

Intelligent Use of Geospatial Information for Emergency Operation Management

Jobst Löffler

Fraunhofer IAIS, Sankt Augustin, Germany
jobst.loeffler@iais.fraunhofer.de

Vera Hernández Ernst

Fraunhofer IAIS, Sankt Augustin, Germany
vera.hernandez@iais.fraunhofer.de

Jochen Schon

Fraunhofer IAIS, Sankt Augustin, Germany
jochen.schon@iais.fraunhofer.de

Jens Pottebaum

University of Paderborn, Germany
pottebaum@cik.uni-paderborn.de

Rainer Koch

University of Paderborn, Germany
r.koch@cik.uni-paderborn.de

ABSTRACT

This paper presents the EU project SHARE which aims at developing a mobile service architecture to support large-scale rescue operations with multimedia communication and information services. The task of planning and controlling large-scale rescue operations requires flexible and robust tools which help the rescue forces to do their search and rescue work with maximum efficiency. Resource planning tools and cartographic information about the operation site are essential to fulfill the complex task of operation management. The Interactive Resource Management and MAP3D are two modules which have been developed in the SHARE project to enable the rescue operation leadership to do efficient coordination of their forces during an operation. Our paper will focus on features and interdependencies of both tools taking into account innovative feedback and interaction mechanisms.

Keywords

Mobile data services; rescue operations; 2d/3d map services; resource management; ontologies

INTRODUCTION: RESCUE OPERATION MANAGEMENT USING THE SHARE SYSTEM

This paper presents results from the EU-IST project SHARE (Mobile Support for Rescue Forces – Integrating Multiple Modes of Interaction) which has the goal to provide an advanced system of mobile communication and information applications to rescue organizations like fire departments. SHARE technology is intended to support rescue teams working on large-scale rescue operations by providing GIS enabled decision support. In the focus of applications offered by SHARE are decision support, accessibility of crucial operation information and collaborative work through synchronized information management as well as communication with improved efficiency. The communication applications are based on push-to-talk over cellular technology for mobile audio and video communication in flexible groups.

The SHARE system currently offers five applications to the user. First, a digital map application allows for navigation and annotation of 2D and 3D digital maps of the operation site (Hernandez Ernst and Ostrovskii, 2007). Also location-based services are included. The second application which is called Interactive Resource Management (IRM) provides the means to easily manage and distribute the resources available in the operation, gives decision support and allows for allocation of new resources while the operation evolves. Map3D and its interactions with the IRM application is in the main focus of this paper and will be described in detail in the following sections. Third, applications like Push-to-Share (PTS) Voice which supports audio communication and digital message forms (DMF), a textual messaging tool, are designed to enhance the quality and efficiency of the communication in comparison to state of the art communication tools. PTS Video is the fourth application which enables the operation leadership to receive up-to-date video material of the specified operation sections. Finally, there is automatic indexing and content-based retrieval of multimedia data generated during the operation (Löffler and Larson, 2005).

This data is stored in a multimedia database managed by an Ontology Data Service (ODS). The ODS uses the existing data to derive new knowledge and give decision support.

The SHARE consortium comprises 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 and DMF 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 Fire Department of Dortmund is technical adviser in the specific domain, assesses the quality of the system developed by the consortium and, finally, integrates the solution into their working environment. 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. The usage of knowledge management tools and ontology-based information systems are explored by NCSR “Demokritos”, Greece. Tele Atlas, Belgium, provides 2D and 3D digital maps with new features which are used in the MAP3D service developed by Fraunhofer IAIS.

TECHNICAL SYSTEM ARCHITECTURE

The system design of the SHARE project is driven by two major concerns. On the one hand several services have to be deployed on mobile end devices. On the other hand knowledge about the operation is constantly generated and has to be made available to all system components including the services on the mobile devices. A service-oriented architecture based on a server-client design was implemented because it meets the requirements towards information accessibility and system performance best. Figure 1 shows a high level view on the architecture. The mobile end devices on the left side host several local services like speech recognition and text to speech which can potentially be accessed from every running application.

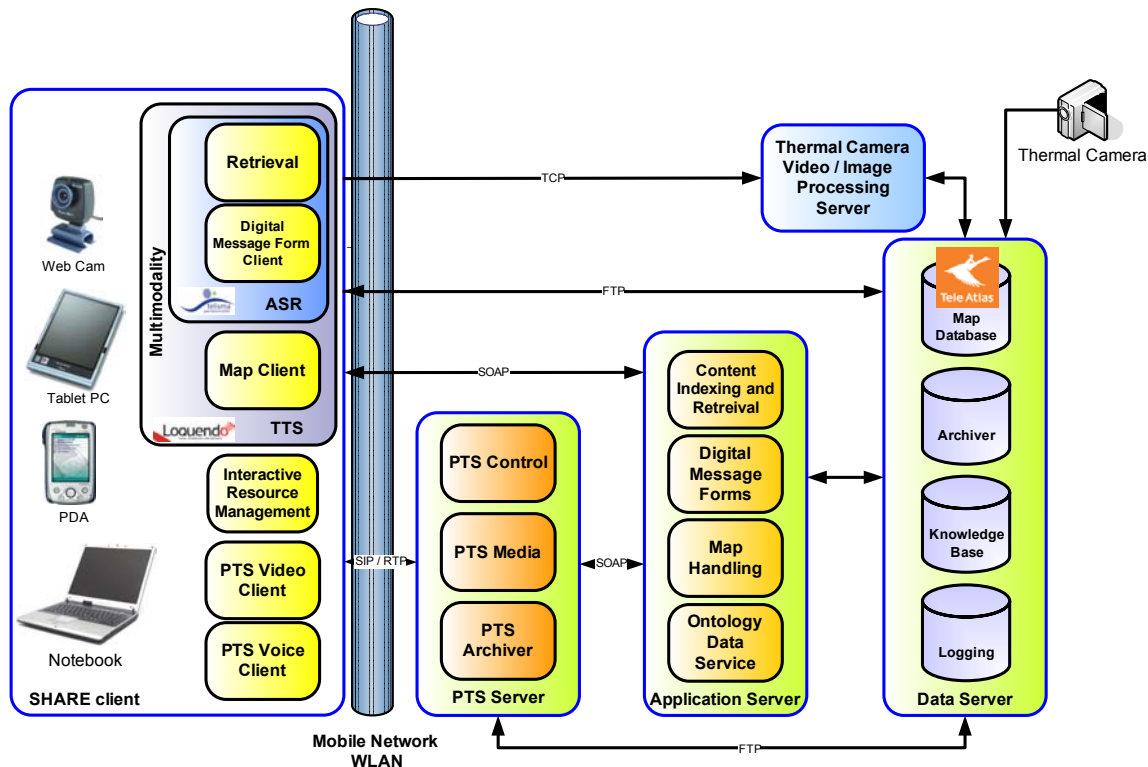


Figure 1 SHARE System Architecture

The SHARE system combines information management applications like MAP3D and IRM next to communication

applications like DMF and PTS. Those applications can directly be accessed through the graphical user interface (GUI) on the mobile end devices. Knowledge about the operation and multimedia data which is generated by the applications is processed, formatted and stored at the SHARE server backend (Data Server). In return the server backend offers a service platform (Application Server) which enables all clients of the SHARE system to retrieve the stored information and get decision support. The third element of the SHARE server backend is the PTS server which takes care of the distribution of communication streams between SHARE users.

All information applications are highly interdependent. Changes which are performed in one application often lead to necessary adaptations in the others. The interdependencies are often very complex and will be explained in detail for the MAP3D – IRM example in section “Bridging MAP3D and IRM services via knowledge management”. Since the SHARE system is designed for collaborative work the usage of the different applications (i.e. the creation of new sections in the operation area with the MAP application) also initiates a process to ensure a synchronized state at every connected client. To achieve this goal an event message system based on the Java Messaging Service (JMS) was established on server side. All clients subscribe to message queues which are related to the applications they are offering. In case of update events the messages are enqueued in the appropriate queues and distributed to all subscribers.

During an Evaluation phase in September 2006 at the fire department Dortmund, Germany, the SHARE system proved to meet the requirements of the fire fighters towards efficiency. In this phase a first approach was made to integrate the new technology into the infrastructure of the end user. The Fire Department of Dortmund currently begins to equip command cars with notebooks which are the basis for an application of the SHARE system. Also the system enforces the efforts for applying information and communication technology to crisis management. PDAs represent a subsequent step of system integration. In most fire brigades these devices are not available nowadays. Therefore SHARE builds concepts and highlights the open potentials in this area. In the last phase of the project we will focus on a tighter coupling of the supported applications to enhance decision support and improve the robustness of the collaborative workflow.

MAP APPLICATION: MAP3D

The map application plays a crucial role for the SHARE system since it provides the user with an accurate and enhanced representation of the current situation and the operation environment. Maps are also already used in the classical rescue workflow, in first line to give the officer in charge an overview of the location of the brigades at the operational zone. While the classical approach uses cartographic prints with pinned symbols (Fig. 2a) or independent online mapping systems to visualize a location or route, the SHARE system integrates the mapping component providing appropriate functions and data to be understood and processed by the specific user (Fig. 2b).

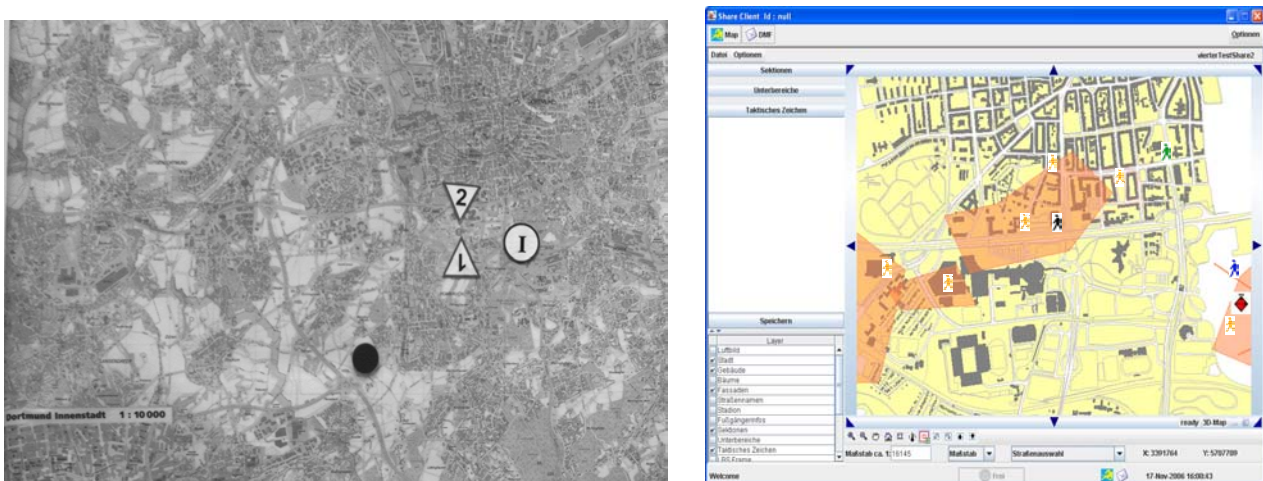


Figure 2: a) analog map currently used by fire brigade in Dortmund. Sections are pinned with numbers. b) MAP3D application with street information, sections and resources

The conception and realization of map components for the efficient support of rescue operations require special considerations due to its use in critical situations: insecure networks, continuous changes of the situation context,

fast decision making, use by non specialist on geographical information systems (GIS). The presentation of situational data has to be manageable, comprehensive and reliable, avoiding overburdening the user with needless information. Further, the system should be provided with “intelligent” features to react on context changes.

Application overview

To satisfy these requirements MAP3D (Hernandez Ernst and Ostrovskii, 2007) has been conceived and developed for SHARE as a three-tier server-client application including functionalities to support the efficient information, communication and decision support during the operation.

The basis tier comprises the spatial and operational data. The spatial data is based on the Tele Atlas 2D-3D digital map which offers the complete 2D information about roads, buildings and points of interests. For the SHARE project this data was enhanced with information about locations of trees, street lamps, claddings and building footprints as well as the height of buildings and trees as relation attributes. 3D landmarks of important buildings are also available. The operational data contains all information produced during an operation: the operation identifier and the geographical boundaries, all annotations made by operation leaders as well as the position tracks of the involved human-resources. The data is managed using the spatial component of a relational database (Oracle 10g), which allows to perform spatial operations, like filtering, searching for “nearest” objects, and provides secure management and fast transaction mechanisms. Using the spatial functionalities the relevant information for SHARE was extracted from the raw data to build an easy and fast to access 2D spatial model, from which a 3D data model can be constructed by the client. Further some additional raster data like building plans and orthophotos as aerial view were included as data sources.

The second tier includes the application services and provides a standardized and system independent access to the SHARE information. The service layer provides the interaction infrastructure between all SHARE applications among each other and with the up-to-date data. Spatial information can be accessed by standard protocols through a map and feature server (GeoServer¹) with interoperable services, namely Web Map Services (WMS) and Web Feature Services (WFS) conforming to OGC². All client requests to spatial services are based on standardized protocols. The input and change of spatial data uses transactional feature services, while the developed Location Based Services are built up on filtering and styling definitions specified by OGC and ISO/TC 211. As consequence, MAP3D is an open and portable application, which can be used in any environment with standardized interfaces.

The third tier identified the client applications. To support different output devices a light application for PDA’s was developed, principally to give the brigade resource on-site an orientation of the situation. The application accesses completely rendered maps provided by the map server, containing all relevant spatial and operational information. The user can ask the server for further information about streets and annotations by clicking on the map and can interact with the map using standard navigation components (zooming, panning, etc.). The client functionalities for the PDA applications are reduced to navigating through the map sent by the server and getting feature information from the server. A second application for notebooks or tablet PCs was developed for the officer in charge and his staff. The application combines vector and raster data accessed via the map server, providing a highly interactive interface to the user. The application is customized depending on the role of the user, providing different menu options and functionalities. Due to the fact, that the main logic of both applications (the PDA and the notebook) is situated on server side; there is no risk of incompatibility. The notebook version is merely more advanced in the interaction possibilities and makes also use of analysis services.

Providing information

When a user starts the application, MAP3D visualizes the area of the current operation which is provided by the *Project Provider Service*. MAP3D supports better orientation on the context area by showing synchronized 2D and 3D views of the location. The 3D view uses information about buildings and trees height to render a photorealistic image of the same location that can be seen on the 2D map. 3D VRML³ objects for trees, street lamps and landmarks are also loaded into the scene and the building facades are texturized with the real pictures improving the recognition effect. The 2D and 3D view can be maximized and minimized according to the user task (Fig. 3 and Fig.

¹ Open Source OGC compliant Map and Feature Server, <http://www.geoserver.org>

² Open Geospatial Consortium, <http://www.opengeospatial.org>

³ Virtual Reality Modelling Language, Specification for 3D

4). The 3D view is not just important for orientation, but also to give details, which can not be seen in a 2D perspective. The building height, the existence of trees, balconies and outbuildings can answer questions like if the passing of fire cars with ladder of certain lengths can be interfered, if there is enough place on the roof for helicopter landing, etc.



Figure 3: 2D and 3D view of landmark (stadium)

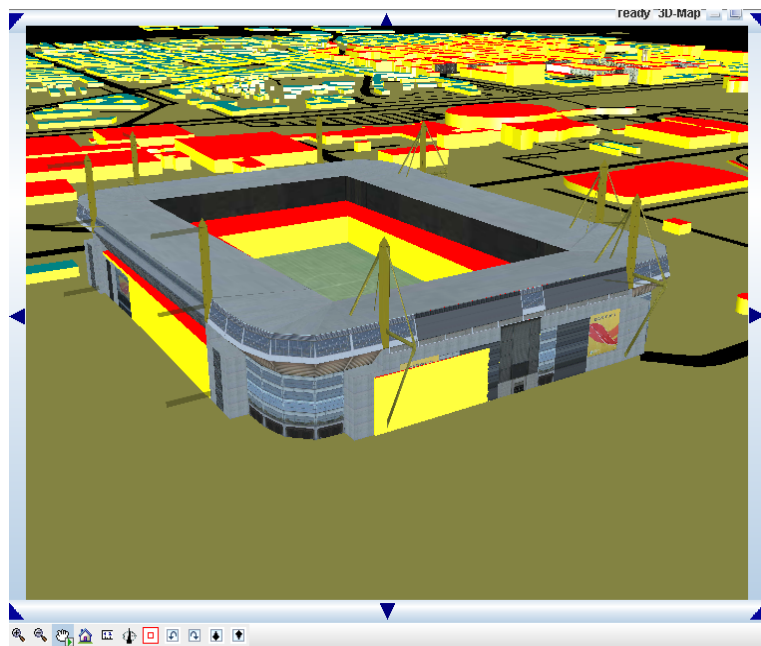


Figure 4: enlarged 3D view with stadium

More than giving context orientation, MAP3D informs the user about the current operational situation. All annotations done (the position of the rescue operators, classified by their roles, pedestrian information) are presented

up-to-date using the spatial services and the Java Messaging Service (JMS) which announces to all applications that actualized information can be reloaded. This service is activated when new annotations (these are sections, subsections and point's of interest marked by the use of tactical symbols) were created or edited and submitted to the server. Annotations can be entered or edited by A-, B- and C-level leaders, depending on their responsibility. The system doesn't constrict the types of annotations, which are allowed for each user role, since the responsibility level for a role can change according to a specific situation. For a better comprehension by all users the annotations are also rendered on the 3D view as transparent surfaces and 3D icons (Fig. 5), allowing the user to "walk" around the section or to incline the perspective to better understand which buildings are contained in the danger zone.

Interacting with the map the user can access specific information like street names and comments given to the annotations. The MAP3D application supports the multi-modal SHARE interface. When an object (street or annotation) is selected, a tooltip with the desired information is popped up and the text is read out by TTS (text-to-speech synthesis). The user can switch on/off information by deactivating the legend entry. For each user group the legend can be pre-configured to provide just the relevant data layers. This status can individually be changed and re-established

Providing Communication

The communication is supported by the exchange of operational information via map. One form of communication is provided by the annotation functionality. Operation leaders can draw regions as polygons or lines on the map which are assigned to a certain brigade group. These regions are called sections and can have subsections for a detailed assignation of positions. Further tactical symbols used by the brigades in their analogous workflow are categorized and can be dragged into a map position. The leader can give names and comments to the created annotations. Once the leader submits the changes to the server all the applications receive a signal to update their data. So each user is informed if a section has been assigned to him. The second communication mechanism makes use of GPS sensors. The user position is sent to the server in certain time intervals. The *Resource Service* stores and interprets the data and renders a map with the firefighters positions classified according to their role using different colors. This layer can be switched on and of by the user and always contains the current information of the operation field.

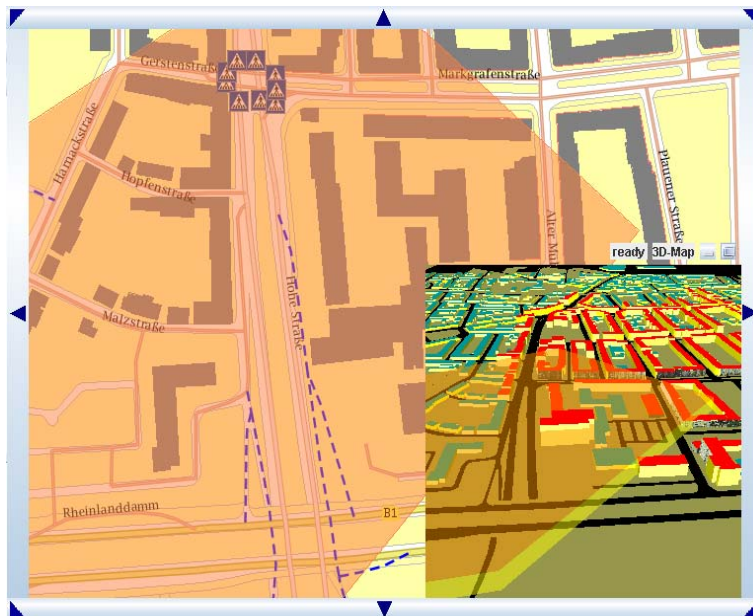


Figure 5 Visualization of section annotation in 2D and 3D as transparent surface

Providing Decision Support

The processed cartographic representation of spatial information, often called geo-visualization, aims at supporting 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 for decision support. MAP3D is connected to

the Ontology Data Service (ODS), where the operational data relevant for all applications is stored. Each time a spatial feature is changed, e.g., by creating an annotation, the ODS is notified and receives a reference to the feature for the SHARE Ontology. The ontology collects all the references to the spatial data and can be used to get an answer on complex questions like “show me all landing places within 500m from my position?”. The ODS allows to decode the textual query and requests the spatial services to filter out buildings having the requested characteristics and that are in a radius of a specific coordinate, which can be obtained from current position of a certain operator. The MAP3D client receives a highlighted view of the corresponding buildings.

One important aspect for decision support is the use of operation data for post-analysis, to learn about the chronological development of the situation and to discover issues that may have been overseen. For such an analysis time plays an important role, how was the development of the danger and the exertion of the rescue. The 3D map can help to visualize temporal information if the dimension used to represent the height of objects can be interpreted as a temporal scale. That means the 4th dimension (time) would fall on the same position as the Z or height dimension. Both interpretations could be combined on a same scene. A distance metric can be used for the height of existing objects like buildings or trees, a temporal metric can provide virtual objects, like emergency sections or walking paths, with a simulated height or bottom reference point. By doing this, one can compare temporal differences between the virtual objects, for instance which is been created before (this object may have a lower height or position on the space than a later created).

Both 2D and 3D maps can provide information to support decision making processes. For commanders maps and plans represent one of the most important foundations to draw conclusions from the conditions of an incident. The usage highly depends on different levels of command: While operational levels do not have to decide for wide-area measures and therefore are searching for very detailed information of affected objects, tactical and strategical levels need more general, but very clear information often without having a direct view to the fire site. Thus Figure 3 includes the 2D view to a fire brigade plan which is useful for the operational commander, Figure 4 shows a 3D object from which tactical decisions like the selection of the adequate firefighting vehicles and devices can be derived.

INTERACTIVE RESOURCE MANAGEMENT SERVICE: IRM

The visual representations offered by the map service contain different links to resources, e.g. personnel. The most important aspects are:

- The usage of the map application highly depends on the functions officers overtake in an operation. Therefore the SHARE system has to provide adequate access to 2D and 3D functionality.
- The annotation of maps represents the visualization of information incurring during an operation. Special requirements in the domain of crisis management result from the dynamic application and management of resources. In the formalised language of this domain these resources are also represented by symbolic descriptions.

The management tasks related to resources are very critical to the efficiency of an operation. The commanding officers base their decisions on the availability of resources. Their hierarchical structure is often visualized by an assembly of magnetic symbols. In addition, paper sheets provide information about the important parameters. Even within one organization these are not always standardized. Such sheets also build the bridge to map applications in operation control: Exemplary focusing on the German directive “FwDV 100” (Plattner, 2005) the geographical fire site is structured by a) available resources, b) spatial conditions and c) regulations. These three aspects must correspond to each other, thus the hierarchy of the command must be congruent to the spatial decomposition of the fire site. Every geographical section needs by regulation a responsible commander. As maps are also used in paper format the problem of inconsistencies is directly implied. The information about the resources is communicated at the fire site via the existing communication channels, radio speech communication and paper-based message exchange in command staffs. The command structure is managed by the top level operation control which depends on clear and adequate status messages from operating units. Both spatial and organizational problems have to be dealt with: while maps are used for a decomposition of a fire site into sections and sub-sections, using tactical symbols to identify objects and resources, hierarchical overviews are used to have a clear view on assumption relationships, responsibilities and communication channels.

In the field of fire brigades, rescue service and emergency aid resources always operate as a combination of human resources and material. Human beings can be characterized by their qualification while material subsumes equipment and vehicles. Vehicles are specialized concerning their operative equipment. Additional elements for

operation planning are pre-defined formations consisting of personnel and vehicles. They are defined to be responsible for special tasks or a specific area. These non-operative resources can be deployed to an operation by building dynamic formations, announcing commanders, assigning assistants and staff organizations and integrating them into the command and communication structure. The management of this structure which underlies very dynamic changes is a foundation for the documentation of an operation and thus is an important instrument concerning law and regulations. Therefore it is important to support responsible commanders by adequate tools. These have to provide a clear impression of available resources, characteristics of these resources, related tasks and additional operational parameters.

The Interactive Resource Management (IRM) (Pottebaum, Konstantopoulos, Koch, Paliouras, 2007) for more details) must be divided into its client and server parts. The client-side application provides functionality to view resource information, manage resources at the fire site and supervise the connection between operation control centres in the backend and the operation scene. It presents these methods as different views to resource information. In addition, the view is dependent on the role an officer overtakes in an operation. An operation unit leader has different requirements for information support than a strategic commander on top of the command hierarchy. “View Structure” provides information about subsumption relations and information like radio names, calculated manpower figures, names and more specific data. “Manage Subordinated Units” already implies that an officer only manages the part of the command structure he is responsible for. Manage functions include deploying, moving between formations and removing resources. More general functions are packaged to “Supervise Resources”. These mainly concern activities for sending resources from the non-operative status at their home bases to the fire site. In contrast to that the “Manage” tasks address resources by using operative information. The graphical user interface of the IRM application is focused on the command structure and utilises the same tactical symbols like the map application. Through this visualization operative and non-operative data is accessed (see Figure 6).

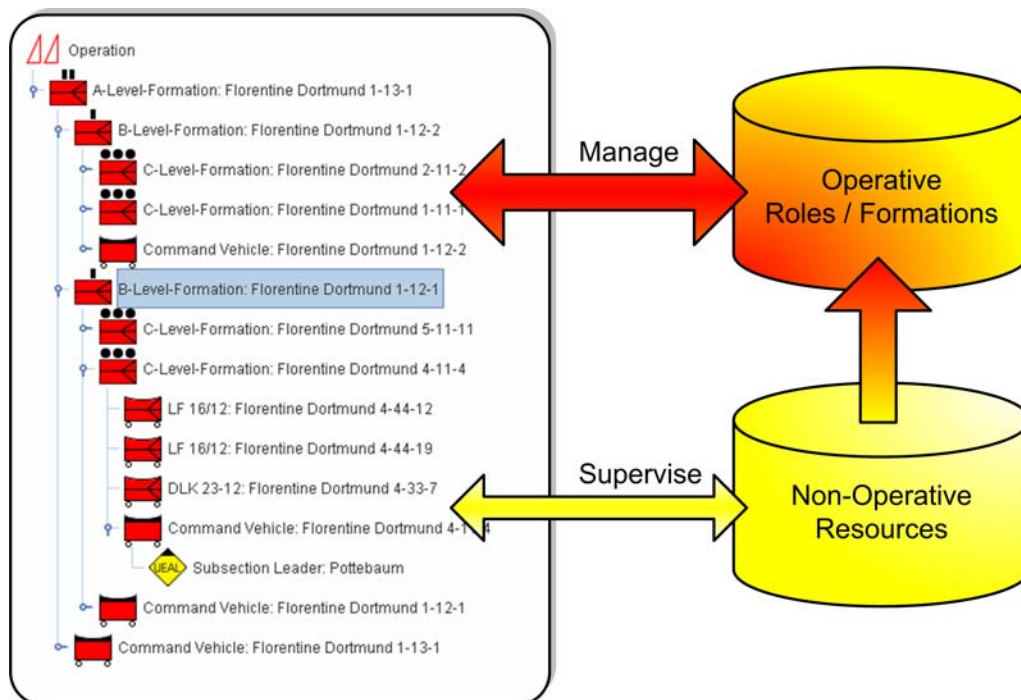


Figure 6 User access to resource information

The intelligence of the IRM is highly based on consistency checks on its server-side. The Ontology Data Service which builds the framework for the IRM methods (Konstantopoulos, Paliouras, Chatzinotas, 2006) utilizes Description Logics to model the concepts, relations and restrictions in the domain of fire and rescue operations.

Therefore the domain is modelled with OWL-DL⁴. This model is populated in an operation with instances for formations, roles and other dynamic concepts. Every action performed on the ontology is passed to a reasoner checking the data for inconsistencies. These can build the basis for extended exception messages presented to the user.

BRIDGING MAP3D AND IRM SERVICES VIA KNOWLEDGE MANAGEMENT

Bridging geo-spatial information services and resource management applications for rescue operations using ontology-based knowledge management helps reducing the complexity of the management task for large-scale rescue operations. By providing two separate views on the operational situation, which are interconnected by the same knowledge base, the system enables the user to acquire important information efficiently and to make decisions on a reliable information basis.

With MAP3D and IRM the SHARE systems offers two separated visual representations of the operational situation to the users of fire brigades. MAP3D visualizes geographical information of the operation site and allows annotations, like section information, on the map belonging to the ongoing operation. IRM gives an interactive tree visualization of the resources deployed in the operation. Both representations are strongly related to the basic command hierarchy commonly used in large scale rescue operations. According to this command hierarchy the operation is organized by dividing the operation site into sections and sub-sections and assigning suitable resources to them. Sections/subsections are headed by fire fighting officers responsible for all personnel and equipment within a section/subsection. The overall operation is managed by the officer-in-charge together with his staff, called A-level services. In today's daily workflows, the A-level officers use paper maps, magnetic boards and tactical symbols to do planning of resources and to explore and structure the operation site. A certain fire fighting unit is represented by a tactical symbol which can be placed in a section of the map for instance. Today's working practices do not allow information sharing between people that are placed in different locations. Sharing of map information between the A-level and section leaders (B- level) is not possible that way. All changes in the resource distribution have to be communicated by radio between the command levels. Inconsistencies cannot be avoided using these working practices. In the case that many rescue organizations are working together on an operation site, the task of managing all resources and structuring the area becomes a very complex tasks which cannot be handled satisfactorily by simple analogue tools as used today.

SHARE allows information sharing and communication in flexible groups to optimize the workflow during large-scale rescue operations. Predefined knowledge about such rescue operations (defined by regulations or made by experience) is stored in the central ontology-based database of the system and made accessible via the ontology data service (ODS). As the operation evolves the ontology is extended. Both, MAP3D and IRM are using the ODS to store and retrieve information. The ODS itself is able to check incoming information for consistency and to release alarm events in case of inconsistencies. This information architecture is well suited to combine geospatial information visualization and hierarchically organized resource planning tools while maintaining full advantages of both applications. Detailed planning of resources with automatic consistency checks and visual structuring of the operation site is possible that way.

Starting at the described state-of-the-art a very challenging relation can be seen between map application and IRM. The most important overlapping is the building of sections and sub-sections. Every geographical focus area drawn in the map has to be followed by a correlating entry of resources. By this the responsibility for such an area is defined. Another matter of consistency is the use of tactical symbols. Using a symbol for a resource item in the map implies that the same resource must also be available via IRM. It can then be checked by the information about the resource and the symbol can be enriched by tactical annotations. In large-scale emergencies the task of handling the map and managing resources can be separated to different staff members. Thus the IRM can support the collaboration by eliminating former sources of mistakes. One further use case for the IRM support in the map application is the search for a specialized operator. The searching commanders utilize the map to locate him, using 3D features to clarify his current situation, e.g. concerning mobility. By getting additional information out of the IRM ontology the officer is identified as the person searched for.

The current prototype of the SHARE systems supports a weak interconnection between the MAP3D and IRM services. The next development step will introduce a strong coupling between these services and allow use cases as

⁴ Web Ontology Language, a language to specify an ontology. The suffix DL describes the opportunity to include Description Logics

described above. A detailed evaluation by the fire department in the next project phase will provide insight into the advantages of the approaches presented here.

CONCLUSIONS

We described the SHARE project and gave insight into the SHARE system as an integrated platform for communication and information services used to support emergency operation planning and management. Innovative concepts for group communication, information sharing and knowledge management are implemented in the SHARE prototype. As central parts of the system we presented the MAP3D service and the interactive resource management application. Both of them are essential to successful operation management and offer new advantages that outperform existing tools used by rescue organizations nowadays. The combination of geospatial information services and resource planning tools by using knowledge management was described as an important concept that aims at reducing the complexity of the management task for large and heterogeneous operations. A weak coupling of IRM and MAP3D is already implemented by the existing SHARE prototype which was evaluated by the fire department with great success. The next step of bridging the two applications by knowledge management in depth and of synchronizing the two visual representations will be done in the near future. An detailed evaluation of the final prototype by fire fighters will then follow and will prove the quality of our concepts.

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