: cart-mounted (fiscal year 2001), backpack-mounted (fiscal year 2003), and handheld (fiscal year 2004).

Fig. 1. Progress in miniaturizing RFID reader-writers. (Left: FY2001, Center: FY2003, Right: FY2004).

In our system, passive RFID tags are used as information-storage units. Our passive tags use the 2.45 GHz band and have 128 bytes of memory. The tags are manufactured by Intermec Technologies Co. The system has anti-collision algorithm to enable to read up to 50 tags at the same time. As mentioned in the previous section, the problem with a passive RFID system is that the readable range is quite short. Assuming the necessity of reading a difficult-to-reach RFID tag in the event of a disaster (such as one buried under rubble), extension of the readable range is necessary. When the development process began, we attempted to make a device with the longest readable range possible with the passive RFID technology then available in Japan (about 2 meters). To do that a high-output stationary reader-writer requiring a private radio station license was modified and rendered portable by adding batteries,. However, since miniaturization is critical for mobile activities in disaster areas, a low-output device was adopted in fiscal year 2004. The new low-output reader-writer has a readable range of about 50 centimeters.

The reader-writer must also accurately detect a lot of tags in a disaster area. Therefore, in fiscal year 2005, we adopted a hybrid tag, which consists of both an active and a passive RFID tag, for use in our system. Figure 2 shows the hybrid tag. The active RFID tags act as radio beacons. Rescue workers in disaster areas carry RFID reader-writers, find beacons from active tags, approach the passive tags, and write or read disaster information to or from the passive tags. The active tags are manufactured by RF CODE Inc. The active tag transmits a weak periodic beacon signal on 303.825 MHz that the reader can pick up at a distance of about 10 meters. Figure 3 shows our most recent hybrid RFID reader-writer. The picture on the left of Figure 3 shows the front of the system: a PC with the PC card of a passive RFID reader-writer, and the picture on the right shows the rear: an active RFID reader unit and battery.

Fig. 2. Hybrid RFID tag
Left: Passive tag
Right: Active tag
(12.5 square centimeters)

Fig. 3. Hybrid RFID reader-writer
(developed in FY2005)

The passive RFID reader-writer and the active RFID reader unit are connected via LAN cable. When the terminal reads the beacons of active tags, the IDs appear on screen and an alarm sounds.

4 Overview of RFID System Application

The system for emergency response should be flexible. Therefore, in the RFID system's first stage, it should be equipped only for the fundamental function of reading and writing messages. After that function has been developed, the system should be used for more speculative purposes, such as feeding back the findings of rescue teams and public investigators to the information-gathering part of the system. Such a "market pull" approach will be more effective than a "technology push" approach in popularizing the system.

Hereafter we focus on showing examples of the kinds of information that an RFID system in a disaster area can exchange. Of course, our RFID system is not limited to the following examples.

*Message board:
*Messages for rescue teams:

Information on rescuing victims from collapsed houses can be provided to rescue teams. This information may also be helpful in rescues in other places.

*Message exchange for citizens:

Locations of refugees and relief services, and confirmations of individuals' safety can be provided to the public.

*Information on buildings:

Conditions of buildings damaged by fire or earthquake or emergent risk assessments of damaged buildings can be posted.

Disaster areas are confusing, and it is necessary to search for victims, and control and record rescue operations efficiently. In major disasters, teams must conduct medical triage, which is the process of prioritizing medical treatment and evacuation. During triage, paper tags indicating levels of priority are attached to victims. Our RFID system can support triage by reading triage tags. The number of victims remaining in a first-aid station would be easily determined by counting the number of active tag beacons, aiding in the emergency evacuation process. The RFID system would also help in investigation of accidents. For example, in a train wreck in Amagasaki, Japan in April 2005 in which more than 100 people were killed, information on positions of several victims in train cars was lost during the confusing rescue operations. Precise investigation of the accident was not possible because the scene was disturbed. If our RFID tags had been attached to victims and to rescue locations, it would have made a more precise investigation of the accident possible.

To implement the applications mentioned above, we have developed the following fundamental functions since fiscal year 2001:

* Simplified write function

Writing Japanese character strings to a single RFID tag, an operator inputs characters by keyboard, and the sequence of the character codes is written into a passive RFID tag. This supports the tag's basic function as a message board.

* Read function

Reading Japanese character strings from an RFID tag and saving them to a control PC. When more than two tags are read simultaneously, all data on the tags will be saved on the PC.

* Read-out function

Voice synthesis of Japanese character strings read from an RFID tag in real time.

* Write function

Automatic location of an empty tag among multiple RFID tags and writing of information to the empty tag.

* Retrieval function

Deletion of data on RFID tags and reuse of tags for other data.

* Reading and writing binary data function

To deal with both message board and other application data, the system will also read and write binary data.

* Writing and retrieving binary data division function

To write data in excess of the capacity of a single tag, the system divides the large data into several segments and writes them into several tags each. The system reads data from the several tags and then merges and restores the data into its original form.

In the near future, we plan to implement the following fundamental functions.

* Data encryption function
* Access control function

Based on the fundamental functions mentioned above, we have implemented the following two functions for use in disaster relief:

1) Rapid safety inspection of damaged buildings

After a large-scale earthquake, architects inspect damaged buildings in the disaster area. We have developed a function to write and read assessment results to or from an RFID tag. This function is intended to check previous building data against current status to speed assessment of damage. The user inputs the grade of a building's incline and other data, and the application classifies the buildings into three risk categories: dangerous, requiring special attention, and safe. Assessment results are electronically deposited on-site for use by other rescue teams, thus avoiding duplicative investigation, streamlining relief subsidies, and contributing to the timely establishment of a detailed disaster database. Figure 4 shows a questionnaire form used for rapid inspection of the safety of a damaged building.

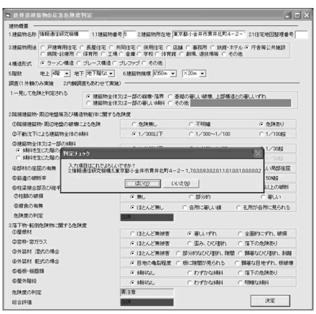

Fig. 4. Questionnaire form used for rapid safety inspection of damaged buildings

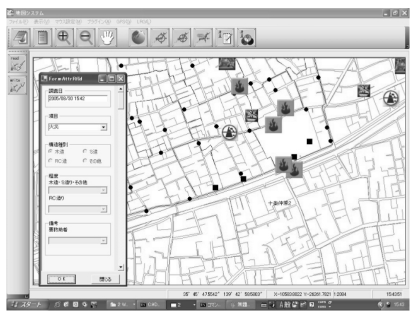

Fig. 5. Image of GIS screen and RFID reader-writer interface

2) Field damage information collection using a geographic information system

We combined our RFID system with a field damage information collection system that incorporates a geographic information system (GIS). The field damage information collection system was developed by Kogakuin University [2] and the National Institute of Fire and Disaster [3]. To use the system, investigators point to locations represented on the GIS screen and input information about collapsed buildings, fires, and road blockages at that location. The GIS displays our RFID reader-writer window on the screen, and the data from the GIS is transferred to RFID tags. The combined system can pinpoint a worker's present position using the connected global positioning system (GPS). Figure 5 shows a screen image of the GIS and RFID reader-writer interface.

5 Experimental Results

In fiscal year 2002, development of the system has evolved as one of the themes of the Special Project for Earthquake Disaster Mitigation in Urban Areas (hereafter referred to as "the DDT Project") launched by the Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT) [4]. Other DDT project efforts include field experiments and training exercises for rescue robots. Our RFID system has also been used in field experiments and training exercises. These experiments and exercises evaluated the system's performance and clarified the system's strengths and weaknesses. In the following section, we describe two of these field experiments.

5.1 Disaster Prevention Training Field Surveys

We tested our system in a community disaster prevention training exercise in September 2006. During the test, pictures of collapsed buildings were posted in different places in the test area. A hybrid RFID tag was attached to each poster. Two investigators carrying PC terminals with RFID reader-writers evaluated the level of damage to the buildings in each poster. The investigators input their inspection results into the terminals and RFID tags. Figure 6 shows a poster and a tag being accessed by an investigator.

Fig. 6. Poster and tag being accessed by investigator in a disaster relief training exercise. (Sep. 2006, Kamijujo, Tokyo).

During the test the readers were able to detect active tags at a range of 4 to 6 meters. This shows that the active tags help the readers find the passive tags. This range helps avoid interference between beacons. However, if the tags are buried under rubble, this range may not be adequate. An avalanche rescue system with both non-battery and long-range tags has already been commercialized [5]. The tags for the avalanche system may be better for our system than the ones we currently use. We also plan to measure radio intensity of RFID systems using various radio frequency bands in an electric wave darkroom. The results of this measurement will show whether our readers can detect RFID tags that are buried in rubble.

The following problems emerged during the field experiment: the terminal is hard to operate and is too heavy, the liquid crystal display is difficult to read in bright daylight, and the alarm that sounds when an active tag beacon is detected is hard to hear. However, these problems are all easy to solve.

The investigators' PCs had ad-hoc and multi-hop network functions installed that operate using a 2.45-GHz IEEE802.11 wireless LAN. Each PC transmitted the collected information to the disaster response headquarters by multi-hopping over PCs that were nearby. This function is also helpful for sharing the collected information with other PCs, thereby avoiding duplicating investigations.

5.2 Messages for Follow-Up Rescue Teams

In April and October 2006, our system was used in training exercises that simulated a situation in which disaster victims were trapped in a collapsed house and rescued by robots. In the exercises, after the victims had been rescued, members of the rescue team put hybrid RFID tags on the entrances of dummy collapsed houses. Information about the rescue work was stored in the tag, and the information was shared with the following rescue team or investigator. In June 2006, our system's performance was also evaluated in a rescue training exercise that simulated an act of nuclear-biological-chemical terrorism. Figure 7 shows pictures of the trainings.

Fig. 7. Rescue workers placing our RFID system tags at trainings. Left: Hybrid RFD tag being placed at entrance of a dummy collapsed house by a rescue worker. Right: Message being read from the tag by a follow-up investigator.

The rescue worker who participated in the experiments commented on our system as follows: Although installing a tag does not disturb rescue operations, it is difficult to use the present terminal for data input. In order for a rescue worker to operate the reader, the reader must be robust and operable by people wearing gloves.

6 Discussion and Conclusion

We have been attempting to further miniaturize the reader-writer. We are planning to replace the active RFID reader unit with a PC card by the end of the current fiscal year. The PC that controls the passive and active RFID reader-writers is operated by Windows XP, so a more compact PC, e.g. a PDA, can be used for our system.

However, the PDA's screen may be too small for rescue workers wearing gloves to operate the GIS screen.

Currently, our system is intended only for use in times of disaster. However, as RFID systems come into wider use, we plan to develop the RFID system to become more broadly applicable to areas such as fire and crime prevention. Therefore, a new research and development project called RFID-based Positioning Systems for Enhancing Safety and Sense of Security, also promoted by MEXT, was started during this fiscal year.

Technology not used in normal situations will not be used in emergency situations. On the contrary, if an emergency response function is incorporated into popular equipment, the function will become more popular. In Japan, most mobile phones have built-in cameras and barcode readers. If the RFID reader-writers are also built into mobile phones, and RFID applications come into daily use, the applications described in this article have a better chance of success. We are currently collaborating with a Japanese mobile phone carrier to build an RFID reader into a mobile phone.

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Managing Catastrophic Events by Wearable Mobile Systems

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Abstract. Proetex is a European Integrated Project dedicated to micro- and nano-technology-based wearable equipment for emergency operators. During the first year of work, a careful analysis of several emergency scenarios has been carried out and has resulted in the design of a complete "smart" uniform for fire-fighters and emergency rescuers. These garments aim at monitoring both physiological parameters, position and posture of the operators and the presence of external potential sources of danger and to send these data to a remote coordinating unit. In the following, the main issues of the design flow will be described and discussed.

Keywords: Wearable, smart textiles, sensors, transmission.

1 Introduction

Smart sensor systems based on new micro- and nano-technological solutions are the key for the success of future applications of e-textiles. Ubiquitous recording and transmission of human and environmental data will allow conceiving new applications that will leverage the existing textile and electronic technologies. The challenge offered by emergency situations is mainly in the complexity of recorded data and in the necessity for the remote station to quickly analyze them and for the operator to receive only feedbacks that are really necessary (in form of alarms generated in response of real dangers) in an easily comprehensible way.

During the project, three different releases of smart garments will be delivered. After the first year, the first release will be based on already assessed technologies that will allow to record: - heart and respiratory rate; - core temperature; - external temperature; -absolute position via GPS; - operator posture.

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These systems are distributed among different garments: all systems that need a direct contact with the operator skin are embedded in an inner garment, while the others are integrated in a jacket that also hosts alarm systems and an electronic unit for signal processing and transmission hardware. A textile antenna is also hosted by the outer garment.

In the following, the analysis of different emergency scenarios is first described, in order to allow the appreciation of the heterogeneous constraints that different situations impose on the design of specific systems; then, the detailed description of these systems is given; finally, integration and transmission issues are briefly discussed.

2 Emergency Scenarios

The needs and expectations of the end-users about the use of a new generation of wearable devices, in terms of tasks and minimum required performances for the use in a real context have been investigated by suitable questionaires that have been distributed among fire-fighting and civil protection operators. By interpreting these needs, it is possible to establish a list of requirements and specifications for the systems, which represent the starting basis for the design (end-user driven design). An intense co-design with users is a key innovation element preventing the main risk of user low user acceptance of the project outputs.

Within the Proetex project also a data communication system is foreseen, which allows the transmission of sensor information to the user, to other operators or to local or remote control centers. For this reason it is really important to understand which are the current communication practices, both in terms of technology (devices and protocols), and of contents (what data are usually communicated to the control station, what is the feedback from the station), to guarantee a better integration of new developed communication systems with the existing ones.

Proetex addresses both Civil Protection and fire-fighting operators markets: by considering the great difference between the two users' needs (the work of a Civil Protection rescuer in case of earthquake or flood, for example, is deeply different than fire-fighter interventions in case of fire), since the preparatory phases, it has been decided to develop different prototypes of garments specialized for each application. It should also be considered that fire-fighters and Civil Protection garments have to comply with different specific European Standards, in terms of security and resistance to harsh environment conditions (e.g. EN 469 for fire-fighters garments). For these reasons it has been proposed to initially develop two different garments, one for fire-fighters and one for Civil Protection rescuers, with some common features (sensors to measure physiologic parameters, core and environment temperature, posture and activity), but specialized according to the specific user's needs.

To identify these needs, a small set of scenarios has been considered, presenting different conditions in terms of environment, weather (temperature, humidity...), duration and type of intervention. Some scenarios show situations representative of the main activities of Civil Protection rescuers, while others show typical interventions of fire-fighters.

A questionnaire has been prepared and submitted to the end-users representatives involved in the project (Brigade de Sapeurs Pompiers de Paris - BSPP, the French

Department de la Defence et de la Securité Civil - DDSC and the Italian Civil Protection - ICP-Eucentre.

1. *Violent earthquake and volcano activity*. This is a possible situation only in highly seismic regions in European countries, like Greece, Portugal, Turkey or southern Italy but earthquakes represent one of the major events of natural disasters all over the world, with mobilization of international aids and specialized rescue teams. The most important features in this scenario are the huge dimension of the area and the great number of civilians involved. According to the interviewed people, the main difficulty is the communication with people involved, that makes difficult to obtain complete information about conditions of different areas (earthquakes often damage or destroy traditional and mobile telephone infrastructures, as much as roads, not allowing the rescuers to reach working areas). Other difficulties are the exact localization and co-ordination in a large area of hundreds of rescuers, whose activity is monitored and managed by a remote control station (Italia situation room - Unified Centre, in the case of the Italian Civil Protection). In the development of devices for this kind of intervention, risks as the presence of fire, of toxic materials, or gas escapes should not be underestimated; it should also be considered that the work of a rescue team could lasts for many hours, with obvious problems of instrumentation efficiency, power management and storage.

2. *Heavy rains or flooding*. This scenario represents situations that could involve almost all European countries where, after extended periods of heavy rains, a river could flood the countryside and threaten villages and towns, or landslide could happen in mountain regions. In these situations rescuers work in difficult conditions caused by low temperature (hypothermia risk), rain, road interrupted by water, flood and drowning danger. As in the previous scenario, interviewed people ask for devices able to improve localization of rescuers, communications among them and between them and the monitoring station, since the involved area could be really huge. Main constraints for the equipment are the need of use for many consecutive hours.

3. *Night earthquake on a snowy mountain zone in winter*. This scenario represents the worst environmental conditions in which a rescuer could work, with low temperature during the day and very low temperature during the night, with potential frost-bite risk, high humidity, snow and poor visibility. Interventions like this often take place in lands difficult to access, due to their geography, with people (and thus potential victims waiting for rescuers) scattered in a wide area. In this condition the need for communication improvements among rescuers and between them and the monitoring stations is underlined. As in every earthquake, structural collapses that could involve also first aid operators should be taken into account, as much as gas escapes or the presence of toxic materials. As for scenario 1, although only restricted areas in European countries could be interested by such a phenomenon, great catastrophes of this kind all over the world could ask for specialized intervention teams coming from European countries.

4. *Fire-fighters tackling a large industrial fire*. This is a typical intervention for fire-fighters in urban and industrial areas of almost all European countries. According to the interviewed operators, hundreds of fire-fighters can be involved in such an intervention; there are specific coded rules of engagement depending on fire cause,

involved (toxic) materials and topology of the area; fire-fighters activity is always monitored by a local mobile command post, and by a remote station. Unlike previous scenarios, interventions last usually only few hours but in really critical conditions, in presence of fire, possible explosions, inflammable or toxic materials (often present in industrial installations), with a high risk of structural collapse. In this scenario, fire-fighters work in high-temperature, dark, smoky and noisy (due to the fire) environments. End-users expectation is that new wearable devices will improve security and efficiency of people working in the operation field, but also control and command of fire-fighting operations by local and remote stations.

5. *Wild-land fire*. This scenario considers the presence of wild-land fire in an unhabitated area in places difficult to access by rescuers' means, but not far from villages or towns. Operators stress the importance of quick interventions, to prevent the spreading of fire from its arising initial area. Rules of engagement state that activities should be monitored and managed by one or more mobile local command posts, placed in safe areas near the work field. Rescue teams (not single fire-fighters) keep radio-contact with the local command posts during all the phases of their activity, while these are always in contact with a remote control station. Interventions in this scenario could involve, depending on fire size, environment, weather conditions and area morphology, even hundreds of "ground-attack" fire-fighters, as well as "air-attack units" (planes or helicopters with flame retardant or water tanks) to be monitored and commanded continuously. Work conditions could be complicated by smoke and dust (which decrease operatives' visibility), by heat, noise, and by the contact with water and chemical additives for flame retardancy used by the fire-fighters. Also in this case, end-users ask for devices that could improve security and efficiency of the operatives (sensors for temperature and heat flux, organic volatile gas detectors), as much as command and control of the operatives by the command stations.

3 Garment Design

In order to answer the needs expressed by the end users, a complete uniform has been designed for each category of operator. For both civil protection and fire-fighters, the measurement of the main physiological parameters (heart rate and breathing) is done by inserting suitable sensors in garment in contact with the skin (inner garment). The same approach is followed also for producing a wearable system for victims. The only difference is that for victims a patch, instead of a t-shirt, has been designed, considering the possible difficulties for victims to wear a garment. Then a specialized outer garment for each operator category is foreseen. Besides containing a specific series of sensors, the outer garment also hosts alarm actuators and an electronic box, for signal collection, processing and transmission.

3.1 Inner Garment

The first inner garment prototype will be realized in two different versions with the aim to evaluate which of them allows better performances with emergency operators:

- A firemen shirt with 5 electrodes (same structure of the victim patch).
- A firemen shirt with 3 electrodes and a piezoresistive sensor.

The sensorized region will be realized in a one step process. Therefore, the electrodes and the sensors will be perfectly integrated in the final garment [1]. The fireman shirts are not usually tight-fitting so the sensing region will be made with a different elasticity in order to allow a better contact with the skin. The sensorized region is placed corresponding to the xiphoid process for maintaining a stable contact also in motion condition. The same principle has been applied also for the victim patch which will be stuck by an adhesive band, to the chest of the injured person.

Shirt with 5 electrodes

This first prototype version includes 5 textile electrodes and a temperature sensor as shown in Fig. 1a. Electrodes are used for monitoring ECG signal and respiratory activity. In order to monitor the breathing, the electrodes E2 and E5 (larger with respect to E1, E3, and E4) inject a high frequency (50 KHz) and low amplitude current in the body whereas the electrodes E3 and E4 measure the impedance change [2-3]. The relationship between the air flow through the lung and the impedance change on the thorax permits to monitor the respiratory activity. The electrodes E3 and E4 allow as well to acquire a differential ECG lead. The E1 electrode is used as reference.

A monolithic temperature sensor (LM92) is placed in a dedicated pocket in the axilla area of the shirt in order to guarantee the contact with the skin.

Shirt with 3 electrodes and a piezoresistive sensor

This first prototype version includes 3 electrodes, a piezoresistive and a temperature sensor (Fig.1b). In this case the electrodes E2 and E5 are used to acquire a differential ECG lead whereas E1 is the reference. The electrodes have all the same dimension because they do not have to inject current. The piezoresistive sensor permits to monitor breathing by measuring the cross-sectional changes on the thorax. In fact this sensor changes its electrical resistance according to the strains due to the respiratory activity [4]. The same monolithic temperature sensor (LM92) used in the previous prototype, is placed in an apposite pocket in the internal face of the shirt.

Fig. 1. Inner Garment Prototype with a) 5 electrodes; b) 3 electrodes and a piezoresistive sensor

3.2 Outer Garment

In order to give a maximum of information about the operator situation in the environment, a series of sensors has been selected for the outer garment:

• GPS location
• Temperature of the environment (air)
• Motion detection (posture and activity)

At this stage, most of these sensors are not realizable in textile form, therefore their integration in the jacket without negative impact on the ergonomy has been the challenging objective of this activity. Of course the choice of the sensors' location for the best quality of the information collected, their ability to be replaced in an easy way for maintenance and the pertinence of the selected sensors are the key-targets for the first series of prototypes. The garment will also include a communication interface, which consists of a textile antenna coupled to a transceiver module, and a set of alarm generators (sound and visual) that will be hosted respectively in the collar area and in the wrist area.

The power will be supplied jointly by a battery included in the electronic box and an experimental flexible battery integrated in the garment and link by textile compatible wire. The garment design has been developed taking into consideration ergonomics issues and simplicity of wiring, as shown in the following figure.

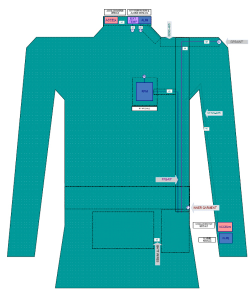

Fig. 2. Outer Garment Prototype with sensor and electronic positions

4 Textile Sensors

The first release of the prototype will include several sensors able to monitor important parameters relevant for the operator such as resumed by the following table.

Table 1. Sensors that will be integrated in the ProeTex prototypes. For each sensor the relative measured parameter and the garment in which it will be integrated are reported.

Parameter	Sensor	Garment
Heart Rate	Textile electrodes	Inner garment; Victim patch
Respiratory Signal	Textile electrodes	Inner garment; Victim patch
Core Temperature	LM92 integrated sensor	Inner garment; Victim patch
Operator position	GPS module	Outer garment
Operator activity	3 axial accelerometers	Outer garment
External Temperature	Thermocouple	Outer garment

The following part of this section deals with the solutions adopted in the project in order to measure the parameter of interest.

4.1 Heart Rate

Heart rate can be obtained by the ECG signal acquired with textile electrodes as described in Section 3.1 (electrodes E1, E2 and E5). In order to evaluate the influence of the equipment worn by firemen on the quality of signals, preliminary tests have been carried out according to the following experimental protocol:

- Fireman at rest
- Fireman going up and down the stairs
- Fireman putting on the oxygen bottle
- Fireman going up and down the stairs with the oxygen bottle

The first trials have been done to evaluate the quality of signals with both dry electrodes and electrodes coupled with hydrogel membranes. Due to the physical activity and the equipment, the skin of the firemen during the operation is usually wetted by sweat, for this reason the use of hydrogel membrane has turned out to be unnecessary, as can be observed by comparing the signals acquired in rest condition, with and without the membrane, (fig 3a and 3c).

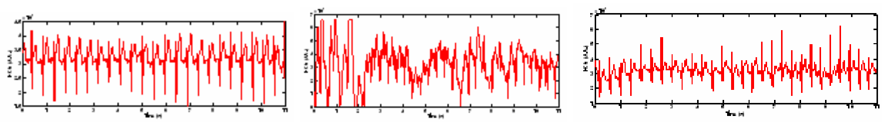

Fig. 3. Waveforms of the ECG signal with a) the fireman at rest (wet electrodes). b) the fireman in movement (wet electrodes) c) the fireman (with oxygen bottle) in movement (wet electrodes).

The second series of tests have been devoted to select the most reliable position in terms of signal quality, for textile electrodes and sensor. Several positions have been checked during emergency activity leading to the solution described in section 3.1. This configuration allows for instance the use of the oxygen bottle, that is normaly used during activity not interfering with signals quality as can be seen in Fig. 3b and Fig. 3c. The signals acquired in motion condition without and with oxygen bottle (Fig. 3b and Fig. 3c) present some movement artefact with respect to the traces visualized in Fig. 3a and obtained with the fireman at rest. In any case, by means of an appropriate algorithm it is possible to evaluate the heart rate. It is important to notice that the signal acquired with the standard fireman equipment (oxygen bottle) is much more stable with respect to the one acquired without. This is probably due to the position of the electrodes (on the thorax) and a better contact of the sensorised region guaranteed by the straps and the belt of the fireman equipment.

4.2 Respiratory Signal

Breathing monitoring using textile electrodes (impedance pneumography)

In order to evaluate the performance of impedance pneumography, some tests have been carried out on the fire-fighters (by using the electrodes configurations shown in

Sect. 3.1). The tests have been carried out according to the same experimental protocol illustrated in the *heart rate* paragraph. In Fig. 4a the waveform of the respiratory signal with the fireman at rest using respectively wet electrodes (due to sweat) is shown.

Fig. 4. a) Waveforms of the respiratory signal with the fireman at rest using wet electrodes; b) Waveforms of the respiratory signal with the fireman (with oxygen bottle) in movement using wet electrodes

The signal acquired during motion with oxygen bottle (Fig. 4b) presents some movement artefacts with respect to the traces visualized in the figure and obtained with the fireman at rest. As before, an appropriate signal processing allows to remove the noise in order to extract respiratory parameters (for instance respiratory rate).

Breathing monitoring using piezoresistive fabric sensors

Piezoresistive fabric sensors can be realized using cotton fibre and yarns with electrical properties. The most striking feature of these sensors is represented by the changing of electrical resistance when exposed to an appropriate strain. Different materials have been investigated in order to improve the performance of these sensors. Preliminary tests have been carried out in comparison with reference measurement systems and they have given satisfactory results as shown in Fig. 5.

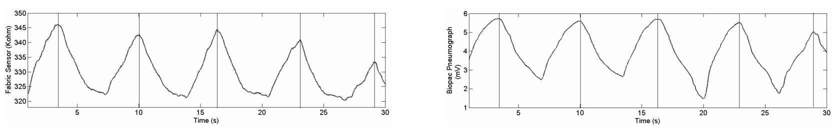

Fig. 5. Comparison of respiration signals obtained with a) a piezoresistive fabric sensor and b) a conventional respiratory effort transducer

4.3 Core Temperature

The core temperature of the human body will be measured from the surface of the skin of the operator in the conditions preserving the thermal insulation. In this way,

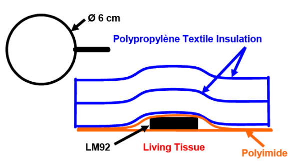

Fig. 6. Design of the core temperature sensor

the heat loss is minimized, a zero heat flow area is obtained under the insulation and the isothermal conditions are brought close to the surface of the skin. As a result, the temperature sensor fixed on the skin under the insulation will deliver a result which is a good indication of the core temperature. An integrated sensor will be used (LM92, National Semiconductor) following the insulation strategy reported in Fig. 6.

4.4 Operator Position

The global position sensor will be realized with a commercial GPS module (included in the electronic box) connected to an antenna placed in the outer part of outer garment (shoulder region).

4.5 Operator Activity

The aim of operator activity monitoring is to provide information of dangerous situation for the operator. In particular, data acquired from 3-axial accelerometers will be elaborated to gather information about user immobility and user falls . Two triaxial accelerometers will be embedded in the first prototype of the outer garment. One accelerometer will be fixed to the torso and the other fixed to the wrist. The first sensor will be used both to detect user activity and fall while the other will be employed in order to have more detailed information on activity (a subject can have activity also when the torso is not significantly moving). Preliminary trials have been performed by applying a triaxial accelerometer to the chest of a subject that was asked to execute certain tasks (i.e running and stopping, jumping, walking). These trials have been useful to identify the parameters that can be extracted from the accelerometer in order to monitor user lack of activity (immobility) and fall.

4.6 External Temperature

The external temperature (environment temperature) sensor will be realized with a thermocouple located in the neck area of the outer garment (in the front external part). Moreover a circuit for thermocouple compensation has to be placed near the sensor in the inner part of the outer garment.

5 Electronic Integration and Transmission

The electronic integration partners developed, designed and miniaturized the signal processing and transmission modules for the life sign sensors, defined a topology for the entire network [1], and integrated the electronic subsystems into an efficient, wearable data acquisition and transmission module that transfers the data to a centralized monitoring system upon requirement request. A module for civilian victims, with reduced capabilities and local data visualization was also considered.

A proof of concept was implemented to confirm the feasibility and to adjust the features to the end-user requirements. The main functions of the first prototypes of the Professional Electronic Box (PEB) and Victim Electronic Box (VEB) were:

Life signs monitoring [2]: Acquisition of electrocardiogram (ECG) with signal processing for extraction of heart rate, acquisition of respiration signal using piezo-resistive and impedance measurement methods with extraction of respiration rate, acquisition of body temperature.

Activity monitoring [3]: acquisition of 3-D accelerations with processing for basic classification of user movement, acquisition of position coordinates with a GPS module.

Alarm generation based on parameterized limits: checking the heart rate, the respiration rate, the activity and the location of the professionals.

Wireless communication over Bluetooth: sending vital signs, extracted features and alarms to control center, receiving configuration and inquiry commands from control center

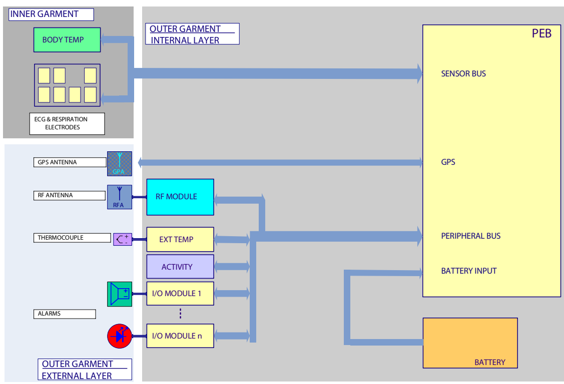

Fig. 7. The general block diagram of the first PROETEX electronic prototype

6 Conclusions

The first year of the Proetex Project has been dedicated to the definition of the specifications for the first releases of prototypes. These wearable systems include an inner garment able to collect physiological parameters as heart rate and respiratory signals and an outer garment where operator position and outer temperature are included. All signals are collected by an electronic box that also includes a GPS.

Acknowledgments. The European Commission, funding the Project PROETEX under the IST Programme, Contract n. 26987, is gratefully acknowledged.

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Towards the Integration of Real-Time Real-World Data in Urban Search and Rescue Simulation

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Abstract. The coordinated reaction to a large-scale disaster is a challenging research problem. The Robocup rescue simulation league addresses this research problem but is currently lacking an interface to real-world real-time data to test the validity of both simulation and simulated reactions. In this paper, we describe a wearable-computing-based real world interface to the Robocup Rescue simulation software and provide some updated results of preliminary evaluations.

1 Introduction

Large scale urban disaster situations such as earthquakes, floods or terrorist attacks pose an important threat to modern urban civilization centers. Examples such as the Kobe earthquake, the pacific tsunami, the hurricane Kathrina or the tragic events of September 11th 2001 demonstrate that although preventive measures and disaster response plans were in place, these events pushed existing countermeasures over their limits, resulting in loss of human lives, chaotic situations and long term adversary effects on the affected regions.

After the Kobe earthquake, the japanese government decided to promote researchers to work on problems related to large-scale urban disasters. One of the outcomes of this initiative was the Robocup Rescue competition. Using the same successful method of competition-based benchmarks that the Robot Soccer competition was applying, the Robocup Federation added two new competitions to the Robocup, Robocup Rescue Robot League and Robocup Rescue Simulation League.

In the Rescue Robot leagues, physical robots are designed and tested in simulated disaster situation. The aim of the robot and its operator is to map an unknown environment and provide information about simulated disaster victims such as their location and situation, their simulated medical condition and other helpful indications such as ID tags. Robot and operator work under strict time constraints, the operator can only perceive the situation in the disaster arena through the sensors of the robot. In order to support the development of autonomous robots, there are parts of the arena that are covered by a simulated communication blackout, i.e., cannot be explored by a tele-operated robot.

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The Rescue simulation league aims at simulating large-scale disasters and exploring new ways for the autonomous coordination of rescue teams [8]. In the Rescue Simulation league, the goal of a team participating in the competition is to provide a software system that reacts to a simulated disaster situation by coordinating a group of simulated agents such as police, ambulance and fire brigade agents. This goal lead to challenges like the coordination of heterogeneous teams with more than 30 agents, the exploration of a large-scale environment in order to localize victims, as well as the scheduling of time-critical rescue missions. Each of these agents only has a limited amount of communication bandwidth they can use to coordinate with each other, so the problem cannot be addressed by a central coordination entity but has to be solved by a true multi-agent system. Moreover, the simulated environment is highly dynamic and only partially observable by a single agent. Agents have to plan and decide their actions asynchronously in real-time. Core problems are *path planning*, *coordinated fire fighting*, and *coordinated search and rescue* of victims.

The performance of a team in a scenario is scored by the simulation software that provides a number of measures derived from the simulation, e.g., the survival rate of civilians, the overall health of the simulated responders and the percentage of buildings burned down. These measures are then used to calculate the final score of a simulation run. Thus, in order to reach a high score, a team has to optimize their multi-agent system towards maximizing beneficiary elements of the scoring function while minimizing the adversary elements.

Both leagues change elements of the competition and scoring functions from competition to competition to foster the development of new capabilities and sustain a continuous progress towards obtaining real-world usable systems which is the long-term goal of the leagues.

Comparing the results of the two leagues over the last years, we find that a rapid progress has been made in specific areas such as robot self-localization and mapping[4] and autonomy[11], but that little progress has been made so far towards the application of the technology developed in real-world disaster and training situations.

Applying the simulation system in the real world currently lacks the interface to the real world information, i.e., currently, the simulation system relies on carefully designed special-purpose map data and observations generated by the simulation itself, e.g., agent motion is computed by a traffic simulator and cannot be observed from real-world motion of responders. However, by using wearable computing technology, we can provide such observations to the simulation system. This has three uses. First, it can be used to record real-world data from real-world intervention scenarios and by this, assess the validity of the simulation. Second, it can be used to observe the reaction of the team multi-agent systems to real-world data. Third, it is a step towards using both the simulation system and the team multi-agent systems to support incident commanders and responders in training and real interventions by providing autonomous decision support and faster-than-realtime simulation for strategy decisions.

The solutions presented in this paper are based on the open source agent software [2], which was developed by the *ResQ Freiburg 2004* team [10], the winner of RoboCup 2004. The software prototype designed for linking responders to the simulation has also been released [1].

We propose preliminary results from a wearable computing device, acquiring disaster relevant data, such as locations of victims and blockades, and show the data integration into the *RoboCupRescue Simulation* [8] platform, which is a benchmark for MAS within the RoboCup competitions. Communication between wearable computing devices and the server is carried out based on the open *GPX* protocol [20] for GPS data exchange, which has been extended for additional information relevant to the rescue task. We show exemplarily how the data can consistently be integrated and how rescue missions can be optimized by solutions developed on the RoboCupRescue simulation platform. The preliminary results indicate that nowadays wearable computing technology combined with MAS technology can serve as a powerful tool for Urban Search and Rescue (USAR).

The remainder of this paper is structured as follows. We present an interface between human rescue teams and the rescue simulator in Section 2. In Section 3 we give some examples how approaches taken from MAS can be utilized for data integration and rescue mission optimization. In Section 4 we show the results of experiments integrating data into RoboCupRescue and infrastructureless indoor tracking of responders and conclude in Section 5.

2 Interfacing Human Responders

In wearable computing, one main goal is to build devices that support a user in his primary task with little or no obstruction. Apart from the usual challenges of wearable computing [19,18], in the case of emergency response, the situation of the responder is a stressful one. In order to achieve primary task support and user acceptance, special attention has to be given to user interface design. For this application, the user needs the possibility to enter information about his observations and needs feedback from the system which recorded and transmitted the information [1]. Furthermore, the user needs to receive information from the system that provides task-related instructions from the command center.

The implementation has to cope with multiple unreliable communication systems such as existing cell phone networks, special-purpose ad-hoc communication and existing emergency-response communication systems. As the analysis of the different properties of these communication systems is beyond the scope of this article, we will therefore abstract from them and assume an unreliable IP-based connectivity between the mobile device and a central command post. This assumption is motivated by the fact that both infrastructure-based mobile communication networks and current ad-hoc communication systems can transport IP-based user traffic.

For mobile devices, a number of localization techniques are available today, for an overview see [6]. Although some infrastructure-based communication networks are also capable of providing localization information of their mobile terminals, we assume the presence of a localization device with a GPS-like position accuracy.

The rationale behind this is that the localization information provided by communication systems is not very precise (e.g. sometimes limited to the identification of the

[1] Technically, this feedback is actually not required by the application, but we envision that it will improve user acceptance.

current cell, which may span several square kilometers) and therefore not usable for our application. The GPS system also has well-known problems in urban areas and in buildings. But by applying techniques such as the ones stated in [13], we have improved its reliability and accuracy for indoor localization.

The situation of the device and its user is also characterized by harsh environmental conditions related to the emergency response, such as fire, smoke, floods, wind, chemical spilling etc. The device has to remain operable under such conditions, and moreover to provide alternative means of input and output under conditions that affect human sensing and action abilities. Moreover, the system has to be integrated into the user processes of emergency response, e.g. it must have no impact on response times of units and therefore should be integrated into the normal gear of responders.

As these requirements are quite complex, we decided to design and implement a preliminary first test system without these requirements and later a wearable emergency response system which is supporting the requirements in its system design.

2.1 A First Test System

In order to analyze the properties of the communication and localization systems and test the software interface to the simulation system, a preliminary test system has been implemented, for which three requirements have been dropped, the design for harsh environmental conditions and emergency response processes, indoor localization capability and the ability to use multiple alternative input and output.

The communication and localization system is independent of the user requirements with the exception of the fact that the system has to be portable. Therefore we chose a mobile GPS receiver device and a GSM cell phone device as our test implementation platform. The GPS receiver uses the bluetooth [3] personal area network standard to connect to the cell phone. The cell phone firmware includes a Java VM based on the J2ME standard with JSR82 extensions, i.e., a Java application running on the VM can present its user interface on the phone but can also directly communicate with bluetooth devices in the local vicinity and with Internet hosts via the GSM networks GPRS standard.

The implementation of the test application is straightforward: It regularly decodes the current geographic position from the NMEA data stream provided by the GPS receiver and sends this information to the (a priori configured) server IP address of the central command center. The utilized protocol between the cell phone and the command center is based on the widely used GPX [20] standard for GPS locations.

A detailed description of the protocol extension can be found in [9].

2.2 A Wearable Emergency-Response System

In order to fulfill more requirements, another system has been designed based on additional hard- and software. The system uses a miniature PC system, the so-called *OQO*. It is based on a transmeta CPU running the Linux operating system, has bluetooth and WiFi wireless interfaces, and can be extended via USB interfaces. The wearable CPU core runs the main application program. For localization, a bluetooth GPS receiver and a XSENS 6DOF motion sensor are used.

As already stated, the design of the user interface is a crucial one for this application. Therefore, we use a glove as wearable user input device [14] and a wireless link between the user interface device and the wearable computer. Such an interface has already been used in other applications such as aircraft maintenance [16] (see Figure 1(d)).

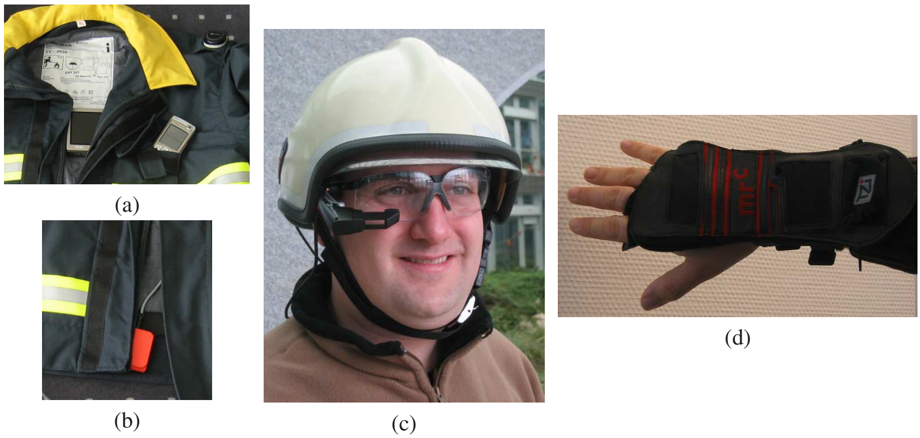


Fig. 1. The *OQO-based wearable computer*: (a) CPU unit with GPS and mobile phone. (b) Sensor for Pedestrian Dead Reckoning. (c) HMD worn by the test person. (d) A glove-based wireless wearable interaction device.

The primary output device is a head-mounted display that can be integrated into existing emergency-response gear such as firefighter helmets and masks (see Figure 1(b)). In applications where headgear is not commonly used, the output can also be provided through a body-worn display device or audio output.

3 Multi Agent Systems (MAS) for Urban Search And Rescue (USAR)

3.1 Data Integration

Generally, we assume that, if communication is possible and new GPS fixes are available, the wearable device of a rescue team continuously reports the team's trajectory as a *track* message to the command center. Additionally, the rescue team might provide information for specific locations, as for example, indicating the successful exploration of a building, the detection of a victim, and the detection of a blocked road, by sending a *waypoint* message.

Based on an initial road map and on the information on road blockage and the autonomously collected data on trajectories traveled by the agents, the current system builds up a connectivity graph indicating the connectivity of locations. The connectivity graph between a single location and all other locations is constructed by the Dijkstra algorithm. The connectivity between two neighboring locations, i.e. the weight of the corresponding edge in the graph, depends on the true distance, the amount of blockage, the number of crossings, and the number of other agents known to travel on the same route. In the worst case, the graph can be calculated in $O(m + nlog(n))$, where n is the number of locations and m the number of connections between them. The knowledge of the connectivity between locations allows the system to recommend "safe" routes to rescue teams and to optimize their target selection.

The search for victims of many rescue teams can only be coordinated efficiently if the rescue teams share information on exploration. We assume that rescue teams report when they have finished to explore a building and when they have found a victim, by transmitting the according message to the command center. The command center utilizes this information for distributing rescue teams efficiently among unexplored and reachable locations.

3.2 Rescue Sequence Optimization

Time is a critical issue during a real rescue operation. If ambulance teams arrive at an accident site, such as a car accident on a highway, it is common practice to optimize the rescue sequence heuristically, i.e. to estimate the chance of survival for each victim and to rescue urgent cases earliest. During a large-scale disaster, such as an earthquake, the efficient distribution of rescue teams is even more important since there are many more victims and usually an insufficient number of rescue teams. Furthermore, the time needed for rescuing a group of victims might significantly vary, depending on the collapsed building structures trapping the victims.

In RoboCupRescue, victims are simulated by the three variables *damage*, *health* and *buridness*, expressing an individual's damage due to fire or debris, the current health that continuously decreases depending on damage, and the difficulty of rescuing the victim, respectively. The challenge here is to predict an upper bound on the time necessary to rescue a victim and a lower bound on the time the victim will survive. In the simulation environment these predictions are carried out based on classifiers which were induced by machine learning techniques from a large amount of simulation runs. The time for rescuing civilians is approximated by a linear regression based on the buridness of a civilian and the number of ambulance teams that are dispatched to the rescue. Travel costs towards a target can directly be taken from the connectivity graph. Travel costs between two reachable targets are estimated by continuously averaging costs experienced by the agents [2].

We assume that in a real scenario expert knowledge can be acquired for giving rough estimates on these predictions, i.e. rescue teams estimate whether the removal of debris needs minutes or hours. Note that in a real disaster situation the system can sample the approximate travel time between any two locations by analyzing the GPS trajectories received from rescue teams in the field. Moreover, the system can provide for different means of transport, i.e. car or by feet, the expected travel time between two locations. The successful recognition of the means of transport from GPS trajectories was already shown by Liao and colleagues [15].

If the time needed for rescuing civilians and the chance of survival of civilians is roughly predictable, one can estimate the overall number of survivors by summing up the necessary

[2] Note that the consideration of specific travel costs between targets would make the problem unnecessarily complex.

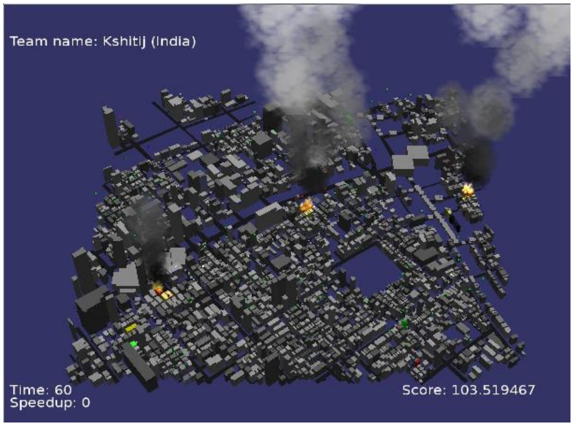


Fig. 2. A 3D visualization of the RoboCupRescue model for the City of Kobe, Japan

time for each single rescue and by determining the overall number of survivors within the total time. For each rescue sequence $S = \langle t_1, t_2, ..., t_n \rangle$ of n rescue targets, a utility value $U(S)$ that is equal to the number of civilians that are expected to survive is calculated. Unfortunately, an exhaustive search over all $n!$ possible rescue sequences is intractable. A good heuristic solution is to sort the list of targets according to the time necessary to reach and rescue them and to subsequently rescue targets from the top of the list. However, this might lead to inferior solutions. A better method could be the so-called *Hungarian Method* [12], which optimizes the costs for assigning n workers to m tasks in $O\left(mn^2\right)$. The method requires that the time needed until a task is finished does not influence the overall outcome. However, this is not the case for a rescue task, since a victim will die if rescued too late. Hence, we decided to utilize a Genetic Algorithm [7] (GA) for the optimization of sequences and to utilize it for continuously improving the rescue sequence executed by the ambulance teams.

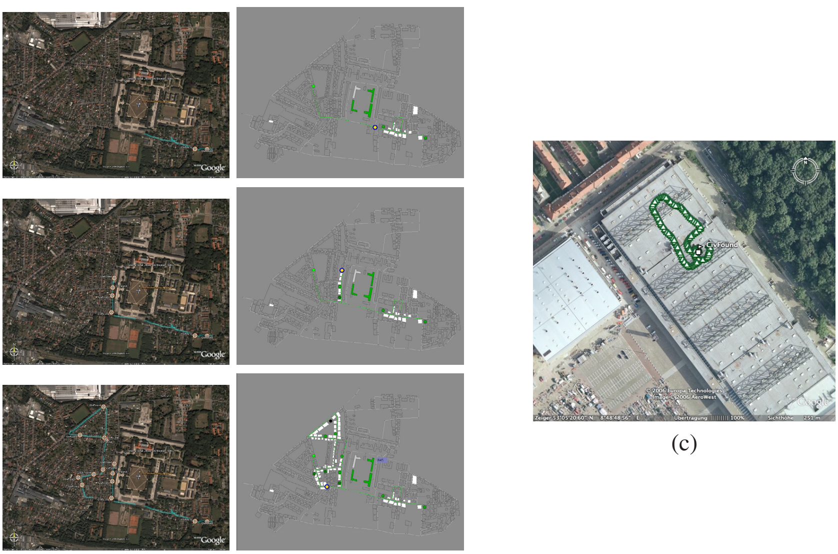
The GA is initialized with heuristic solutions, for example, solutions that *greedily* prefer targets that can be rescued within a short time or urgent targets that have only little chance of survival. The fitness function of solutions is set equal to the sequence utility $U(S)$. In order to guarantee that solutions in the genetic pool are at least as good as the heuristic solutions, the so-called *elitism* mechanism, which forces the permanent existence of the best found solution in the pool, has been used. Furthermore, we utilized a simple one-point-crossover strategy, a uniform mutation probability of $p \approx 1/n$, and a population size of 10. Within each minute, approximately $300,000$ solutions can be calculated on a *1.0 GHz Pentium4 computer*.

We tested the GA-based sequence optimization on different city maps in the simulation and compared the result with a greedy strategy. In each of the tested environments, sequence optimization improved the performance of the rescue team. More information on the results can be found in [10]. One important property of our implementation is that it can be considered as an *anytime algorithm*: The method provides at least a solution as good as the greedy solution, but also a better one, depending on the given amount of time.

4 Experiments

The system has preliminary been tested by successively integrating data received from a test person. The test person equipped with the first test device described in Section 2 walked several tracks within a district of the City of Bremen (see Figure 3). During the experiment, the mobile device continuously transmitted the trajectory of the test person. Additionally, the test person reported *victim found* waypoints after having visual contact with a victim. Note that victim waypoints were arbitrarily selected, since fortunately there were no real victims found in Bremen.

In order to integrate the data into the rescue system, the received data, encoded by the extended GPX protocol that represents location by latitude and longitude, has to be converted into a grid-based representation. We utilized the Universal Transverse Mercator (UTM) [17] projection system, which provides a zone for any location on the surface of the Earth, whereas coordinates are described relatively to this zone. By calibrating maps from the rescue system to the point of origin of the UTM coordinate system, locations from the GPS device can directly be mapped. Figure 3(b) shows the successive integration of the received data into the rescue system and Figure 3(a) displays the same data plotted by *GoogleEarth*. Note that GPX data can without any conversion be directly processed by GoogleEarth.



(a) (b) (c)

Fig. 3. Successive integration of data reported by a test person equipped with a wearable device. (a) The real trajectory and observations of victims plotted with GoogleEarth (victims are labeled with "civFound"). (b) The same data integrated into the rescue system (green roads are known to be passable, white buildings are known as explored, and green dots indicate observed victims). (c) The result of an indoor tracking experiment performed at Robocup 2006, visualized in Google Earth. The event took place in the exhibition center Messe Bremen which can be seen in this aerial photography.

In a further test, a person wearing the emergency-response wearable system was tracked while walking indoors and the trajectory data and victim identification information was visualized in realtime. The test took place at Robocup 2006 in front of a scientific audience. Indoor localization was performed by using an implementation of pedestrian dead-reckoning and GPS data fusion [5].

5 Conclusion

We have demonstrated a system which is generally capable of integrating trajectories and observations of many mobile devices into a consistent world model. As shown by the results of the simulation, the consistent world model allows the system to coordinate exploration by directing teams to globally unexplored regions as well as to optimize their plans based on the sampled connectivity of roads. To apply this global coordination also outside the simulation, i.e. to send the road graph and mission commands back to the wearable devices of real rescue teams in the field, will be a part of the future work.

Through augmentation with additional sensing techniques such as pedestrian dead-reckoning, we can obtain sufficient GPS-like accuracy even in poor signal reception conditions such an in buildings or urban corridors. However, when used for an extended period, pure PDR accumulates position errors that lead to unreliable positioning. We are therefore studying techniques to augment PDR-based indoor localization to limit error accumulation.

Finally, we plan to use our system to record a training event of emergency responders and compare the instructions given by our system with commands given by human incident commanders. This hopefully will lead to a better understanding of advantages and limitations of our system and to new information that can be taken into account for designing the robocup rescue simulation software in order to create more realistic challenges for the robocup community.

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Playing with Fire: User-Centered Design of Wearable Computing for Emergency Response

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Abstract. This paper presents an approach of using game-like techniques to engage firemen from the Paris Fire Brigade into a participatory design process of wearable computing for emergency response. The approach is motivated by explaining the specific difficulties of the domain and technology and by explaining how to address them in a user-centered design approach featuring multiple prototyping steps. A multiplayer virtual reality computer game is one of these techniques. The paper shows how the design of the computer game is informed and validated by other techniques and how it can be used successfully to simulate certain characteristics of the domain and the technologies that are relevant for design. As such we present it as a tool to mediate and facilitate the collaboration of technology providers and users, empowering end-users to leverage their domain expertise to explore, assess and design well-fitting solutions in a creative, reflective and enjoyable collaborative process.

1 Introduction

In the European project wearIT@work we are doing research and development of wearable computing technologies for emergency response [1]. In order to engage our end-user organization, the Paris Fire Brigade, into a user-centered participatory design process, we developed game-based design techniques, including a board game and a computer game, to provide the firemen with an enjoyable means to experience prototypes of future wearable technologies in simulations of their work context. In the following sections we motivate our approach by presenting the design challenges involved with the particular technology and application domain. Then we present the two design techniques and some initial results and discuss their implications for prototyping user experiences for the design of innovative technologies.

1.1 Wearable Computing

In the wearIT@work project we consider various types of wearable technologies, such as head-mounted displays, wireless communication, physiological and environmental sensors, on-body computing, and sensor networks. For the case of firemen, we can think of wearable computing as all IT that is either integrated with clothing or personal equipment or worn itself in that way. The essential characteristic is that wearable computing should be as unobtrusive as possible, such that it supports the user in carrying

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out the primary task as undisturbed as possible and not requiring the primary task to be interrupted [2]. Besides suitable ergonomics and modes of interaction, it is the overall system's sensitivity towards the usage situation and the user (context awareness and personalization) that contributes to its unobtrusiveness. The specific potential of wearable computing for emergency response comes from this quality of being unobtrusive and highly adaptive: in principal it allows for IT support even under the difficult domain conditions described below. But because of these very qualities it is also particularly difficult to design systems that fit sufficiently well with the supported work processes.

1.2 Emergency Response

As one would expect for a community of practice [3] operating under such working conditions, the Paris Fire Brigade displays very strong cohesion as a group, specific formal and informal organizational processes, a professional jargon, and specific rites and rituals. This is to say that the organization poses a considerable challenge to a proper understanding of its workings, to engaging its members in an open participation and in animating a pleasant overall design process. Because of the risks involved, emergency response organizations are typically very cautious with adopting new technologies. For wearable computing this is reinforced by its key potential of close integration with the supported activities, requiring an in-depth understanding of current work practice and probably resulting in substantial change to these practices.

1.3 Sharing User Experiences

The basis for our design approach is the notion that the users, their social organization, their tasks and the technologies they use to accomplish these tasks constitute a socio-technical system of interdependent factors. This means that a well-running working context has established a favorable fit between these factors. It implies that changing one of the factors usually requires the adaptation of the others. For example, the introduction of a new technology may require the adoption of new working procedures. Therefore, we understand our design task as facilitating the transition from one well-running state of the socio-technical system to the next [4]. Achieving a good design solution is typically not possible by changing a single factor and adapting the others. This is because the implications of a given change for the socio-technical system as a whole can typically only partially be determined beforehand. One of many reasons for this is that skillful workers typically cannot precisely explain their know-how because of its tacit nature [5]. And this sets a limit to the analytical assessment of both technological options and the impact of changes to skillful work processes. Put simply, this is why firemen would typically favor assessing a new technology by trying it out in the context of their work. In their case the problem is even harder as fire fighting typically consists in a team effort with a specific organizational structure and allocation of roles and responsibilities. Individual firemen typically do not have expertise in all possible areas of their profession and more importantly they cannot act out their expertise in more than one role at any given time. Therefore, the full expertise is only accessible through a collaborative group action. In the case of novel technologies such as wearable computing, trying them out in actual usage situations is possible only at later stages of the development process because functional prototypes may take a considerable time to develop [cp. 6]. Additionally, such functional prototypes will typically not be available in sufficient numbers for group assessment. For this and other reasons, a new well-running system state is typically achieved through a sequence of multiple changes and adaptations that allow for practical assessment by putting intermediate designs to work. Schön calls this way of how practitioners may apply their expertise to creative thinking 'reflection in action' [7]. Additionally, when trying to facilitate such a design process it is crucial to realize that the socio-technical system that is supposed to make the transition to a new well-running state consists of people with histories, skills and values as well as an organization with a certain culture. Largely irrespective of the quality of a given design with respect to functional requirements, the whole design process may fail if the transition is not supported in an appropriate way with respect to these human and organizational factors. A typical example would be a useful technology that is largely ignored by its intended users because the design process did not include a suitable appropriation process [8]. In the wearIT@work project we have defined three key mechanisms to accomplish a successful transition of the socio-technical system:

Shared Mutual Understanding of Users and Designers. This includes continuous empirical studies of the context of use and continuous explanations of technological options to the users.

Participatory Design of Innovative yet Usable Solutions. This includes continuous implication of users in all design activities, including in particular a series of prototyping techniques that provide rich user experiences of new technologies.

Designing for the Complete User Experience. This means understanding the factors that make both the design process and the product of design a pleasant experience for the users and observing them as much as possible.

We have conducted intensive empirical studies at our user organization, ranging from numerous interviews, over non-participative observation to hands-on reconnaissance and incident command training. These studies provide the foundation for the design techniques that we are developing. They enable us to make informed choices as to how to represent the domain and inspire us to propose certain design options. Moreover, they enable us to ask the right questions during design workshops and to understand the answers provided by our users. What is important to understand is that despite our intensive empirical studies we are in no position to give the answers to design questions ourselves. Our knowledge largely consists in know-what and not know-how; it lacks practical experience. And this is exactly where the proposed prototyping techniques empower our users to inform us.

2 Prototyping User Experiences

Figure 1 shows our three different simulation environments. The right part shows a picture of the training facility of the Paris Fire Brigade. The middle part shows a virtual environment of the facility. Based on this and other models we are currently creating a virtual reality simulation. To the left is a paper floor plan of one of the floors of the training facility. Using such plans and other very simple artifacts representing firemen, hazards etc. we have developed a technique for intervention simulation that resembles classical board games. We were let to use board games and computer games as tools for design by specific empirical observations. While taking part in the intervention command training, we observed that firemen use maps and plans to analyze and train interventions on paper. Also, while visiting various fire stations we observed that playing computer games is a highly popular leisure activity for many young firemen. In both cases, the point is that we found specific and valued practices in our user organization on which we could build. We understand the environments as tools to facilitate and mediate the communication between developers and users [9, 10]. By providing a simulation of the working environment, its properties and artifacts that allows a group of firemen to carry out a virtual intervention, our intention is to provide a platform that allows developers to express technological options in a way that is meaningful within the domain and that allows users to assess these options by acting them out. This approach draws on work in the area of experience and virtual prototyping [11-15] which acknowledges the importance of recreating user experiences to obtain valid assessments of design. By having all three environments share the same setting we can use results from low-fi environments to inform the specific setup of the more hi-fi ones and, conversely, we can use the results from the latter to validate and enrich the results from the former, as indicated in Figure 1. All three environments share a game-like interaction in the sense of a role-play to achieve a common goal [16]. Whether this is perceived as a game-like experience depends much on the way the simulation is organized. Our intention is to provide an engaging game-like experience to make the design process as enjoyable as possible and leverage critical and creative feedback.

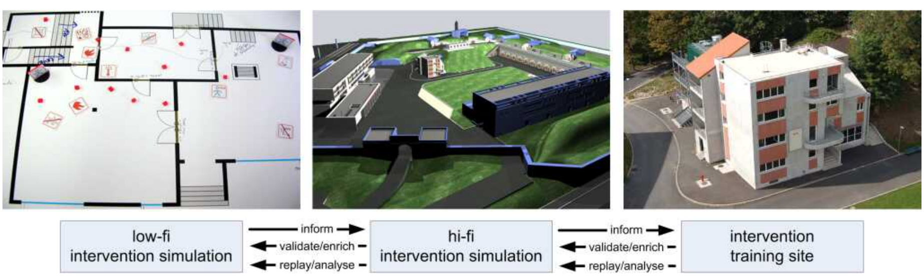

Fig. 1. Three environments for prototyping during intervention simulations: board game, computer game and training site

2.1 Interventions on Paper

The key idea of the board game is to enable and encourage users to change design artifacts without having to acquire any specific competence. Pen and paper artifacts with an intentionally non-professional look are supposed to keep the users' participation threshold at a minimum, inviting them to criticize what they don't like and ideally to take the pen and create design suggestions themselves. The board game is played in two rooms, R1 corresponding to the exterior and R2 to the interior of the training house. The exterior was represented by a large site plan and several photos of the building, whereas the interior by plans for all floors of the building. The floor plans are used with game pieces that represent actors (firemen, victims) and environmental conditions (fire, smoke, locked doors, poor visibility). The rooms on the floor plans are individually covered. In order to gain a more detailed understanding of current work practices [17] and also to prepare the actual prototyping, we defined two session types. The first one is called "intervention 2005" and basically requires the firemen to undertake the intervention with the means that they have at their disposal today. The second is called "intervention 2020" and requires the firemen to imagine using services that wearable computing might provide, such as audio/video communication, physiological monitoring and indoor localization. These services were provided by human facilitators and represented with pen and paper.

"Hello, there has been an explosion at the old Fort de la Briche in Saint-Denis. Now the building is on fire."

We conducted our first workshop with a group of 12 firemen at the Paris fire station of Antony in September 2005. The simulated intervention was based on the scenario of an incident at a chemical production facility. At first, the players gathered in room R1 and inspected the site plan and the photos of the building where the incident was supposed to have happened. They were informed about the incident based on a scenario that stated general facts and constraints about the situation (nature of the incident, suspected number of victims etc.) but included no indications on how to react. After having sufficiently understood the situation, the team leads sent their teams on first reconnaissance missions. The teams went over to room R2 and placed their pawns at the entrance of the building and started uncovering the first room. When they wanted to report back to their team leads, the players went back to room R1, received new missions and carried on. The intervention evolved in terms of the placement and change of symbols and also through numerous annotations made by the firemen to indicate opened doors, placement of water hoses etc. It is important to note that the running back and forth between the rooms successfully created the difference of knowledge and perception that would occur in reality between the attack teams and their team leads. It is this difference that we were able to exploit during the "intervention 2020" when introducing prototypes of new information technology. Even though we used simple paper prototypes animated by facilitators we were able to make the firemen experience their contribution to bridging this difference in knowledge and perception. During this session an interface prototype of a group support system was created by the firemen based on the identified information needs. Moreover, the running back and forth between the rooms added considerably to the animated nature and fun of the game play. In particular, there were moments of stress and some disorder when the two teams simultaneously engaged in reconnaissance missions and at one time met in the cellar of the building without knowing of each other's presence. Note that we asked the players to do thinking-aloud during the simulation so as to share their thought processes with us but to ignore the other players' presence. Between phases of engaged action the firemen regularly slowed down their game play or interrupted it altogether to discuss the current situation or the suitability of a particular technological support. This switching between action and reflection was facilitated by the game not progressing without the firemen's actions. While the spatial setup and the thinking-aloud introduced informational artifacts, the firemen were very capable of compensating these deficiencies during game play and benefiting from them during reflection. The firemen reported that they enjoyed the game very much. This is reflected by the fact that they changed from being rather shy and polite in the beginning to being very curious and open over the course of the session. One of the team leads told us that he would like to use the board game as a tool for intervention analysis and debriefing. This is a particularly satisfying result because it means that the board game allows for sufficiently interesting and realistic simulations and would provide an additional value to the firemen besides being a tool for design. The board game sessions also have been very informative for the subsequent setup of the virtual environment. We identified a number of new features of the environment that are important for the firemen (e.g. explosion marks on walls). Most importantly, we obtained a much better understanding of the actual collaborative processes during an intervention and how we should represent them in the computer game. For example, we were told that in reality the intervention would have involved more than 4 times as many firemen. The game session was analyzed by means of video recordings, annotations done by the firemen on the board games, transcripts of radio communication, notes taken by facilitators during the session and a debriefing after the simulation.

2.2 Virtual Experience Prototyping

The main drawback of the board game simulation was that all interactive features of the IT systems had to be emulated by human facilitators. While this is possible and allows obtaining interesting results at a very early design stage, it also requires a considerable effort and there are obvious limits as to the realism with which facilitators can emulate interactive features, such as real-time physiological monitoring. With our first virtual environment we wanted to create interactive virtual prototypes for video communication, physiological monitoring and indoor localization in order to be able to demonstrate an interactive prototype of the group support system for which the interface had been designed during the board game session. Our second VR simulation was designed specifically for the international IT fair Cebit in March 2006. What we aimed at was providing the visitors with a hands-on experience of how wearable computing can benefit emergency response. To this end we set up a building floor in our VR environment that was sufficiently complex to easily get lost in. Visitors could try to get to a specific location where we said a victim would be located and then try to find their way back out again, as could be the case in a search and rescue mission. We told the visitors that while walking around in the building they would automatically deploy small sensor nodes that would be able to determine their current position and communicate information out of the building to the local command post. The point of this was that the concept of a sensor network for use with emergency response is a good example for a technology that is not easy to understand by typical users in terms of its implications for the domain. What we wanted to show is that the virtual reality simulation enabled normal users to easily grasp the workings of this technology and explore its use in a way that is meaningful in this domain. As shown in Figure 2, the sensor nodes where represented in the virtual environment as a trail of red cubes along the path of the virtual character. Moreover, messages with some information about the character such as heart rate, remaining oxygen etc. where communicated along the sensor trail. This was visualized by turning the currently transmitting sensor node green such that the path of the message could easily be observed. To the side of the computer where the virtual environment was running, we had another computer with a large display that was representing the command post system. This system showed the information transmitted through the sensor network, in particular the location and orientation of the virtual character and the location of the sensor nodes. The latency due to the transmission across the sensor network could easily be observed, adding a degree of realism as compared to our first virtual environment. In case there were two visitors at the stand, the one at the command post could give navigational instructions to the one playing the virtual character thus exploring the collaborative use of this functionality. In terms of wearable computing we set up a simple autonomous system consisting of a computing unit integrated into a belt (the so-called QBIC from ETH) and a head-mounted display from Carl Zeiss integrated into a breathing mask (see Figure 2, d). This wearable system was wirelessly connected to the virtual environment receiving the angle between the virtual character's current orientation and the closest sensor node. This information was presented on the head-mounted display as a sort of compass, with an arrow pointing into the direction of the closest sensor node. With this simple information the actor could easily navigate back along his own trail of sensor nodes, turning around until the closest was right in front of him and then going from one sensor node to the next. Obviously, in our virtual environment the actor could also see the sensor nodes on the screen but this would likely not be the case in reality when heavy smoke could severely reduce visibility. Our visitors quickly grasped the idea of navigational support by means of a sensor network and started exploring its use. In fact, we had about a dozen actual firemen use the system during Cebit and they not only reported that they could readily understand the suggested technology but they gave rich feedback on both possible services based on this technology and issues related to its usage. For example, they pointed out that the system could provide alternative retreat paths to the firemen but also pointed out that sensor nodes could be submerged in water, kicked aside or get squashed. And this is what we see as the strength of this approach: being able to express even complex technological concepts relatively easily such as to enable domain experts to explore them in a way that is meaningful to them and thus guide further conceptual refinement and technological development. We intend to deploy the currently prepared third version in the course of 2007 in two different ways: 1) as a temporary installation at the headquarters of the Paris Fire Brigade for a serious of dedicated virtual prototyping sessions 2) as a permanent installation at a number of Paris fire stations such that the firemen can play the simulation unattended and how and when they want. Note that users are likely to find unattended game sessions quite a different experience than arranged and supervised sessions, and that feedback from the former might be more open and richer. This way, we intend to make the wearable technologies known throughout the user organization and ideally start a sustainable process of reflection and participatory design in the community of the several thousand young firemen in Paris.

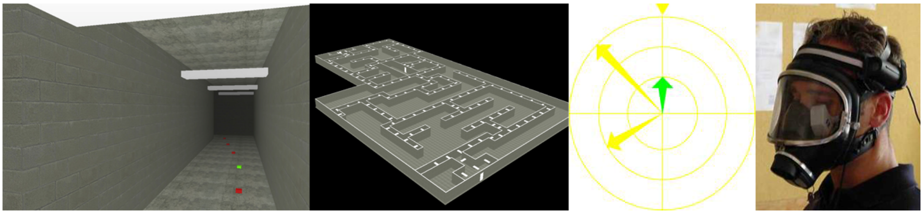

Fig. 2. From left to right: a) First-person view of the building floor used for simulating a search and rescue mission. Note the trail of sensor nodes along the corridor. b) Overview of the building floor. c) Compass-like navigation support on HMD for Cebit demonstration d) Mask-integrated head-mounted display (HMD) from Carl Zeiss.

2.3 Evaluating Virtual Prototyping

Until today we used qualitative analysis of video recordings and post-simulation interviews to assess the viability of the approach. Currently, we are expanding on previous work at our institute on physiological monitoring during game play [18]. Based on laboratory studies of players of the computer game America's Army, this research indicates that a number of psychological reactions consistently correlate with discernible physiological reactions. We have been conducting experiments with a customized version of Unreal Tournament, measuring different physiological parameters (EDA, EMG, heart rate) in order to determine the different emotional states of the users and – in this case – modify the game behavior in order to maximize user engagement. We conducted this preliminary study to prepare physiological monitoring during interventions of the firemen in our virtual simulation. Here, we are interested in the emotional state of the user not only to assess the general game experience but more specifically to assess the users' experience of using the virtual prototypes of the wearable systems [19]. Additionally, we intend to make use of the monitoring during the simulation in order to adapt e.g. multi-modal interfaces. Finally, we'll be conducting physiological monitoring during simulated interventions at the actual training site to validate our in-game measurements.

3 Conclusions

The results show that even through simple techniques such as the board game and also through simple versions of collaborative virtual environments rich enjoyable experiences can be provided to the users and that these can prompt the users' to participate actively and creatively in design. In particular, the approach can sustainably empower users to shape technological development and at the same time evolve their working processes and possibly attitudes towards these technologies from the very start of the design process. The acceptance of the approach by users is made clear by the fact that the currently developed version representing the training facility is planned to be used during incident command training. Specifically, the playful nature of the technique and the possibility to elicit feedback by engaging firemen in action were appreciated as important features by senior fireman. The key contribution however is that game-like techniques allow the firemen to “play out” or demonstrate their skills and experience through action and interaction. In this sense, our game environments can be considered tools for telling stories through action. And our research clearly shows that storytelling is a favored means of relating experience among the firemen. It is important to observe that the complexity of a virtual prototype can range from extremely complex to extremely simple. In the case of our first VR simulation for example, we decided to simply take the location information for the firemen from the known position of the virtual characters. This is to say that we did not prototype any localization system at all but just used the information that the VR provided anyway. As explained below, we introduced a virtual prototype of a sensor network in our second VR simulation which can be used to deduce location information for the firemen [20]. The point is that the virtual environment often allows to prototype high-level services without having to implement much of the system that would actually provide these services in real life. The benefit of this is that the interaction of the users with the systems and the experience in the context of use can be demonstrated and evaluated at a very early stage with very little effort. The obvious downside is that all phenomena that occur because of a particular system implementation that is not reflected in the virtual prototype will not occur in the simulation. In our case, the first VR simulation exhibits completely accurate and instantaneous location information, whereas the sensor-network based localization in the second VR simulation exhibits varying accuracy and latency, as is to be expected from this localization system. In a sense, this is an almost trivial statement about the limitations of all simulations. A simulation uses a model of reality and the behavior of the model will be incomplete or different with respect to reality. What is not at all trivial is the question what conclusions to draw from this for the design of virtual prototypes. The key to the answer is that virtual prototyping is being undertaken to answer specific questions as to the design of actual solutions. It is with respect to these specific design questions that the appropriateness and usefulness of a given abstraction for simulation has to be assessed. We intend to evolve the virtual environment into an Open Virtual Laboratory for Ubiquitous Computing to be used by other researchers and users to experience virtual prototypes in collaborative and context-rich environments. Our future research will address how to make this environment a sustainable, valid and stimulating tool for reflection, assessment and creative design and using it an attractive and pleasurable experience.

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Improving Communication for Mobile Devices in Disaster Response

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Abstract. During disaster response, networks can become overloaded and are susceptible to complete failure in the disaster area. This disables mobile communication, hindering response efforts from mobile users. Mobile users make use of various heterogeneous devices and require infrastructure to facilitate the communication of distributed information. Communication flow among mobile users is disorganized as it is either too strong and hierarchical or too flexible and dynamic. We have designed ubiquitous mobile infrastructures to match the response environment's communication flows and telecommunications, and produced a ubiquitous mobile communication system (ubimobcom). The design standardizes the information exchanges between mobile users. In this paper, we show that ubimobcom makes cooperation and coordination among mobile users possible at the disaster. Using ubimobcom, mobile users can be coordinated and can cooperate in outdoor areas, besides; they can continue connected with their disaster operation center. We describe the ubimobcom system to illustrate the use of communication by mobile users to disasters that may range from minor to catastrophic.

1 Introduction

In response to a disaster, communication is a vital resource for both victims and response units. The following situation occurred in California, USA [1]: Testing Technology in a Disaster Response: *"Hundreds of computers and even cellphones were shut down, and then the network was slowly turned back on, segment by segment. Too many high-bandwidth applications had clogged the network, including a powerful video camera and "rogue" transmitters set up by participants intent on creating their own mini-networks."* This illustrates how communication in disaster response is fragile for two primary reasons: technology and organization. Providing improved communication in these circumstances requires solutions to both the organizational and technological aspects. Mobile devices in a disaster response are geographically and logically distributed. This introduces the requirement for appropriate infrastructures to enable mobile communication. The information that is communicated must also be provided in an organized manner. We propose communication flow that is used to organize the distributed information to ensure that

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ubiquitous mobile infrastructures will work properly when responding to a disaster. We introduce the mARCE [6] emergency response system to illustrate the implementation of the described solutions to improve mobile communication in disaster response. We improve internal and external communication of displaced units using the ubimobcom system in outdoor areas. Ubimobcom system does not take into account sensor networks because disasters almost occur in outdoor environments. The research of sensor network has been improved in embedded technology or in indoor environments.

The remainder of the paper is structured as follows: in Section 2, we describe ubiquitous mobile communication that enables improved communication for mobile devices when responding to a disaster. This incorporates communication flow design and telecommunications infrastructures. In Section 3 we sum up with a conclusion of how ubiquitous mobile communication can be improved in disaster response.

2 Ubiquitous Mobile Communication

Mobile users in a disaster area make use of various heterogeneous mobile devices. Communication capabilities in a disaster area are likely to be weak due to the breakdown of communication technology, and also because of the breakdown in organizational communication. We offer ubiquitous mobile communication to mobile users that address communication flow design and telecommunications infrastructures.

Ubiquitous mobile communication enables mobile users to make use of ubiquitous computing technologies allowing response efforts to be carried out at various locations within the disaster area. Ubiquitous mobile communication gives mobile users the ability to communicate in two main areas; organization of the response action and interaction with civilians. The first makes use of the opportunity to communicate, coordinate, and cooperate. The second uses the ability to search, rescue, evacuate, and save citizens depending on their roles, responsibilities, capacities, and circumstances.

2.1 Communication Flow

There are numerous country-specific emergency communications frameworks such as ICS[10], [11], NIMS[12], AIIMS[13], etc. that we have analyzed. Based on this analysis, we decided that a specific communication flow for mobile devices is needed. These frameworks are not capable of addressing the problems that occur in today's disasters (for example, the hurricane in New Orleans). The problems include: 1) Improving the information flow among mobile users, helping with the communication, coordination and cooperation of operational efforts, and enhancing operational safety. 2) The efficient and effective use of network resources. 3) Accessibility to the mobile user's applications. 4) Mobility of mobile users without communication technology's disruption.

We are focusing on internal and external communication between mobile users. We use this communication flow to improve internal communication inside displaced units and external communication between displaced unit and its disaster operation center. For example, a displaced unit arrives to the emergency area. It has a team, which includes three mobile users. One of them is in charge of response coordination. S/he can communicate with her/his team and manager of disaster operation center using a PDA. S/he does not need to worry about information flows and telecommunications because s/he has everything configured on her/his mobile device.

We have designed a simple communication flow that is easily adapted to ubiquitous mobile infrastructure. To enable the development of the appropriate communication flow required to respond to a disaster efficiently, we have used the ARCE (Aplicación en Red para Casos de Emergencia) [2],[3] philosophy. ARCE is a web based system that coordinates assistance requests and responses in a multinational environment [2]. ARCE enables the design of an Information System for Emergency Situations (ISES), which models different emergency scenarios, varying from minor to major disasters.

Communication flow shares an understanding of roles, responsibilities, capacities, impacted areas, disruptions to critical infrastructures, situations where secondary hazards may develop if initial damage is not mitigated, time needed to restore disrupted systems, and circumstances under which citizens encountered the disaster. To respond to a disaster, mobile users need different resources and the ability to work in a variety of situations. To speed up the response tasks from every mobile user, we have designed a general communication flow as shown in Fig. 1. It consists of Response Coordination that coordinates Logistic Service, Response Tasks Management, Technical Assistance, and Resource Management. Logistic Service includes transportation, provision and shelter, and social assistance. Response Tasks Management manages response tasks such as search, rescue, save and evacuate citizens. Technical Assistance gives technological knowledge to mobile users. Resource Management manages request management and resource distribution. This general communication flow organizes the distributed information on the mobile device ensuring that ubiquitous mobile infrastructures will work properly. Using the general communication flow, every mobile user could focus on resolving his task instead of wasting time trying to resolve all the problems that arrive frequently, saturating the network.

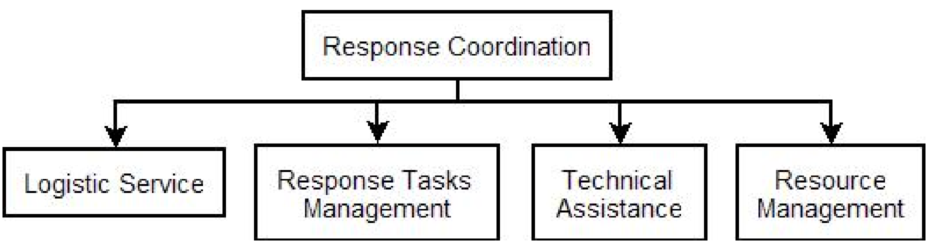

Fig. 1. General communication flow

2.2 Telecommunications Infrastructures

Telecommunications and the services they provide play an essential role in the response to any disaster scenario. Telecommunications give mobile users the possibility to communicate, cooperate, and coordinate by continuously accessing the ubiquitous mobile infrastructures.

Ubiquitous mobile infrastructures are built by mobile offices and help units, as provided in [6], [7], [8]. Mobile offices [6] are nodes situated in outdoor areas near to the emergency scenery, where services are supplied to mobile users. A mobile office consists of a collection of technology that includes laptops, batteries, wireless routers, radio antenna, Bluetooth, PDAs with GPS, GPS receivers and satellite signals. The mobile office does not use network sensor because they are designed for outdoor environments. Help units [8] are PDA interfaces to access m-Emergency software, which is responsible for managing hardware, network, communication and the Information System for Emergency Situations (ISES). Help units can communicate with mobile offices by infrastructures that make use of wireless networks or satellite signals. These ubiquitous mobile infrastructures are designed using UILE (ubiquitous computing framework) [4], [5], and m-ARCE [6] guidelines.

UILE identifies concerns that should be taken into consideration when incorporating ubiquitous computing features in applications, with a focus on two primary areas; mobility and context-awareness. UILE considerations are used to identify what mobility concerns should by addressed by telecommunication at the disaster area. They also consider how a distributed system should be built in outdoor environments. Using UILE guidelines, telecommunications should provide ubiquitous mobile infrastructures with mobility concerns such as those mentioned in [4], [5]: *1) Service discovery*, *2) Quality of service assurances*, *3) Network roaming*, *4) Distribution*, *5) Limited connectivity*, *6) Transaction management*, *7) Security*, *8) Location*, *9) Proximity*, *10) Ad-hoc networking in outdoor environments*, *11) Software roaming*. In addition, many contextual concerns should be addressed in the m-Emergency software. m-Emergency software should be developed including contextual concerns such as those described in [4], [5]: *1) User context*, *2) Social context*, *3) Device context*, *4) Mobility*, *5) Location related context*, *7) System context*, *8) Temporal context*, *9) Application specific context*, *10) Environmental context.*

m-ARCE, based on the ARCE system, provides the requirements for designing the m-Emergency software, mobile offices, and help unit interfaces. UILE promotes the modularization of the ubiquitous computing concerns using Aspect Oriented Programming [9] techniques. This enables the m-ARCE application to focus on delivering the required organizational support with the assurance that the mobility and context-awareness concerns will be performed at the appropriate points in execution.

2.3 Ubiquitous Mobile Communication System (ubimobcom)

We describe the ubimobcom system using m-ARCE, which builds on the existing ARCE structures to provide m-Emergency software and mobile offices.

Figure 2 shows communication between help unit and mobile office. On the left, we illustrate a help unit, which connects communication flow, network, hardware, and m-Emergency software to a Mobile Office. On the right, we show the mobile office, which implements a heterogeneous network consisting of a broadband satellite network, and wireless network (WLAN). The mobile office acts as a server to the mobile help units which are distributed throughout the disaster area. Various concerns including limited connectivity contingency plans and location monitoring are implemented to provide a robust and reliable infrastructure for mobile communication between devices.

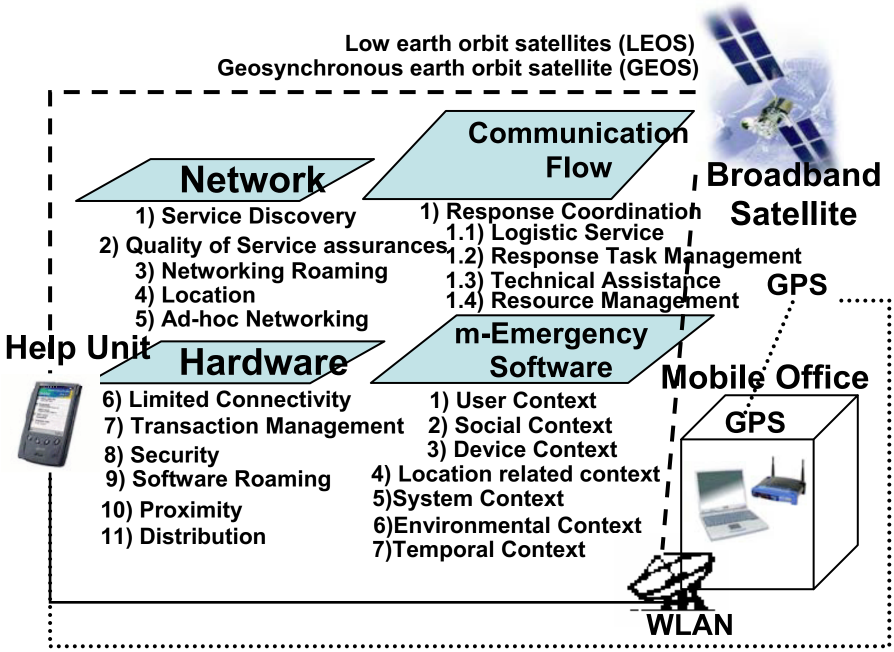

Fig. 2. Communication between Help Unit and Mobile Office

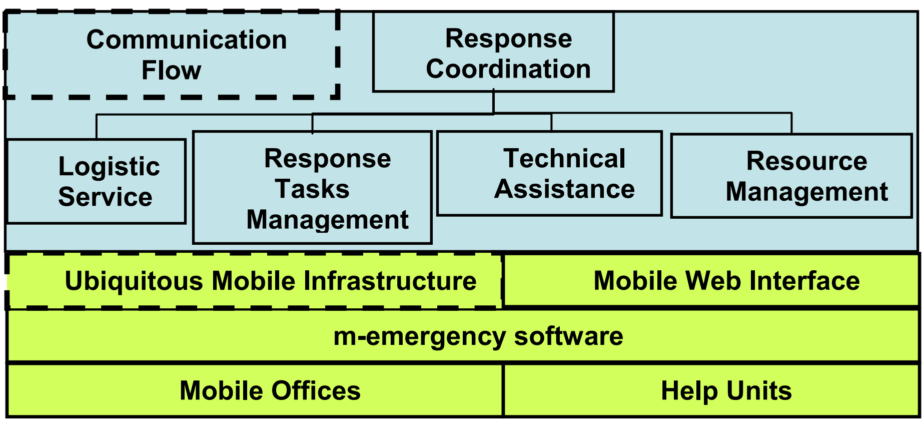

Fig. 3. Ubiquitous mobile communication architecture

Ubiquitous mobile communication provides a consistent communication to mobile users to enable such users to work together effectively and efficiently in the response to a domestic disaster, regardless of cause, size, or complexity, including acts of terrorism.

Figure 3 depicts ubiquitous mobile communication architecture. On the top (organizational aspect), communication flow provides response coordination to mobile users. A qualified mobile user can be made responsible for logistic service, Response

Tasks Management, Technical Assistance, Resource Management, or all of the mentioned. However, it must be ensured that all users have the ability to communicate with the user who is in charge of response coordination.

On the lower section (technological aspect), ubiquitous mobile infrastructure gives data services to the communication flow. It is developed by m-emergency, which manages mobile offices and help units. m-Emergency is accessed via a web interface on help units.

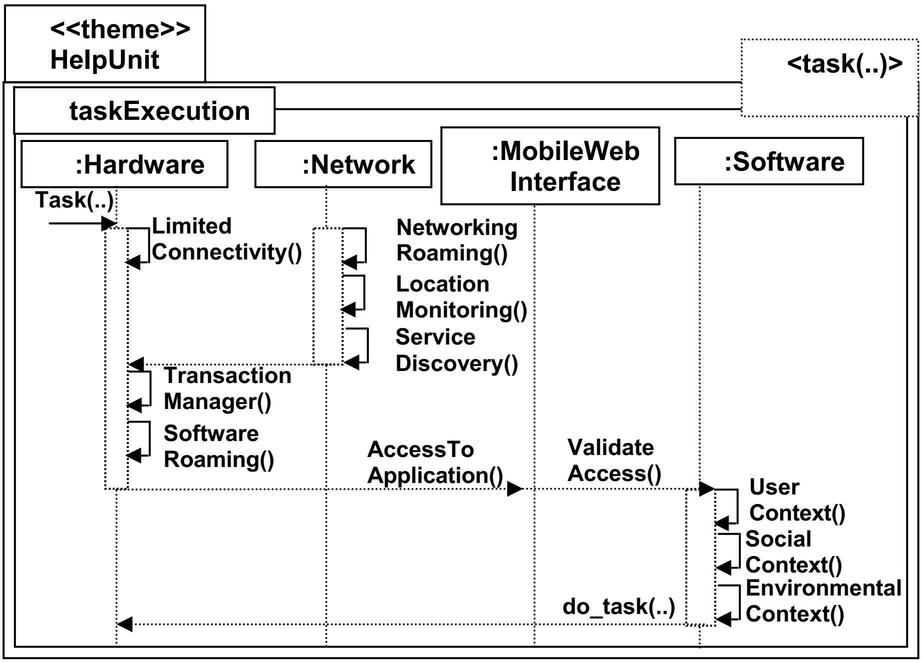

Fig. 4. Help unit – response task diagram

Figure 4 graphically illustrates the series of events that are carried out during the execution of tasks by help units. A Theme/UML [15] diagram represents the execution of tasks, by both classes and AOP aspects. Aspects modularise crosscutting concerns such as the ubiquitous computing concerns incorporated in the emergency response software. This functionality is carried out at specified points in execution, i.e. during user tasks. In this scenario: 1) A mobile user carries out a response task using a help unit (PDA). 2) The response task is processed by hardware, network, and software and accessed by Web mobile interface. 3) Limited Connectivity - PDA hardware catches the task, and verifies if its battery has enough capacity. 4) Networking Roaming - PDA finds a network signal such as radio, WLAN, or satellite. 5) Location Monitoring - PDA gets GPS coordinates. 6) Service Discovery - PDA discovers network services. 7) Transaction Management – PDA assurances data integrity. 8) Software Roaming – PDA has an agent that reduces the quantity of network calls to overcome network latency problems on slow networks. 9) Access toApplication – PDA uses mobile Web interface to access the application. 10) Validate Access – PDA's Web interface validates mobile user. 11) User Context – PDA gets knowledge pertaining to the mobile user. 12) Social Context – PDA uses Role-Based Access Control (RBAC) such as that designed in [14]. 13) Environmental Context – PDA determines the context of the physical world in which the application is running; for example, light, temperature, etc.

As mentioned, the ubiquitous computing concerns are implemented as a collection of aspects and helper classes. As the mobile user carries out the required tasks during the disaster response, concerns such as those illustrated in Figure 4 are performed at the appropriate points in execution.

Listing 1. Service Discovery Implementation

```
public class ServiceDiscoveryListener extends Thread {

   private IncomingData incomingData;
   private Object currentMessage;
   private IncomingHandler iH;

   public ServiceDiscoveryListener(String IP,int portNo) {
      incomingData = new IncomingData(IP,portNo);
      iH = new IncomingHandler("HelpUnit");
      iH.start();
   }

   // This run method listens on a Mulitcast port for a
message,
   // then hands the message to the handler for processing.
   public void run () {
      while(true){
         currentMessage = incomingData.receiveObject();
         iH.addToQueue(currentMessage);
      }
   }
}
```

Listing 1 illustrates and example of one such implementation. Service Discovery is required by help units in order to connect to a mobile office to gain both organizational and technological aid. Service Discovery is implemented as an aspect with a series of helper classes. One such helper class is the `ServiceDiscoveryListener`. A `ServiceDiscoveryListener` object is responsible for recognizing and handling objects of type `ServiceDiscoveryEvent`. Each mobile user is assigned an IP address and multicast port in order to receive messages from both mobile offices and other mobile users. The listener executes in a separate thread while waiting to receivenotifications. On being notified of a `ServiceDiscoveryEvent`, an appropriate message is passed to a queue of events to be handled by the receiver.

The implementation of ubiquitous computing concerns as aspects allows the base mARCE emergency response application to focus on delivering the organizational and infrastructural functionality as a primary focus. The result is a comprehensive ubiquitous mobile communication system, which aids the communication of mobile users during disaster response.

3 Conclusion

Because mobile devices are restricted by various device limitations (for example, memory's capacity, screen's size, etc), we have built a specific communication flow that can be used by any mobile user. Not only do we want to standardize the information exchanges between mobile users, but also to replace communication flows that have been used until now. We propose to plug in mobile devices to the present communication flows with an information flow that can be supported by them.

When improving communication in the response to a disaster, researchers and designers must consider ubiquitous and mobile computing concerns in addition to providing an Information System for Emergency Situations. Enabling mobile communication provides means for mobile users to cooperate and coordinate in response to a disaster.

Introducing general communication flow and telecommunications infrastructures for mobile users can alleviate technological and organizational problems that arise in communication when responding to a disaster. By introducing structured communication flows the information is represented in an organized form and can be distributed effectively. Providing the infrastructure necessary for the information to be relayed between mobile devices enables communication to resume. The provision of these factors improves ubiquitous mobile communication between mobile offices and help units during a disaster response offering accessibility to telecommunications. This in turn results in a reliable and trustworthy information flow in both minor and major disasters.

Finally, the objective of the field research reported here is to gather the knowledge of our co-workers (UILE – ubiquitous computing framework) which aids us to improve ubiquitous mobile communication for use with our Information System for Emergency Situations (ISES).

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Robust Audio Indexing and Keyword Retrieval Optimized for the Rescue Operation Domain

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Abstract. Due to the extreme environmental conditions, speech recognition in the rescue operation domain is a complex and difficult task. Various types of noise and speaker stress represent the main problems for the recognition engine. Within the SHARE project, a dedicated domain specific training corpus was recorded to improve the robustness of the audio indexing service. An experimental evaluation showed that a speech recognition model trained with a small amount of domain specific data outperforms models based on a large set of already available data from other domains. Using the domain specific models, the number of false alarms produced in a noisy testing environment could be reduced by 80%.

1 The SHARE Project

This paper presents results from the EU-IST project SHARE, which has the goal to provide an advanced system for mobile communication and information services to rescue organizations. SHARE technology is intended to support rescue teams working on large scale rescue operations. The main objectives of services offered by SHARE are decision support, provision of online access to operation information, improvement of communication and cooperation, and increase of work speed and efficiency. The communication services are based on push-to-talk over cellular technology for mobile audio and video communication in flexible groups. A multimodal user interface for the information services is provided using automatic speech recognition (ASR) and text-to-speech synthesis (TTS). Automatic speech recognition is also applied for detecting keywords within the audio communication streams during the operation [1]. Improvements to our keyword spotting approach and technical details will be described in the following sections.

The SHARE system currently offers five services to the user. First, a digital map application allows navigation and annotation of 2D and 3D digital maps of the operation site and includes location-based services. The second service is called Push-to-Share (PTS) Voice, supporting audio communication in flexible groups. PTS Video is the third service, providing video communication functionality in adjustable groups. Another service is used for automatic indexing and content-based retrieval of audio communication messages and thermal videos that can be captured during an operation. Finally, a service for dynamic

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resource management is integrated into SHARE. At the back-end side, an ontology database service and a multimedia archival service are used for knowledge management.

The SHARE consortium consists of nine project partners from six European countries. Fraunhofer IAIS, Germany, is project coordinator, system integrator and performs research in automatic speech recognition. Siemens AG, Austria, provides and extends the push-to-talk technology and is responsible for the system architecture. University of Paderborn, Germany, develops a module for dynamic resource management and is the main interface to the application partner, the Fire Department of Dortmund, Germany. The companies Telisma, France, and Loquendo, Italy, provide ASR and TTS technology for the multimodal interface. The University of Thessaloniki, Greece, is working on thermal video processing for rescue operation management. Use of knowledge management tools and ontology-based information systems are explored by NCSR "Demokritos", Greece. TeleAtlas, Belgium, provides 2D and 3D digital maps with new features which are used in the MAP3D service developed by Fraunhofer IAIS.

2 Indexing and Retrieval Service

During a rescue operation the information derived from textual and audio-visual communication within SHARE is stored. The indexing and retrieval service enables the fire fighters to easily access this data during the current operation or during a later analysis of operations and practice scenarios. Especially for video and audio data an adequate preprocessing is necessary to retrieve the results of a query in an acceptable time. Therefore, the indexing service is continuously running in the background searching for relevant features in the audio and video data. In this paper only speech data is regarded for indexing and retrieval.

The indexing service and the retrieval service are integrated in the SHARE system using two external SHARE components – the *multimedia archive* (MM archive) where all data is stored and the *ontology database service* (ODS) where all information is managed. Fig. 1 shows the integration of the indexing and retrieval services along with the interaction between the different applications.

2.1 Indexing Using Automatic Speech Recognition

The *indexing service* is the central preprocessing part of the retrieval service, processing the whole SHARE audio communication in the background. The indexing service searches for domain-specific keywords in the recorded speech data and stores the results in the central ontology database.

At short time intervals, the indexing service sends a query for unprocessed audio data to the ontology database service. Information about all unprocessed data in the media archive is returned to the indexing service. The related audio files are loaded from the archive and stored at the indexing server for further processing. An *automatic speech recognition* engine developed by Fraunhofer IAIS for keyword spotting and adapted to the requirements of the SHARE

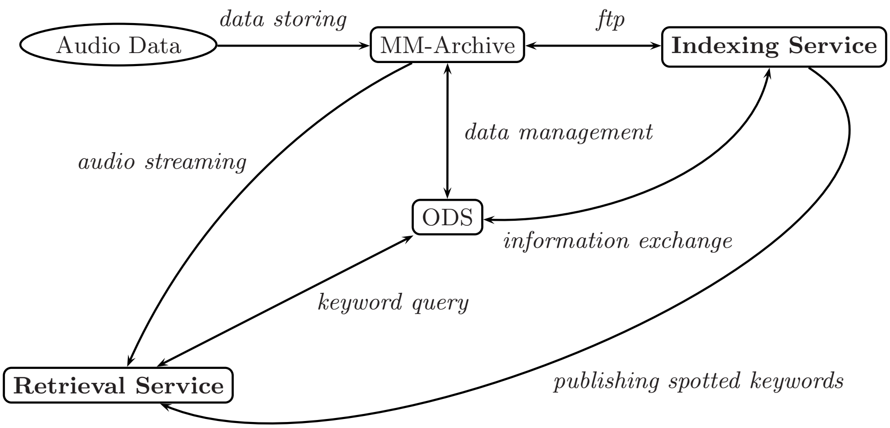

Fig. 1. Integration of the Indexing Service and the Retrieval Service

project (see section 2.3) is used to search for specific words defined in the list of keywords (see section 2.2). Information about the spotted keywords is sent to the ontology database and is stored in the related property field. The audio data is labeled "processed" to avoid an unnecessary second data processing. Additionally, the indexing service submits the currently found keywords and a link to the related audio data directly to the retrieval service interface of every user logged in. Thus every user is informed about the results of the indexing process and is able to access the audio data if the submitted and displayed keywords suggest any interesting audio information.

2.2 Definition of Keyword Lists

Keyword spotting is based on an automatic speech recognition system for identifying words from a predefined list in unconstrained speech. The vocabulary, i.e. all words which should be spotted by the system, is defined in a keyword list. The keyword list in the SHARE project has to concentrate on relevant keywords for the domain. By keeping the list as small as possible without discarding significant words, the robustness and performance of the speech recognition algorithm is enhanced.

A list containing about 120 keywords relevant to the rescue operation domain was collected using tactical documents and recordings of rescue operations. The list has been reduced to a list of generic words important to all users. This static generic list is used in the experimental evaluation in section 3. Furthermore, a concept of a dynamic and thus more adaptive keyword list has been developed and is currently being implemented. User-specific keyword lists will be created and modified dynamically containing all (non-generic) words which are of particular interest for the specified user. Keywords like units, streets, vehicles etc. subordinated to the specified unit will be added or removed depending on the situation and the command structure in the future system.

2.3 The Automatic Speech Recognition Engine

Keyword spotting within the SHARE project is performed using a statistical approach as described in [2] and [3]. The implementation is based on the ISIP speech recognition toolkit[1] which has been adapted to cope with the SHARE keyword spotting task. A phoneme-based garbage model was used to allow keyword spotting in unconstrained speech. Due to the subword modelling approach using phonemes, no additional training is required if the set of keywords is changed. The acoustic models needed by the speech recognition engine are trained on domain specific data. The acquisition of the test and training data is specified in section 3.1.

To use the predefined keywords in the speech recognition engine, all words have to be broken down into phonemes. The static list is automatically phonemized with BONT [2] and manually corrected. For the dynamic keyword lists a manual correction will not be possible. To avoid wrong phonemizations, an exception lexicon with a correct phonemization of anticipated dynamic keywords will be created.

2.4 The Audio Retrieval Service

After the indexing process interesting audio communication is accessible via the *retrieval service* and its user interface. The indexing service sends all currently found keywords and the related streaming address of the audio data to the retrieval service. The information is displayed on the retrieval service interface and the communication can be played back, streaming the audio data from the archive.

In addition, active queries for specific keywords can be formulated and submitted to the ontology database service. It is possible to specify one or more keywords from the static list or to choose a category of keywords (e.g. vehicles, equipment etc.). Moreover, the query can be limited to a period of time and a communication group in which the audio communication has been recorded. The ontology database service performs a query on the database where the audio metadata – including keyword information, time information and information about the communication participants – is stored. The metadata of all communication meeting the constraints of the query is returned to the retrieval service, where the extracted information is displayed and the user can listen to the corresponding audio file.

3 Experimental Evaluation

The characteristics of the SHARE application domain increase the complexity of the audio indexing process. In contrast to other standard speech recognition

[1] ISIP website: *http://www.ece.msstate.edu/research/isip/projects/speech/index.html*

[2] Bonn Transcription System – an automatic phonemizer based on BOSS (Bonn Speech Synthesis System) – [*http://www.ikp.uni-bonn.de/boss/*]

applications such as office dictation systems, most of the voice communication that has to be analyzed is recorded in a rather noisy environment. Background noises such as running fire engines have to be taken into account by the speech recognition system. Moreover, both vocabulary and grammar used by the fire fighters are quite different from standard German language. Commercially available speech recognition models have not been trained using such domain specific data, and the most important keywords do not occur in the training set. Hence, it is not possible to use available speech recognition models without any adaptation to the fire fighter domain. Within the SHARE project, a dedicated audio corpus has been collected to reflect both the environmental and lexical conditions of the application scenario.

3.1 Data Acquisition: The SHARE Audio Corpus

To enable training and adaptation of domain specific acoustic models, Fraunhofer IAIS developed a corpus specification and collected a medium sized set of domain specific audio data. A set of guidelines has been used to support the recording process and record valuable data. First, it is important that there is no mismatch between the channels of the training and the testing recordings, so the same Bluetooth headsets that will be used for the actual system have been used during the recording campaign. All audio data has been recorded at 16Bit PCM with a sample rate of 8kHz.

The speakers – which came from both the fire department and Fraunhofer IAIS – recorded a set of phonetically rich and a set of domain specific German texts. Phonetically rich texts contain an above-average number of different phoneme combinations and are thus highly useful for training acoustic speech recognition models. The domain specific texts have been collected by the fire department in Dortmund and are based on real world situations. They cover a large part of the domain specific vocabulary that should be indexed.

A noisy environment has to be expected in the context of a fire fighting speech recognition application, and thus noise robustness had to be addressed during corpus specification. The recordings have been carried out in both a silent and a noisy environment to gain insights in the occurring noise types and the effects on the recognition performance. The preferable type of noise is a realistic background noise in a fire fighting scenario, such as the noise of a fire engine. With the support of the fire department in Dortmund, it was possible to have two fire fighters with a local accent speaking in front of a running fire engine, yielding a small but very realistic set of data.

To get a general model which is useful for a wide range of testing speakers, it is important that the audio data should be recorded from as much speakers as possible, ideally from fire fighters with a typical accent and speaking style. In order to increase the inter-speaker variability of the training population, a few speakers from Fraunhofer IAIS recorded additional data.

The texts that have been read by the users contain about 4500 different words. These were phonemized using the BONT automatic phonemization system. The phonemizations were manually corrected, yielding an approved 4500 words

Table 1. SHARE Audio Corpus Specifications

Recording Environment	Type of Input Text	Minutes of Data
Silence, Office	Domain Specific	185
Silence, Office	Phonetically Rich	55
Noise, Running Engine	Domain Specific	60
Noise, Running Engine	Phonetically Rich	30

pronunciation lexicon. A total of more than 5.5 hours of data from eleven different speakers was recorded. Table 1 presents the composition of the final recordings. About 4 hours of clean and 1.5 hours of noisy speech data including transcriptions were available for the experiments described below.

3.2 Results

Two standard quality measures from information retrieval – recall and precision – are evaluated to assess the quality of the indexing and retrieval service. A high recall value indicates that most of the existing reference keywords have been found by the indexing service. It is defined as the number of correct keyword hypotheses divided by the number of existing keywords. A high precision value indicates that most of the keyword hypotheses made by the indexing service are correct, i.e. the found keywords really exist in the reference. It is defined as the number of correct keyword hypotheses divided by the total number of hypothesized keywords. The Q-value, defined as the harmonic mean between recall and precision, is used to assess the total system quality. The highest quality is thus achieved by a system with a Q-value of 1.

All experiments presented have been carried out in a speaker independent setup, i.e. the testing speakers were not known when the system was trained and hence no input from the testing speakers was used for training. Speaker independent systems can be used in real world applications without requiring time consuming training from new users. Compared with systems trained for one specific user, speaker independent systems achieve lower accuracy values and require more training data to cope with interpersonal variabilities.

The different approaches presented below were tested using about three minutes of domain specific speech recorded by two speakers. The test set was recorded in both a silent and a noisy environment. A static list with about 120 keywords was used for indexing. The original reference text read out by the two testing speakers contains 42 words where one of the 120 keywords occurs as an infix.

Accepting infixes is essential for evaluation of a German speech indexing system due to the extensive use of compound words in the German language. If, on the other hand, the word that was actually spoken is an infix of a recognized keyword, the result is supposed to be incorrect. Moreover, a spotted keyword result is only correct if no longer matching keyword exists. All three cases are illustrated by table 2 for a system spotting for three different keywords.

The current results for keyword spotting in a silent environment are presented in table 3. Two different models are compared: one is trained with a

Table 2. Keyword acceptance criteria

Keywords: Feuer, Einsatzabschnitt, Einsatzabschnittsleiter

Spoken word	Recognized keyword	Accepted as correct
Feuerwehr	Feuer	yes, keyword is infix and longest match
Einsatz	Einsatzabschnitt	no, keyword not spoken
Einsatzabschnittsleiter	Einsatzabschnitt	no, longer keyword match exists

larger amount of studio quality broadcast news which has already been available at Fraunhofer IAIS and which is known to perform well on broadcast news transcription. The second model is trained on a subset of the data presented in section 3.1. Both data sets were used to train standard crossword triphone models. Each triphone is modeled with a three state Hidden Markov Model using 16 Gaussian mixture components.

Table 3. Results for Testing Data in Silent Environment

Training Data	Minutes of Training Data	Precision	Recall	Q-Value
Broadcast News	540	0.38	0.31	0.34
SHARE Silent	195	0.83	0.76	0.80

The results show that the domain specific models outperform the well trained broadcast models, although the training data set is much smaller. The number of false alarms is reduced by 69% and the amount of keywords that exist in the reference text but were not detected is reduced by 73%. Using the SHARE data set, the acoustic models reflect the actual transmission channel used by the fire fighters. Moreover, triphone combinations that occur very often in the fire fighter domain are not or only seldom covered by the broadcast training corpus. For example, the first triphone of the phonemization for the keyword “Löschzug” does not occur at all in the broadcast training corpus while the SHARE corpus contains 202 occurances of the same phoneme combination. Using the SHARE models, the keyword “Löschzug” and its plural form “Löschzüge” is detected each time it occurs in the testing set while the broadcast system misses all six occurances.

The original noisy recordings are hard to understand even for humans, and keyword spotting experiments using the unfiltered data did not produce any meaningful results. A noise reduction tool based on Wiener Filtering was provided by the project partner Telisma and applied to the noisy recordings, yielding the noisy test set for the broadcast and SHARE models. Table 4 shows the keyword spotting results for the two different models.

Although the overall system quality does not reach the accuracy when testing with silent data, the noisy experiments still show that it is advisable to use a domain specific training set, even if it is small. As in the silent case, large relative improvements for recall and precision can be observed when comparing the SHARE models with the broadcast system. The reduction of false alarms

Table 4. Results for Testing Data in Noisy Environment

Training Data	Minutes of Training Data	Precision	Recall	Q-Value
Broadcast News	540	0.06	0.10	0.08
SHARE Silent	195	0.40	0.19	0.26

by 80% is an important first step towards real usability of the system in noisy environments.

4 Conclusion

The results presented show that the effort for recording a domain specific audio corpus pays off in terms of information retrieval quality. The indexing results using the dedicated SHARE training data in a silent testing environment are promising. First experiments with noisy testing data indicate that the importance of a domain specific corpus is still valid in a noisy environment. The number of false alarms is reduced by 80% compared to the performance of the well trained broadcast models, while the amount of training data is significantly reduced.

Future experiments should analyze and improve the robustness of the indexing service in the presence of environmental noise, including contamination of the training set with both filtered and unfiltered noisy data. Mature model adaptation methods known from speech recognition such as MAP [4] and MLLR [5] will be applied to adjust the domain specific models even more towards the testing situation.

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Extending the Fire Dispatch System into the Mobile Domain

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Abstract. At emergency services around the world, the use of IT is oftentimes still limited to the stationary HQ dispatch system. This paper suggests how to overcome this limitation by introducing a Mobile Information and Communication System for Emergency Services, MIKoBOS, that digitally links the emergency site with the central dispatch system. For use in the situation room and beyond, digLT is presented, a digital situation table with Fovea-Tabletts®, allowing a team of experts to more easily develop a common picture of major emergency situations they are to manage. An actual emergency response scenario is used to discuss how these technologies may be applied and integrated.

1 Introduction

Major emergency response operations require a joint effort by responders from multiple organizations in multiple locations, and in a dynamically changing situation information needs to be conveyed quickly to those who require it as an input for their decisions. While state-of-the-art mobile information and communication technology has been adopted for a mobile workforce in other industries for quite a while, emergency services have been more reluctant in this respect. Even today, their dispatch centers often remain an isolated "IT island" where call takers use a resource dispatch system to initiate and monitor a response operation, while commanders at the emergency site rely on traditional voice-based information exchange in order to arrive at a common operational picture. This is remarkable since, in many countries, the control of regular fire department response operations is fully in the hands of these on-site commanders who work from their command post vehicles, whereas the central dispatch center assumes only a support role. It thus makes much sense to extend the department's IT into the mobile domain. This is what MIKoBOS, Fraunhofer's Mobile Information and Communication System for Emergency Services (known in German as "BOS") has been designed for.

When a large-scale disaster response operation, e.g. in case of a major industrial accident or a catastrophic flood event [1], calls for a coordinated effort by multiple emergency services and local governments, decision-makers gather at a joint situation room that becomes the central hub for information synopsis and analysis. Again, these situation rooms are frequently unconnected to the dispatch center and its IT resources, e.g. GIS or database systems. For example, large-scale paper maps are used to pinpoint certain relevant sites (such as damaged infrastructure) or to identify a path

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for moving equipment, even if the dispatch center "next door" has a fancy GIS system. Such tabletop paper maps are inherently inflexible when it comes to handling a dynamic situation, and so Fraunhofer decided to come up with a digital situation table that allows for a large-scale overview map display as well as a detailed high-resolution view of special interest areas. It is referred to as digLT.

This paper introduces both technologies, which were initially developed separately, and identifies how they can be combined in order to arrive at an even more advanced level of IT support for emergency response in a mobile domain.

The remainder of the paper is organized as follows. First, MIKoBOS is introduced with a presentation of its design, functionality and network architecture. Next, digLT, the digital situation table with Fovea-Tabletts®, is discussed. An emergency response scenario suggests how both systems may be used in practice, and subsequently the potential for integration is discussed. Finally, the paper finishes with concluding remarks. The reader is referred to [2] and [3] for an overview of related work.

2 MIKoBOS – Mobile Information and Communication System

MIKoBOS was designed with the intention to extend the scope of the fire department's headquarters dispatch system into the mobile domain and to allow site personnel to conveniently access information that would otherwise be available to them only by way of voice radio message exchange, if at all. For example, information collected from emergency calls may be accessed on-site, available resources may be checked, and situation reports may be sent upstream along with related images. Moreover, MIKoBOS intends to enable personnel roaming at the site to electronically interact with peers, commanders or experts in an upstream manner, e.g. for sensor data transmission or for situation reports, and a downstream manner, e.g. when they receive handling instructions for hazardous material they came across.

Consequently, the system has a three-tier architecture, with a headquarters component that links up with the central dispatch system, a command-post vehicle component that is used by senior personnel, and a component for small mobile devices suitable for senior staff working away from vehicles. These components are referred to as MIKoBOS-LS, -TEL, and -EP, respectively, as shown in figure 1.

The networks identified in figure 1 form the communication infrastructure for MIKoBOS. They allow for information exchange both at the emergency site and between the site and the headquarters; satellite links are used in case the terrestrial communication infrastructure is unavailable, e.g. as a consequence of physical destruction or overload. The basic services provide common functionalities for the function modules above. The communication service serves the dual purpose of supporting multiple network technologies and providing a common interface for other modules regardless of the underlying technology used. It is also responsible for communication status change alerts, bandwidth allocation, and adaptation of the data stream to link conditions according to policies such as priority. Above the basic services, various function modules such as the hazardous material information module and the resource management module have been implemented [2].

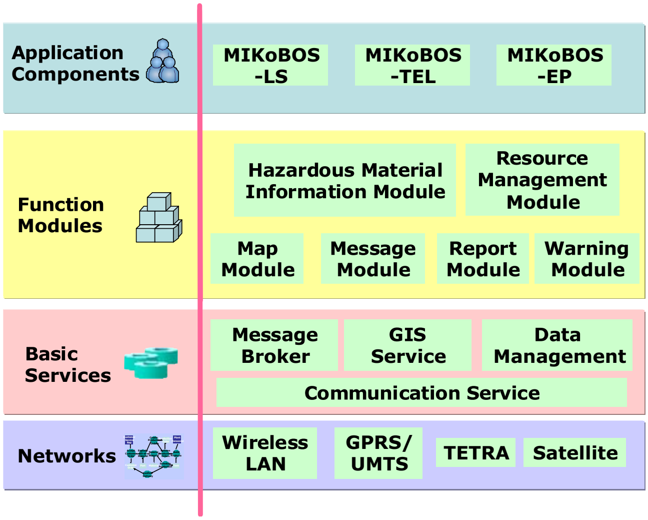

Fig. 1. The MIKoBOS Architecture

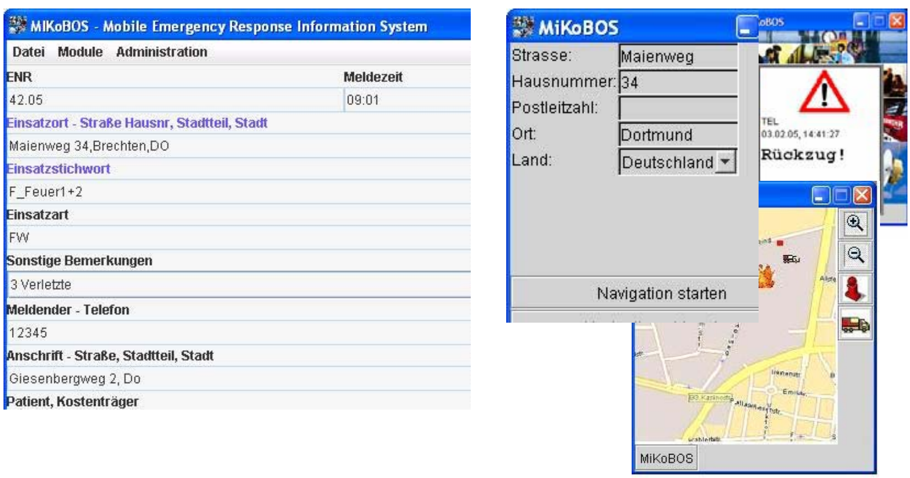

Fig. 2. MIKoBOS-TEL (left) and -EP (right) sample screens

The headquarters component MIKoBOS-LS forms the bridge between MIKoBOS and the existing dispatch information system such as Tyco's CKS-112 [4] for which integration has been accomplished for bidirectional data exchange. MIKoBOS-LS allows control room staff to receive timely updates on the situation at the emergency site through means such as text messages and pictures. MIKoBOS-TEL runs on a notebook PC installed in the command post vehicle at the emergency site. It enables the commander to access headquarters databases, to request additional resources, to report the current situation with the new option of transmitting images. It also allows him to communicate, individually or through group communication schemes, with frontline responders carrying a MIKoBOS-EP device.

MIKoBOS-EP, finally, runs on a ruggedized PDA or similar device and allows staff roaming at the site to link up with TEL or headquarters for downstream data access or upstream reports, again including image transfer. As address information for the emergency site is automatically available on this device anyway, its functionality has been extended by the integration of a GPS based navigation system, so the PDA may additionally help the driver to find his way to the site. Figure 2 shows sample screen shots for both MIKoBOS-TEL and MIKoBOS-EP.

All wide area network data exchange is scheduled by the communication service based on available links, message priority and message size. Figure 3 illustrates the network architecture and shows a selection of WAN links. Experimental results on network performance have been reported in [2]; it turns out that Inmarsat BGAN [5] is among the most suitable satellite options available for MIKoBOS data transfer between headquarters and a command post vehicle parked at the emergency site.

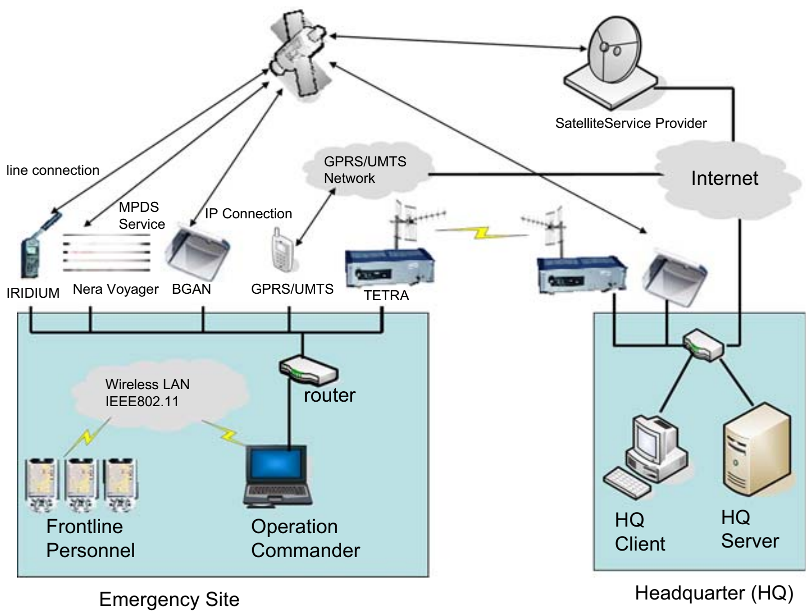

Fig. 3. MIKoBOS Network Architecture

3 Situation Analysis at a Digital Situation Table with Fovea-Tablett®

In many application areas, whether mobile or not, a team of experts must analyze and assess the situation of a defined region in order to decide on further action. Examples for such applications are disaster management or environmental planning where the scene of interest is presented by maps or aerial and satellite images. To accomplish their tasks effectively and efficiently the experts need not only a general overview of the scene but also detailed scene views and additional non-graphical information [6]. In the disaster management domain this still very much done as paper work, that is paper maps with hand drawn overlays and a lot of information taken from conventional folders.

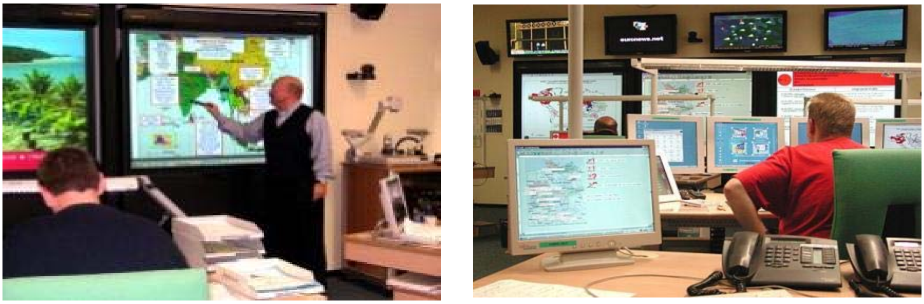

Fig. 4. Two examples of situation analysis in a team

Nowadays modern situation analysis workplaces offer different visualization concepts to support a team of experts. A typical example of a situation analysis workplace is shown in figure 4. The team is spread over several workplaces and has to divide its attention between general views and local tasks.

Fraunhofer IITB has developed a digital situation table, known as digLT, allowing the team to work together at one workplace not just presenting information, but offering an interaction concept to handle the whole scenario as well as local tasks. The technical solution was achieved by combining different display technologies, an automatic image processing algorithm and a geographic information system (GIS). The situation table consists of a work station, a horizontal screen acting as a work table displaying the situation overview, a vertical screen acting as a board for additional information, and so called Fovea-Tabletts® (patented) offering detailed views. Figure 5 shows the digital situation table in action.

Fig. 5. Digital situation table consists of a horizontal work table, Fovea-Tabletts® offering local high resolution, and a vertical screen displaying additional information

The work table is a large low resolution horizontal screen. It is implemented as a back projection screen of approximately 1.2m x 1.6m onto which maps or images of the situation are projected using a commercially available projector which may be a low-cost device. The work table offers the expert team a common scene overview, however the resolution is typically too poor for the recognition of detail information. The Fovea-Tablett® (FT) was thus conceived to provide the team members with a detail view of arbitrary scene locations.

3.1 Detail Views Using the Fovea-Tablett®

A FT is a small portable display unit, a tablet PC with a high pixel density. It is simply placed on top of the horizontal work table. A measuring device determines its position and orientation with regard to the scene displayed on the work table. The position and rotation angle are transmitted wirelessly to the FT which displays the situation data (maps and images) in such a way that the observer has the impression of looking through the FT onto the situation, but with a much higher resolution.

Fig. 6. A Fovea-Tablett® positioned on the work table offers a local view with high resolution

The FT's higher resolution means that maps with a better scale and images with a higher resolution can be analyzed. Figure 6 shows two images of a high resolution FT precisely referenced to the overview image displayed on the work table.

The Fovea-Tabletts® got their name because they copy the principle of the human eye's fovea. The FT technique offers analysts a view with a very high resolution – but also only covering a small part of the situation. On a single work table, several FTs can be used simultaneously and each FT can be arbitrarily moved around the work table surface. This allows the experts to choose freely and quickly their areas of greatest interest. Additionally the team may decide between various views on the scenery by choosing individual overlays showing e.g. water or air quality, or the condition of infrastructure, as determined externally and fed into the system.

Taking a FT from the table breaks the connection to the tracker process and freezes the cut-out of the scenery shown by the FT. The FT can be taken to a separate workplace, where a part of the team can do further analysis of the situation, e.g. annotation of important objects. Coming back to the table, the user is asked whether to save his work into the table server. For this purpose, a separate instance of the GIS system has been implemented on the FT in order to have the necessary functionality.

3.2 Interaction Paradigm

Interacting with the digital situation table should be straightforward for each member of the team. Therefore, an interaction paradigm was developed allowing each team member to interact with the Fovea-Tablett®, the Internet database for additional information about reference objects, and the work table server. Pen control and toolbars are used for interaction as shown in figure 7.

Because the object database described below has one output region on the vertical display only, its availability is restricted to one FT at a time. On completing database access the next FT requesting database information is accepted. If an analyst wishes to retrieve information about a marked object in the scene he must select the data symbol in the FT's tool bar.

Fig. 7. Tool selection by pen

3.3 The Object Database

Objects with additional information are indicated symbolically within the situation where different object types have different symbols. These symbols are connected to the situation by their geo-coordinate and type. After a symbol is selected with the pen on the FT display the referenced object information is presented on the vertical screen. This is a 45" LCD monitor fixed vertically to the work table. Information about the selected object can be data from a database or online data from an arbitrary sensor (e.g. images from a webcam). Figure 8 shows the vertical screen with the scene overview on the left and the information about a marked object with a stored still image on the right.

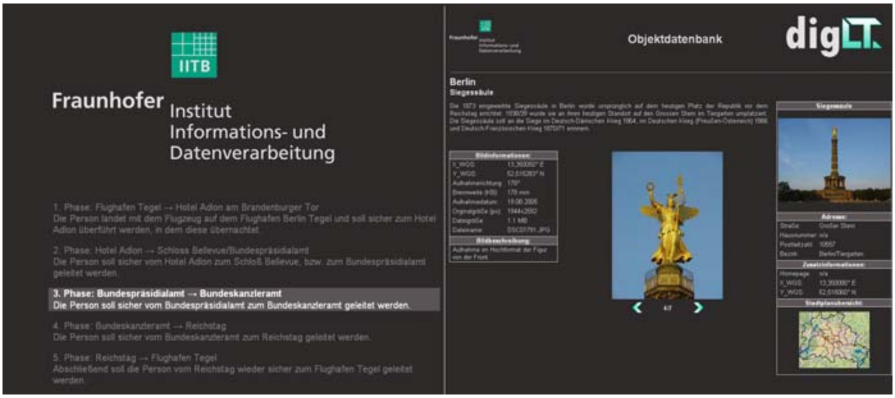

Fig. 8. digLT vertical screen. On the left of the screen the available views on the situation are listed. On the right information for a selected object is presented.

4 MIKoBOS and digLT in an Emergency Response Scenario

This section sketches a typical scenario for a large scale multi-agency emergency response operation and demonstrates how both MIKoBOS and digLT may come into play:

An explosion at a chemical plant has caused a major fire, and toxic smoke is moving into a residential area. The fire department's main tasks are battling the fire and taking air samples around the plant, according to prevalent winds, in order to determine where a hazard might exist to residents. Samples are analyzed, and results are reported to their HQ on a regular basis. Police are cordoning off the area and using vehicle-mounted loudspeakers to warn people in affected areas, as determined by the fire department, to stay indoors behind closed windows. Ambulance services are on standby for evacuation procedures should they become necessary. Senior regional government representatives gather with emergency services' officers at the joint situation room (located next door to the fire department dispatch center) in order to monitor the situation and make decisions. They are in permanent contact with commanders in the field, e.g. the deputy fire chief who oversees the response at the plant.

MIKoBOS-TEL supports the deputy fire chief at the emergency site in multiple ways. First, it allows him to receive updated smoke propagation maps prepared at the HQ according to sensor and meteorological data. Without a digital data link, such maps would not be readily available to him. Second, the system allows him to quickly assess what extra resources are available at the base, without having to enter into a voice radio dialogue with the HQ dispatcher, and he can order equipment to be sent to the site. Third, he may electronically prepare and send situation reports to the dispatch center; unlike today, such reports become documents in the event log that are available to others even if they happened to miss the particular voice radio transmission. Forth, the commander may use MIKoBOS to multicast or broadcast messages to his subordinates at the scene, e.g. on organizational matters. Frontline responders may use MIKoBOS-EP not only to receive such messages, but also to electronically transmit data from sensors they carry, including a camera. MIKoBOS-LS makes sure that information arriving at the HQ is fed into the dispatch system and stored in the event log in a tamper-proof way, and in turn, that information generated at the HQ is available at the site.

digLT technology can help situation room personnel in their effort to establish a common view of what is going on, and to come up with appropriate decisions. A map of the area around the plant may be displayed at the situation table, along with a dynamically computed layer that visualizes smoke propagation based on MIKoBOS transmitted sensor readings. Those in charge of a specific area may use their FT to get a detail view of critical objects such as schools, and the secondary screen may be used to display additional information as a basis for discussion and joint decision-making of fire and police experts. Thus, police efforts to warn residents can be based on a common relevant operational “picture” in both meanings of the word, and medical services may identify areas to deploy their forces as opposed to no-go areas. When an expert has to do back-office work on his task, he may take his FT with him, and later upload updates when he returns to the table.

5 Towards an Integrated Situation Analysis Information System

As mentioned previously, MIKoBOS and digLT have historically been developed separately. However, it is obvious that bringing together the technologies will increase the benefits to users.

MIKoBOS-LS’ close integration with commercial dispatch software for emergency services will allow the situation table system to access data stored in the dispatch system, which usually has a GIS of its own. The MIKoBOS map module is the first candidate for integration with digLT. In turn, field data acquired by MIKoBOS-EP and –TEL are already fed into the dispatch system, and digLT is the right platform for presentation and processing in the situation room. Such data may include images, sensor readings or GPS data from vehicles equipped with a MIKoBOS device.

In a second step, it will be worthwhile to investigate if a mobile version of the digital situation table should be made available for large command post vehicles, thus complementing MIKoBOS-TEL for use by senior on-site personnel. Initial feedback by practitioners suggests that there is a potential for its use at the site. Consequently, MIKoBOS-EP may be integrated into the Fovea-Tablett® along with a GPS receiver, so they may be used away from the vehicle e.g. to enter the exact position of hazardous material found in the vicinity of a crash site. The latter functionality would, for example, significantly speed up the process of defining the “off-limits zone” around a hazmat vehicle, e.g. when radioactive material is thought to have been spilled.

6 Conclusion and Outlook

This paper has presented MIKoBOS, a mobile information and communication system for emergency services, and digLT, the digital situation table with Fovea-Tabletts® for use in situation rooms. It has been shown how both may already be used in an emergency response scenario, and how they may be combined for even greater benefits to the users.

Current work is focused on further development of digLT. The system is currently based on the raster GIS Erdas Imagine by Leica Geosystems®. In the near future, it will be made much more flexible with the objective to support virtually every customer GIS system, which will facilitate the integration with existing dispatch or, more generally, command and control systems. Moreover, the tracking of moving objects is a must. In a disaster scenario where lots of vehicles of police, fire department, and medical emergency services are operating at or rushing to the scene, every unit equipped with a digital communication device will send its GPS data to headquarters where it may be presented symbolically at the digital situation table.

Initially, digLT is being equipped to handle data arising in the mobile domain, and subsequently it is to be merged into the mobile domain to become part of an integrated mobile information and communication system for emergency services.

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Recalling Resilient Actions During Emergency Response

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Abstract. The analysis of emergency response actions usually concentrates on failures as a means to improve future procedures and emergency plans. In this paper we adopt a resilience approach that focuses on the analysis of successful actions. We use group storytelling to recall the actions performed by emergency teams during an incident. A method aimed at recognizing resilient actions is proposed and its application is illustrated in a real case.

1 Introduction

All emergency management phases demand knowledge embedded in procedures and on the intellect of people who handle them. Specifically in emergency response, a great amount of contextual information is generated which results from the development of the event, including the unplanned remedial actions carried out by the teams. Part of these remedial actions and decisions are made on the fly because they are not part of the formal procedures. After the event, the understanding and the analysis of these situations are important to refine the emergency plans. Many emergency investigations do this, but they usually concentrate on failures. Our approach is to concentrate on those actions that resulted in success.

Telling stories is a natural way of transmitting tacit knowledge among individuals, and groups. Stories are great vehicles for wrapping together elements of knowledge such as: tacit knowledge, emotion, the core and the context. They are a very powerful way to represent complex, multi-dimensional concepts. While a certain amount of knowledge can be reflected as information, stories hold the key to unlocking vital knowledge, which remains beyond the reach of codified information [11].

This paper shows how collective stories [14] could be used for identifying resilient actions during an emergency response. The approach used to analyze the incident reports is based on resilience engineering. This approach is challenging, but the benefits are very useful to the design of response procedures. Among these benefits we can mention the initial understanding of how emergency workers adapt their actions in response to unpredicted situations, the identification of the security boundaries, and the possibility of incorporating new successful procedures in the emergency plans. As pointed by Cook and Woods [4], *"an important question for resilience management is a better understanding of how the window of opportunity for learning can be extended or enhanced following accidents"*.

The paper also reports a case study where we used the method and the tool [2] to recall stories during a large fire in a supermarket in Rio de Janeiro. The stories were

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told by firefighters who participated in the response to this incident. We claim that our method is more appropriate than formal reports as it benefits from the group synergy. We believe that using this approach we can recall many actions which otherwise would remain hidden in the minds of those who participated on the event.

The paper is divided as follows: Section 2 reviews the advantages and the drawbacks of collective knowledge recall, and describes how the group storytelling approach can be used to recall knowledge generated during emergency response situations. Section 3 explains a method for identifying resilient actions from stories and the group dynamics associated with this process. Section 4 reports an experiment performed by firefighters who used group storytelling to report their actions during a fire in a supermarket in Rio de Janeiro, Brazil. Section 5 concludes the paper.

2 Collective Knowledge and Group Storytelling

The importance of knowledge has motivated companies to develop practices to facilitate its management. Many organizations assign high priority to documentation, but not all knowledge is stored in documents [6]. The experience of its members, their ideas and decisions are also part of the organization's knowledge. Nonaka and Takeuchi define these elements as tacit knowledge [9]. It consists of technical abilities: mental models, beliefs and ingrained perspectives not easily manifested.

When we want to recall an episode that has occurred in the past and which has been witnessed by a group of people, we should count on their collective testimony to try to reconstitute the episode. It usually happens, however, that any individual participant is unable to tell the full story because s(he) knows only part of the full event. Only when grouped together do the events make sense. This state is achieved through knowledge exchange and combination. Although this is not enough to guarantee the full reconstitution of the episode, as some events may not have been witnessed or some witness may not be available, the collective knowledge recall is more complete than an isolated set of events.

The reporting of an episode can have four versions: the version stored in the minds of the people who witnessed or participated in all or some of the events (the stored version); the version reported by these people, i.e., the externalization of their tacit knowledge (the recounted version); the version known by these people, i.e., the set of knowledge the participants possess (the tacit version); and the real or true description of the events, which is probably non-existent [3] (the faithful version).

The reported version is generated when the participants externalize their knowledge about the events they have witnessed. However, during this process they can forget and disregard events they think are not relevant, making the reported version different from the known version. There are also cases where faulty memory, subjective perception, partial or erroneous knowledge may distort the report. The goal of the tuning/recalling process is to approximate the reported version to the known version. The closer the reported version is to the known one the better the recalling process is. Thus, the first goal of our method is to reconstruct the story as closely as possible to the collectively known story. In our work we used a group storytelling technique, instead of the more traditional approach, based on interviews.

Before an emergency response story can serve as knowledge transfer, it must be constructed. The assembly of a real story is the process of recalling knowledge from past events that have occurred. This can be an individual or a group task depending on whether the story fragments are remembered by one or more individuals. In the latter case, members of a group contribute to creating a story collectively. This technique is called group storytelling. The knowledge generated by a group storytelling process is usually richer than that generated by individuals interviewed individually [13]. A group storytelling process develops on possible differences in points of view, is stimulating and dynamic, and promotes synergy among participants.

The idea of using a group storytelling mechanism is simple, but its execution or implementation is not. It depends on the existence of a knowledge management culture as well as that of a collaborative culture. A collective story is more difficult to obtain but in many cases is also richer. Reading and commenting on other participants' narratives helps activate recall, increasing people's ability to recount what they have witnessed.

The group storytelling approach has been used in some works. Valle, Prinz and Borges reported the use of group storytelling for recalling decision processes [14]. Carminatti, Borges and Gomes compared the group storytelling approach against the interviews and the group dynamics techniques [3], demonstrating the advantages of the first. Schfer, Valle and Prinz [12] applied group storytelling to create team awareness. Acosta et al. [1] used the group storytelling approach to support the externalization of tacit knowledge.

3 The Analytical Method

In this section we present the analytical method for identification of resilient actions described in emergency response story segments. The method comprises six phases:

1. Characterization of the system and its possible working states;
2. Collective recounting of the emergency response story;
3. Construction of a time-line of events described in the emergency response story;
4. Identification of possibly resilient actions;
5. Analysis of identified actions;
6. Selection and incorporation of the resilient actions into the emergency plans;

3.1 Characterization of the System and Its Possible Working States

According to Bertanffy as mentioned by Hollnagel and Sundström [8], a system may be defined as "… a complex of elements in [dynamic] interaction". We shall consider one or more teams acting in an emergency, or even the emergency itself, as a system.

Hollnagel and Sundström [8] state that it is possible to define a system's working states and the transitions between them taking into account how close the system is to its safety limits and how efficiently it reaches the objectives for which it was created. Following this idea, in developing our method we established a phase in which domain specialists meet to define the scope of the assessed system, its objectives, and which components its operators use to manage its efficiency.

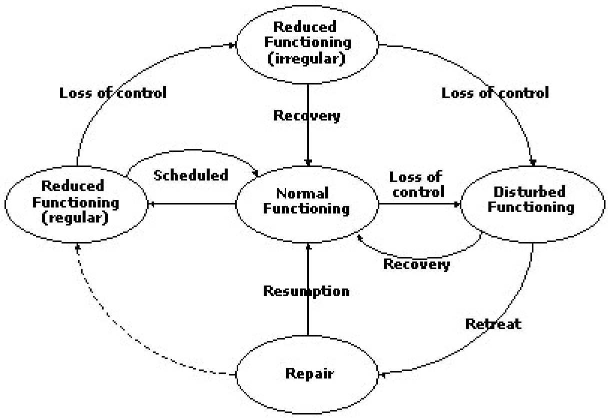

Fig. 1. State-space diagram for service organizations [8]

These same specialists later define a set of states and transitions, which characterize the working conditions in which the system components find themselves at a given moment. Figure 1 presents an example of a system states model, developed by Hollnagel and Sundström [8] for the classification of service organizations' working states. Table 1 presents a description of each of these states.

Table 1. Descriptions of the states presented in the state-space diagram for organizations [8]

State	Description
Normal Functioning	The system reaches its objectives in a reliable and even profitable manner.
Reduced Functioning (regular)	There is a foreseen absence of internal system resources, with resultant reduced productivity.
Reduced Functioning (irregular)	There is reduced system productivity due to an unforeseen absence of internal system resources.
Disturbed Functioning	Represents a state where the system is completely unable to reach its objectives, or even the system's extinction.
Repair	The system is recovering, transitioning from the Disturbed Functioning to the Normal Functioning state.

In our method, system components will be considered variables, each one of which will be in one of the model's operating states at any given time during the events. Threats, foreseen or not, as well as actions, successful or not, affect system components, making them transition among the defined working states.

The domain specialists define, for each system component, which elements should be monitored and what conditions affect them so that it will be possible to determine in which of the model's states the component is in at any given time.

Even though the system's components are correlated, it is possible, and even quite likely, that they be in different states at a certain time. Our intention is to define what state each identified variable is in, individually, before and after a given action, which will allow the confirmation of the existence or not of resilience in this action.

Figure 2 shows the individual evolution, over time, of the states of three components identified as necessary for the management of a hypothetical system. States are represented as ellipses; the transitions between states are depicted as solid symbols. The transitions are of two types: threats or unsuccessful actions that cause transitions from more to less stable states, and actions that cause transitions from unstable to stable states.

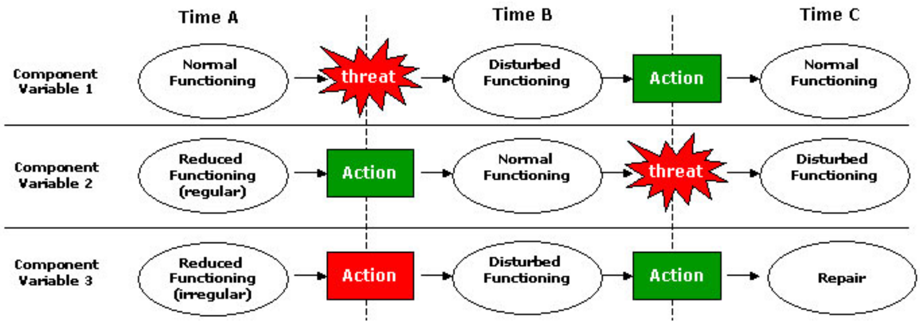

Fig. 2. Evolution of system's components' states

3.2 Collective Recounting of the Emergency Response Story

The second step comprises the recounting of the story of the analyzed event, which describes the participants' and witnesses' report of events. The method for collective recovery of incident story is used for this [2, 3].

The participants in the method can assume four roles: teller, facilitator, coordinator, and examiner. In this study, the tellers need to keep in mind the need to make as explicit as possible any action that occurred during the event. There is a natural tendency for people to make explicit those actions they consider positive, as well as to omit those actions they consider negative or denigrating and which may even make them legally vulnerable. It is the facilitator's work to follow the story development and ensure as much as possible that this does not happen. He also looks for information that helps in the chronological ordering of the story.

In the search for resilient actions, the more information we have available about the context in which the incident occurred, its environment and circumstances, the more likely we will be to correctly identify the actions that contributed to the system's survival and the maintenance of its dynamic equilibrium. After this step we will have a story that recounts the event as seen by those who participated in it or observed it.

3.3 Construction of a Time-Line of Events in the Emergency Response Story

The narrative developed in the previous step may not offer a clear vision of how the events unfolded, which may be an obstacle to the resilience analysis of the acts. After the development of the incident's story one or more time-lines must be developed so as to put the events, and their context, in chronological order. In a collectively developed narrative it is possible that various time-lines be described, such as when there are two distinct teams working on the same emergency. After generating the individual time-lines the method's facilitator must attempt to merge them in such a way as to obtain a single view of all of the events, as shown in Figure 3.

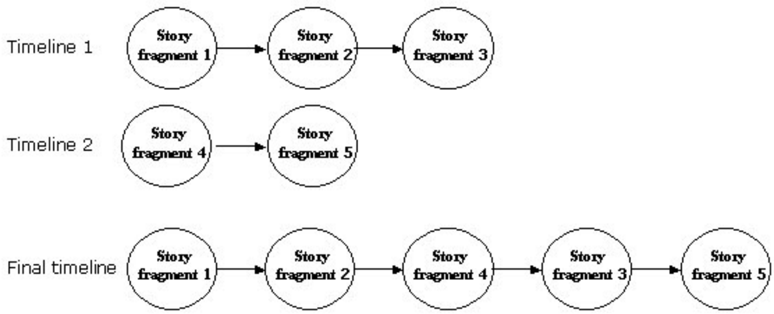

Fig. 3. Time-lines identified in the story

The Critical Decision Method described by Crandall, Klein and Hoffman [5] considers the generation of an event time-line a key step to reach a clear and refined vision of the structure of the mishap. In our case, the vision afforded by the time-line allows the identification of gaps in the recounted actions, which may make evident the need to obtain more information about the event from the participants of the Group Storytelling dynamic to clarify those points.

3.4 Identification of Possibly Resilient Actions

In the fourth step, we add the element called the resilience analyst to the list of roles initially proposed [2]. He is charged with analyzing the incident's story seeking to identify the recounted actions, filtering and identifying, among the various actions described in the story, those that present one or more characteristics of resilience. Among the elements that characterize resilience we can cite: ability to anticipate threats and their consequences [15], capacity of effective response to signs from auditing [7], and awareness [16].

By the end of this step, the resilience analyst will have compiled a list of all the recounted actions that have indications of resilience, which will facilitate the work of the domain experts by sparing them the need to analyze all the story events.

3.5 Analysis of Identified Actions

After the resilience analyst has organized the event's time-line and selected the possibly resilient actions, the domain experts meet to confirm, or not, the existence of resilience in the selected actions. The intent is that they assess the event's story to classify the individual predecessor and successor states of the variables that represent components of the system being studied.

To do this work it is necessary that the domain specialists identify which of the system variables the action effectively acted on, affecting its state. In this way, we can consider the following possibilities:

a. A certain action took a variable that was in a certain state to a more stable state. This action is considered resilient;
b. A variable was in a stable state but with its stability under threat, and after a certain action was undertaken it was in the same state but with the threat removed. This action is considered resilient;
c. A variable was in a certain state and after a given action was undertaken it was in a less stable state. This action is considered not resilient.

In Figure 4 we represent these possibilities relative to the state of a given variable.

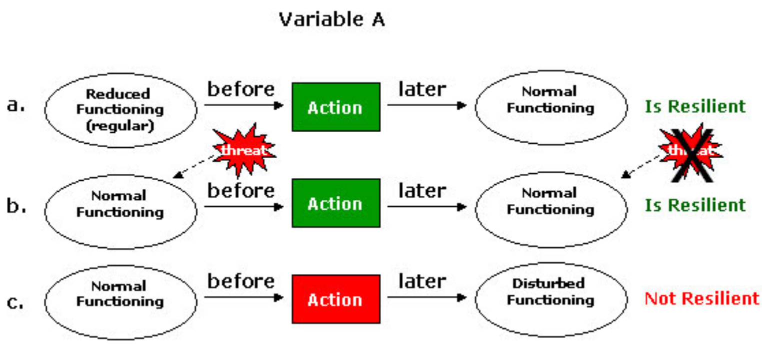

Fig. 4. Predecessor and successor states of Variable A upon execution of a certain action

3.6 Selection and Incorporation of the Resilient Actions into the Emergency Plans

The objective of this work is to identify the tacit resilient actions, those not previously anticipated in plans, but which were adopted during an emergency. For this, it is necessary that the domain specialists ascertain whether the actions confirmed as resilient in the previous step exist or not in the plans. After this, the specialists assess and ratify, if they deem convenient, the incorporation of the identified resilient actions into the organization's emergency plans. This is done based on a cost-benefit analysis of the actions as well as the risks their adoption would entail.

4 The Case-Study

In our case study, we analyzed actions adopted by Rio de Janeiro Firefighters, in Brazil, in a fire that happened at the end of November 2005, in a supermarket considered a medium-size commercial building. This can be considered a rare event as it on average only occurs once every five-years. Due to the approaching holiday season the establishment's inventory was high, favoring the spread of the flames and consequently increasing the effort necessary to fight the fire, which required 10 hours of actual fire-fighting and an additional 10 hours for quenching.

The domain specialist who participated in the experiment then had 25 years of experience with the Fire Department, having occupied a command post for 6 years, besides having participated in several events of this proportion. The specialist defined the components of a system for fighting fires in medium sized commercial buildings, besides analyzing and approving the state-model defined by Hollnagel and Sundström [8], reproduced in Figure 1.

One of the elements of the model generated for characterizing the operating states of the fire-fighting system is reproduced in Table 2. The table shows only one of the identified components – the water supply. The complete model and some additional details of the method are under construction [10].

Table 2. System states and monitoring variables

Variable	States				
	Normal functioning	Reduced functioning (regular)	Reduced functioning (irregular)	Disturbed functioning	Repair
Water supply	Existence of a water pumping system for fire-fighting, comprised of two inexhaustible water supplies	Foreseen temporary partial interruption in water pumping, due to the depletion of one of the truck's fuel supply	The unforeseen temporary partial interruption in water pumping, due to a mechanical malfunction in one of the pumps	Total interruption of fire-fighting water pumping, due to simultaneous mechanical failure in the two pumps	Re-establishment of total water pumping capacity, due to the mechanical repair of the pumps

In our case study, the resilience analyst identified the presence of one or more of the characteristics of resilience in some actions described by the event's story-tellers Among the elements that characterize resilience we can list: the ability to articulate with other organizations [10], ability to anticipate threats and their consequences [15], the ability to respond effectively to signs from auditing [7] and awareness [16]. In Table 3 we highlight a piece of the studied event's story that attests to the presence of one of these characteristics. In this case, the action of requesting water from members of the community was adopted. This action was relative to the water supply component of the fire-fighting system.

According to the domain specialist, the request for help to maintain the water supply is normally made to other fire-department units. Even though this request is foreseen in the plans, the possibility of requesting support from other organizations is not formally registered, which prompted the specialist to suggest that it be included in the emergency plans for fighting fires in commercial buildings.

Table 3. Pieces of a report with resilience characteristics

Resilience characteristics		
Characteristic	Story fragment	Action
Ability to articulate with other organizations	"At first it was difficult to control the fire due to the absence of hydrants in the area. Luckily, a water tanker-truck from CEDAE was passing by, stopped to collaborate, and was joined shortly after by a private truck. That was what sustained the fire-fighting while our water truck went to replenish its water supply. The problem was solved when more Fire-Department water tanker-trucks arrived on the scene and allowed the rotation of the vehicles and a constant water flow."	Request water to the State Water Supply Authority (CEDAE)

5 Conclusions

In this paper we have presented a method for identifying resilient actions during emergency responses. The method consists of six phases and uses the stories told by the participants in the event and the knowledge of specialists to select actions for a comprehensive analysis of their implications in the event states. The resilience engineering approach concentrates on the actions that were considered successful, i.e. brought the emergency from an unstable state to a stable or less unstable state. The method was applied in the analysis of a real event, although only a simple illustration was presented in this paper. The complete study is under construction [10].

We believe that the collective knowledge recall supported by the group storytelling technique associated with the resilience engineering approach is very promising. We have been able to recover events that are not part of the official reports and up to this group storytelling exercise only existed in the minds of the participants. The discovery of resilient actions has the potential of improving the response procedures, i.e., they can promote the processes of knowledge acquisition and transfer, especially the knowledge that remains tacit in the minds of experienced workers. This is particularly important for new technologies, such as mobile artifacts.

The proposed method is under evaluation and still has many uncertainties and limitations. Although we have successfully applied the group storytelling approach in other contexts, we are not sure yet how cooperative the participants would be in emergency reports. The results obtained so far are not enough to confirm our assumptions. The method is also very dependent on the set of states defined by the emergency specialists. An incorrect definition can result on erroneous recommendations. The method will need to be refined and more case studies carried out before we can ascertain its benefits.

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