Improving Usability of Integrated Emergency Response Systems: The SoKNOS Approach

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Abstract: Implementing systems for emergency response poses various challenges. Information from various sources and systems needs to be integrated, processed, aggregated, and visualized in a dynamic and consistent fashion. Amongst all those challenges, one key issue is the development of an optimal user interface, which allows for intuitive operation with different information as well as supports collaborative work, even in stressful situations. In this paper, we introduce the SoKNOS system, an emergency response system addressing those challenges and putting special emphasis on usability. We illustrate how integration on the user interface level enables both efficient engineering and improved usability for emergency management systems, and how collaborative interaction in emergency situations is supported by SoKNOS.

1 Introduction

Disasters are large incidents that typically affect all levels of people in a society, ranging from citizens to government authorities. Hence, there has been an ongoing effort to build emergency management systems such that emergency rescue teams could manage catastrophic events in a more effective manner. In general, the process of emergency management comprises four phases: mitigation, preparedness, response, and recovery. The *SoKNOS*[1] project aims at integrating existing systems in order to arrive at a new generation of emergency management software. On the whole, SoKNOS puts special emphasis on two of the main emergency management principles defined by the FEMA (Federal Emergency Management Agency)[2] [Wor07]: it provides an *integrated* and *collaborative* solution.

1.1 Motivation and Goal

SoKNOS is motivated by the vision of seamlessly integrated, heterogeneous information sources that enable emergency organizations to collaborate in an efficient way. According

[1] *Service-orientierte ArchiteKturen zur Unterstützung von Netzwerken im Rahmen Oeffentlicher Sicherheit*, German for *Service Oriented Architectures for supporting Networks in Public Security*

[2] Agency of the US government tasked with Disaster Mitigation, Preparedness, Response and Recovery planning.

to the classification of disaster information systems provided in [RC06], SoKNOS is a system that supports the response and the recovery from natural and socio-technical disasters. The SoKNOS vision is to enable decision makers:

1. To quickly *find and integrate information* from heterogeneous and distributed environments while keeping the integrated information accessible to other emergency organizations,
2. to *visually explore the situation* at hand, individually or in collaboration, by combining different methods for visual analysis, aggregation, and generalization that work on an entirely consistent information basis,
3. to *collaboratively solve problems* by creating plans and documentations, managing resources and assigning orders.

All these three points address the usability of emergency management systems. Developing such a system with good usability is a particular challenge because those systems are (a) very complex and (b) not used in every day work. Therefore, SoKNOS has been developed with a special focus on an intuitive user interface which can be used collaboratively.

1.2 Background and Challenges

A disaster can be defined as a large-scale, costly, public, unexpected or disruptive event [TP97]. Especially the properties of being *large-scale* and *unexpected* impose certain challenges on a system used in response to such a disaster. In an emergency situation, different organizations need to collaborate, and information from various sources is needed. Since multiple, more or less advanced systems are currently in use, the challange is focused on *system integration*, rather than on designing a good software solution from sketch.

Yet, a system integrating various information sources and diverse functionality also introduces a higher degree of complexity to the user interface. In SoKNOS, we follow the approach of integrating systems on the user interface level. Thus, we aim to provide a framework for reusing existing user interface components, thereby lowering the learning effort for those already familiar with those interfaces. To further improve usability, we show how a consistent interaction metaphor, the SoKNOS toolbox, can be built on top of the integrated components and addresses the challenges of collaborative interaction.

System Integration

There is an abundance of distributed and heterogeneous information sources that could potentially be used for emergency management, for example, services providing weather or traffic information. Since a disaster is unexpected, it cannot be foreseen entirely which of those information sources need to be tapped in an actual emergency situation. Therefore, the possibility of integrating information dynamically is required, instead of hard-wiring information sources. Furthermore, unreliable or incorrect information integration can lead

to erroneous decisions that could even exacerbate the emergency. It is therefore paramount to integrate information in a semantically correct way.

In parallel to the increasing number of potentially available information sources, we observe an increase in visual analysis methods. However, in many cases, different analysis methods come with different, not interconnected tools. Hence, switching the views easily and tracking a particular object across different visualizations is currently not supported. Further on, using several tools in parallel decreases the usability of the overall system since the user has to cope with different interaction metaphors. Therefore, a solution is needed that allows seamless interactions across those different systems. Additionally, the emerging Spatial Data Infrastructures (SDIs) [WBF05] are heading in the direction of integrating geospatial information. Hence, the integration of geospatial and non-geospatial information sources is required.

Usability and Collaborative Interaction

Research on usability of complex systems has gained some attention during the past decades. As the computer industry is maturing, the focus has shifted from a purely technical and machine-oriented perspective to a broader one – understanding the computer only as one part of a socio-technical ecosystem. The user interface is no longer considered only as a decorative display. In fact, the challenge of designing systems with a good usability[3] became an important part of the software development cycle. In fact, the need for adequate and usable interfaces for systems supporting emergency management has recently received special attention. Notable examples are [CT07], stressing the importance of the user interface in emergency management systems, [TCvdWY04], describing design considerations for an emergency management system, DERMIS, and [RAS+02] describing a prototype of a human-centered emergency management system that employs a geospatial perspective on data.

What makes the problem more complex is the fact that full-scale disasters and major incidents rarely occur. Thus, the end users are often not familiar with the interface of the emergency management system. Moreover, emergency management teams are always under immense stress and pressure, thus demanding the interface to be tied as close as possible to the actual needs of the users. These needs include adaptation to the users IT skills, their work roles and their tasks.

As emergency situations require intense collaboration between many people of different organizations, and false decisions made in one organization may afflict the decisions made by other organizations, support for collaborative data exploration, planning and decision making is needed, posing additional challenges for user interface designers and usability engineers: While these situations are common in non-IT settings, e.g. when two people discuss a strategy using a (paper) map, standard desktop systems usually remain ignorant of these needs and still assume only a single user setting. Thus an interface supporting these situations is required to allow fluent interaction, not only on standard, single-user workstations, but also on large interactive displays suitable for multi-user interaction.

[3] A standardized definition of *usability* can be found IN ISO 9241: ERGONOMIC REQUIREMENTS FOR OFFICE WORK WITH VISUAL DISPLAY TERMINALS design

Summarizing these considerations, we extend the user interface requirements identified in [TCvdWY04] to a list five relevant design imperatives for an emergency management systems offering good usability: minimize learning effort, minimize errors, support collaboration, allow tailoring of user roles, and allow accountability of actions.

To show how we address these criteria, we present a prototypical interface that builds upon semantic information integration and takes a holistic perspective on the available information. To support the strive for universal usability [Shn03] in future emergency management systems, we propose a the SoKNOS toolbox, a concept employing both coarse- and fine-grained customization and allowing for consistent single- and multi-user interaction.

The rest of this paper is structured as follows. Section 2 will give a short overview on the SoKNOS architecture, explaining our approach to tackle challenges depicted above. In section 3 and 4, we will elaborate in more detail on the two important challenges with respect to usability: the i) integration and ii) seamless interaction with different information systems, especially for the multi-user collaboration in emergency scenarios. We conclude with a review on related work and a short summary.

2 The SoKNOS System

SoKNOS is a complex system integrating multiple applications that address a large range of tasks relevant for emergency management. Those can be divided into four areas: information integration, information aggregation, information creation, and visualization and interaction [DPZM09]. Figure 1 presents a general view on the SoKNOS architecture, illustrating the key components addressing those areas.

Information Integration

In an emergency management system, information from different, heterogeneous data sources has to be integrated. Such information may be internal (an organization's own resources, data on current problems, measures, and processes, best practices, and so on), as well as external information. External information may range from general information, such as maps, traffic or weather reports, to very specific information, like sensor measurement values. A SoKNOS system may also provide a (full or partial) view on its data as a Web Service, such that collaborating organizations may access each other's data.

A web service repository stores those services as well as functional and non-functional meta information, such as the kind and format of data provided by a service, the organization hosting the service, etc.. A process and a governance repository provide additional information on pre-defined plans and best practices that may be applied in an emergency situation.

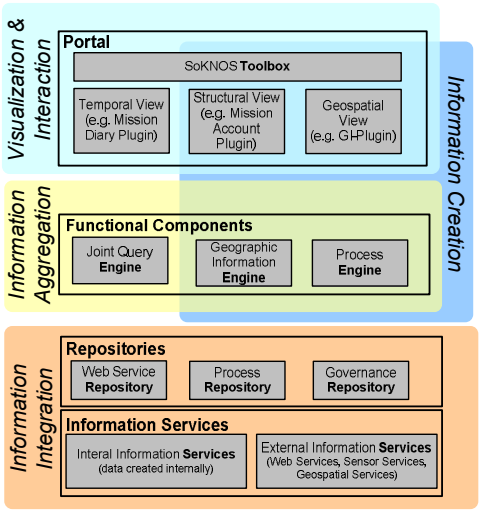

Figure 1: Overview on the SoKNOS architecture

Information Aggregation

The information sources listed above are accessible via a single interface, the *Joint Query Engine*. It is capable of distributing a query to different information services, internal as well as external, and aggregating the results. Thus, information about the same entity, e.g. a broken damm section, can be collected from different information sources in order to provide a detailed view on that entity. This engine is accompanied by two specialized components: a geographic information engine, which is capable of aggregating spatial data, and a message engine, which is used for filtering and clustering messages.

Information Creation

Apart from integrating information, the creation of consistent information is an important issue in emergency management systems. Orders are created, new spatial objects are drawn in the map, actions are planned, and so on. Providing access to the systems in which those data are created and managed allows for various consistency checks. For example, units cannot be associated with more than one measure; measures addressing problems must have a location, and so on.

Visualization and Interaction

As already addressed previously, *usability* is a key issue in developing an emergency management system. Thus, we have put special emphasis on developing an intuitive and easy to use interface to the integrated SoKNOS system. Fig. 2 shows partial snapshot of the SoKNOS user interface.

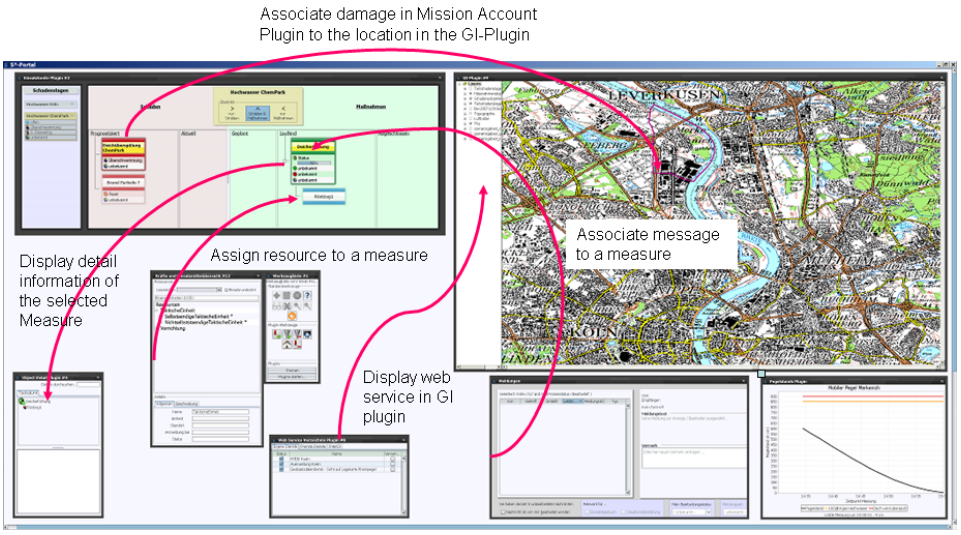

Figure 2: Screenshot of the SoKNOS prototype's frontend

The SoKNOS *Portal* is organized as a plugin-based architecture, where different applications can be integrated as plugins (see section 3), thus providing a flexible and extendible architecture. Plugins are self-contained units with a user interface and business logic of their own, which communicate via well-defined interfaces. In the example, we have integrated an existing geographic information solution, a resource database with a specialized interface, and some applications developed especially for the use in SoKNOS, such as an application for managing threats, damages, and measures. In sum, these applications provide different perspectives (structural, temporal, and spatial) on the current situation. Specialized applications are used e.g. for provisioning of forces and materials, planning, or finding suitable information sources.

A *Toolbox* serves as a central point of interaction for all plugins. Thus, a set of standard tools can be used in different plugins (such as a search tool, which allows searching for resources in the resources plugin, for plans in the planning plugin, and so on). The toolbox can be personalized, adapted according to the user's rights, and allows for multi user interaction by providing each user with their own toolbox (see section 4).

3 Integration on the User Interface Level

Like in most areas, numerous software solutions have already been developed through the years in the field of emergency management. Most emergency response teams use various independent, partially IT supported solutions for selected tasks, such as a database for resources, digital message processing, etc. Integrated solutions, however, are often rare. Instead, existing applications are used side-by-side. The problem with that approach is

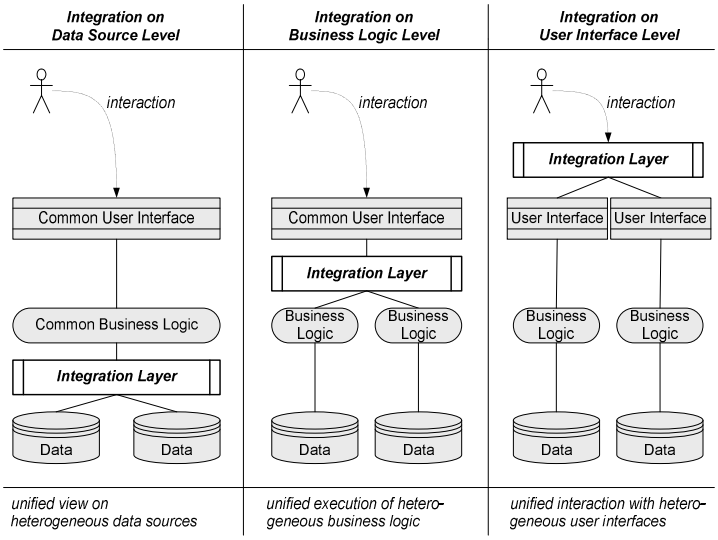

Figure 3: Different approaches to application integration, following [DYB+07]

that users have to switch between applications, so that their focus is lost, and information may be hidden. Furthermore, relations between data stored in different applications are not visible. For example, a message informing about the arrival of a rescue unit is stored in a message system and has no connection to the resource database containing information about that unit. Thus, the user has the additional cognitive burden of creating and remembering such relations.

With SoKNOS, we provide a system which combines existing software systems into one integrated solution. As shown in Figure 3, software applications most often follow a three layer architecture, which consist of: (a) data, (b) business logic, and (c) a user interface. Consequently, there are different approaches to system integration: integrating data, integrating business logic, and integrating user interfaces [DYB+07]. In SoKNOS, we have chosen the latter approach for the following reasons:

- An integration layer such as a portal [Weg02] provides a single point of access to information, instead of having to switch between applications.
- Integrated user interfaces provide the possibility to explicitly showing relations between data stored in different applications.
- Unlike integrated user interfaces, applications integrated on the data or business logic layer have a newly created user interface (see Fig. 3). Thus, users already familiar with existing applications will experience lower learning efforts with integrated user interfaces.
- Reusing existing user interfaces significantly lowers the system development cost, since the efforts of developing a new unified user interface are not present.

As user interface is the single point of interaction for the application's user, interacting with integrated applications allows *unified interaction* with different applications, as depicted in Fig. 2. With the components contained in the SoKNOS system (see above), examples for such cross-application interactions are:

- Relating objects by drag and drop. Examples are associating resources with measures, messages with resources, and so on.
- Highlighting related objects and tracking objects across views. Selecting an object in one application results in highlighting all related objects in other applications. This pattern is also known as *linking* [EW95].
- Entering different aspects of an object in different applications. For example, the basic data on damages is entered in the mission account plugin (see section 2), and their position is entered - more conveniently - in the geographic information plugin by pointing on the appropriate position on the map.

As mentioned in [YBSP+07], such integrated interactions require formal descriptions of the integrated components. Hence, the SoKNOS framework provides means to create and evaluate such formal descriptions in order to facilitate unified interaction. Such formal descriptions require different aspects:

- The domain, i.e. the emergency management domain. Such a description contains definitions for concepts such as problem, measure, unit, etc.
- The user interface components and interactions. A formal description of an interaction contains at least the interaction's trigger (such as clicking or dragging and dropping an object) and effect (such as highlighting an object or relating to objects). Interactions may also have conditions under which they can be performed.
- The users and their roles. In the emergency management domain, there are different user roles with different permissions. Whether a user can actually perform a certain interaction (such as issuing an order) depends on his role and can be formalized as a condition to that interaction.

In general, ontologies [Gru93, GG95] are formal descriptions that meet those requirements developed in the realm of the Semantic Web. Since they have been successfully employed for integration both on the data layer [DH05] as well as on the business logic layer [LPR+05, MBH+04], we follow the approach of using ontologies as formal descriptions for user interfaces, aiming at integration on the user interface level [Pau09]. The SoKNOS portal framework (see above) allows each plugin to be formally described by an ontology; those ontologies are used for facilitating integration and allowing seamless interactions between different, heterogeneous applications.

To improve the usability of applications integrated with our approach, we introduce the use of toolbox. It provides a central point of interaction with all applications encapsulated in a plugin. Thus, the same tools can be used with different applications, providing uniform interaction with different applications. The toolbox will be discussed in more details in the next section.

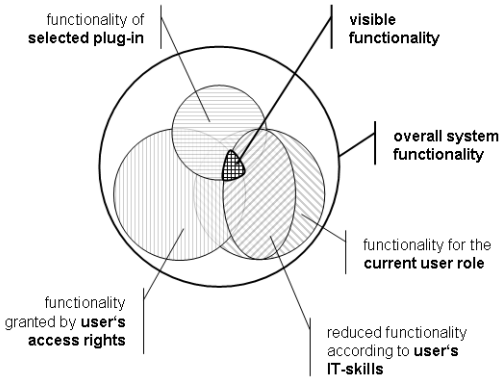

Figure 4: SoKNOS toolbox approach: the overall complexity is reduced according to the selected plug-in, the users access rights and the role the user currently has and the user's IT-skills

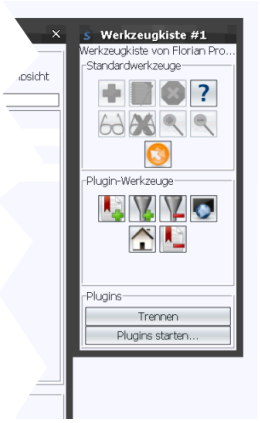

Figure 5: The current implementation of SoKNOS toolbox prototype docked to a resource management plug-in. The visible functionality is determined according to the approach drafted in figure 4

4 Usability and collaborative interaction

As already discussed previously, usability plays a major role in the design of an emergency management system. To provide good usability, the user interface of such a system needs to account for both single- and multi-user scenarios and fully incorporate the possibilities of the analogue world into such a system.

In section 1 we identified five core challenges for the user interface of an emergency management system, namely minimizing the learning effort, allowing the interface to be tailored to user roles, minimizing errors, allowing for accountability of actions and providing support for collaborative interaction. To address these challenges, SoKNOS proposes the *toolbox*, a metaphor that allows consistent as well as role- and task-adaptive interaction throughout the SoKNOS user interface.

The toolbox metaphor is based on the idea of metaphorically transforming the idea of a real world toolbox to the human-computer-interface, offering a familiar mental model of its operation [Nor02] - each plugin's functionality is accessed via tools contained in the toolbox, and each toolbox is personalized for a specific user and his work role. Further, the user "'carries"' his toolbox to workplace, respectively the plugin, where he performs a particular task. The following section elaborate more detailed on how the SoKNOS toolbox addresses the above-mentioned challenges.

Minimizing error rate and learning phase

Literature indicates that constraining the functions in a user interface may both improve learnability of the interface as well as reduce the average error rate [CC84]. Additionally,

there is evidence that users are easily overwhelmed by the large number of features provided by nowadays computer systems [DM00]. This was confirmed by end users from fire brigades and the police in interviews conducted within the SoKNOS project.

In general, role and task adaption is considered beneficial [FMM08]. However, among the advocates of strategies that tackle this problem, there is dispute over the benefits of *adaptive* versus *adaptable* interfaces [FM04, War01]. Adaptive interfaces automatically adapt to the user, while adaptable interfaces are actively customized by the user. The latter suffer especially from the fact that users seldomly customize software if they are not urged to [Mac91].

Motivated by the latter findings, the SoKNOS toolbox approaches interface complexity by providing reasonable, role-adapted defaults, but still allows further customization by the user. These defaults are based on (i) the selected plug-in (see Section 2), (ii) the user role as defined in the regulations and best practices of emergency management organisations and (iii) the current access rights. User roles and plug-in functionalities which can be accessed by the toolbox are modelled with ontologies (see Section 3). User access rights are checked with a Kerberos-related approach during runtime. Figure 4 illustrates our approach schematically, while figure 5 shows the current prototype which has already been well received by potential end users.

Accounting for multi-user interaction

Emergency management organizations commonly use large paper maps and pin boards for collaborative work. As large interactive surfaces grow more affordable, numerous research projects explored their benefits in different scenarios (e.g. [RDS02] in an office setting, [PKS+08] in public space (such as city centres), and [IBR+03] in conference settings). Thus it seems reasonable to assume that large interactive surfaces can also contribute to emergency management scenarios, such that they offer support for collaborative data exploration, planning and decision making.

However, there is still no consensus on how to design multi-user workspaces, at least not beyond very basic interactions [WFM09]. And even though breaking conventions in interface and interaction design might prove beneficial in the long run, it is questionable how well users will perform when confronted with unfamiliar interactions. Thus we propose to ease the migration phase to these new workspaces and by ensuring consistency with single user settings, such that multi-user interfaces resemble the currently dominant WIMP (Windows, Icons, Mouse, Pointer)-interfaces as close as possible. This approach is also found in the CSCW (Computer Supported Cooperative Work)-community, yet more for the reason of existing features than that of interface metaphor familiarity [XSS+04].

To ensure best consistency with single user workspaces and, at the same time, not to lose the benefits of a reduced learning phase, the SoKNOS toolbox also supports multi-user scenarios. Moreover, as accountability is paramount for security critical scenarios like emergency management, it is also necessary to know which user has triggered specific actions. The SoKNOS toolbox meets these requirements by providing each user with his own toolbox that can be attached to the several plug-ins of the SoKNOS system, thereby

supplying the user's security credentials to that plug-in, allowing both proper access right checking and logging of performed activities.

5 Related Work

The topic of public safety has drawn much attention from government agencies and the general public. Indeed, the work in emergency management has become a matter of increased significance [WM08] during the last few years thus, there has been quite a reasonable amount of research projects in the public safety related field. In one way or the other, the four phases of the process of emergency management: mitigation, preparedness, response and recovery have been covered by most of the research projects. Yet, each project has their focus. For instance, projects that emphasize on risk assessment and public safety communication include, CHORIST [CHO06], which proposes solutions to increase the rapidity and effectiveness of interventions following a major natural and/or industrial disaster. It provides a risk assessment report system and a warning message dissemination subsystem to the responsible agents and citizens as well as allowing a rapidly deployable system to establish communication with in-the-field rescue response team. ERMA [ERM06] is a risk management in the domains of natural as well as man-made disasters with a specific focus on needs of small and medium-sized communities. It provides risk assessment and communication services in particular to the citizens before, during and after the disaster. MEDIGRID [MED03], creates a distributed framework for multi-risk assessment of natural disasters and develops web based risk assessment models, using distributed disaster data. On the other hand, projects such as HiTS/ISAC [HiT06] and WORKPAD [WOR06] concentrate in collaborative work. WORKPAD aims at developing an innovative software infrastructure for supporting collaborative work of human operators in emergency scenarios by applying semantic links, whereas HiTS/ISAS focuses on the fusion of information from many different sources in particular for the case of data fusion between authorities and secure cross-border on-line group. In addition, systems that concentrate on forecasting and monitoring risk include InterRisk [Int06], which provides monitoring and forecasting services for environmental management in marine and coastal areas and LESSLOSS [LES04] for earthquakes and landslides. Moreover, projects such as OSIRIS [OSI06] and SANY [SAN06] are related to smart sensor networks. OSIRIS aims at enhancing the overall efficiency of the in-situ data processing chain by connecting the in-situ sensors via an intelligent and versatile network infrastructure that will enable the end-users to access multi-domain sensors information and SANY specifies an open architecture for all kind of fixed and moving sensors as well as develops advance data fusion services.

Furthermore, projects such as OASIS [OAS04], ORCHESTRA [ORC04] emphasize the development of standards and framework for disaster and emergency management at the European level. OASIS aims to develop an information technology framework that integrates Europe's diverse and separate emergency response systems as well as to create standard for exchanging information during disaster and emergency management. ORCHESTRA stresses on the design and implementation of a standard-based IT architecture

that supports the risk and crisis management operations of Governments and Public Institutions across Europe. Other projects such as the SHARE project [KLR+05] also analyzes large emergencies, but focuses on the development of a mobile push-to-talk communication system. Besides, information services for forces in the field are provided and an ontology-based database allows for storing knowledge acquired during the event. As the SHARE architecture is also based on SOA, services developed for it can also be integrated into SoKNOS. In general, SoKNOS shares several focuses of some of the projects mentioned above. Yet, SoKNOS aims to build a service oriented system for emergency management, which emphasizes on the respnonse phase as well as stresses on providing an integrated solution.

6 Conclusion

Systems for emergency situations pose a lot of challenges. Information from various heterogeneous sources and systems has to be integrated, consistently processed, and visualized in an appropriate manner. Interaction with such systems needs to be intuitive enough to allow fail-safe operation even in a stressful situation, and people within an organization and from different organizations have to be able to cooperate and work collaboratively, both locally close and separated in different command rooms. With SoKNOS, we have shown a prototype application to face these challenges. It comprises four relevant areas – information integration, aggregation, and creation, as well as visualization and interaction. In each of those areas, novel and innovative solutions are developed.

As emergency management systems are highly complex, the usability of such a system is of essential importance in emergency management situations. In this paper, we have layed out two research directions within the SoKNOS project aiming at improving usability: systems are integrated on the user interface level in a way that familiar user interfaces are reused, and data objects can be tracked across different applications. Furthermore, methods are developed to support collaborative work of the emergency staff.

First evaluations with users from the domain – fire fighters, police officers, and people from the German THW (Agency for Technical Relief) – have already shown that the research directions discussed in this paper are aiming at a solution that could successfully address the special challenges emergency management systems impose on usability. The methods developed in SoKNOS will substantially improve the usability and interaction modes with future emergency management systems.

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