FACILITY MANAGEMENT DATA IN DISASTER MANAGEMENT

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ABSTRACT: Nowadays large real estates and infrastructural installations are managed using Computer Aided Facilities Management-systems (CAFM-systems). These systems are based on the graphical and alphanumerical base data of the building, as well as real-time data from master control systems and security installations. Even though a substantial number of rules and regulations exist concerning how the information is to be gathered and administered, there are still no standardised international norms in that area. Further, there are no provider-specific data and database structures on how to deal with the large amount of data, since the market is still far from consolidation and no single system has a market-dominating position. This is not a downfall in the daily routine of a facility manager, since most systems integrate all processes of the facilities management, but the incoherent data can cause problems when exchanging them with other applications or during benchmarking.

Severe problems arise with the lack of standards in extraordinary situations when numerous im-portant decisions with major consequences have to be taken within a short period of time. In cases of fires, floods or terrorist attacks the base data of the buildings need to be readily available in an adequate format. Further these data should be constantly updated and integrated with real-time data from the Disaster Management System (DMS). The main challenges in this situation are locating and tracking rescue teams, the local information management and the communication between the on-site staff and the command centre. The Institute for Building Informatics at TU Graz in coopera-tion with the security industry is currently researching and developing a CAFM-based DMS (CADMS). In the following the individual aspects and technical problems are outlined and first re-sults are presented.

KEYWORDS: facility management data, indoor positioning, sensors, system integration.

1 INTRODUCTION

1.1 *Necessary information during extraordinary situations*

The necessary information during extraordinary situations differs greatly from those needed for the normal management of buildings and installations. Regular CAFM-Data focuses primarily on the efficient and cost-effective management of buildings and only in special areas like energy consumption real-time data is gathered. In emergency situations on the other hand, numerous important decisions have to be taken on the spot which are influenced greatly by the current circumstances. Further, the information has to be made available to people who generally are not familiar with the building in question (such as fire brigades, police force, ambulance crews) and have no or very limited knowledge of using a CAFM-system. The existing CAD or CAFM-data of public buildings should be available in a format guided by norms, like it is already the case for emergency exit plans. Existing CAFM-systems should further be extended to allow for the integration of sensor data (from smoke detectors, location data of emergency crews) and for processing and displaying those data in real-time. Operating the system has to be very easy so that the squad leaders and the emergency crews on-site can be trained within 10 minutes, and the efficient and safe functioning of the system is guaranteed.

1.2 *Unification of CAFM-data*

At this moment in time the format in which Computer Aided Facilities Management (CAFM) data exists has only been standardised to a limited extent. This is due to the fact that the discipline of CAFM is a rather new one and there are still a number of areas that have not been covered yet. Furthermore, the market for CAFM software currently is extremely diverse with a large number of mainly small to medium-sized providers which all offer the individual solutions to the problems at hand. This is to say that no single CAFM software supplier has yet had the strength and the market share to ‘enforce’ their own format for CAFM data on the rest of the market.

Even though, the data collected is already governed by a number of guidelines and norms. The principle power behind the guidelines for CAFM is the German Facility Management Association e.V. (GEFMA). The GEFMA is at the forefront of bringing structure into the market and standardising the discipline of CAFM as a whole. Generally speaking the GEFMA has issued two main guidelines concerning the structure of CAFM data and systems. Firstly, the GEFMA 430 which deals with the structure and the categories into which the data can be placed. This guideline uses a number of existing DIN norms as its basis so it can be said that at least the data structures and categories have been more or less standardised. Secondly, the GEFMA 410 governs all the interfaces between a CAFM system and other software with which it might come into contact with.

Overall it can be said that the format and structure of CAFM data has only been standardised to a limited amount especially since the guidelines by the GEFMA are not binding. Therefore, it is still early days and much more effort is needed to completely standardise the data formats in use within CAFM systems. The main part of the research lies with the extension of existing models for buildings (such as IFC) to incorporate the needs of CAFM. The aspect of processing and making the data available for emergency situation has not yet been focused on.

1.3 *Goals of the CADMS-project*

In the following, the research project Computer Aided Disaster Management System (CADMS) carried out by the Institute for Building Informatics at Graz University of Technology will be outlined and initial results will be presented. The main focuses are on the integration of CAFM data and positioning data from multi-sensor systems as well as on the development of an efficient user interface for the command system and the mobile devices used in emergency situations.

2 GRAPHICAL AND ALPHANUMERICAL CAFM BASE DATA

State-of-the-art CAFM-systems into which a CADMS can be integrated use two different types of base data to describe and evaluate the buildings. By base data we mean the underlying data about the real-estate that is vital to the processes within the building and is therefore absolutely necessary for an efficient CAFM-system to function (Figure 1). The first type of data is the graphical data and the second one is the alphanumerical data. Graphical data is concerned with the visual representation of the real-estate and its contents. This type of data is particularly important for the CADMS as the process of locating emergency crews within the building is to be based on the existing floor plans of the real-estate in question.

The second type of base data utilised by CAFM-systems is the alphanumerical data. Alphanumerical data mainly describes the ‘contents’ of a real-estate and is therefore of great importance for the CADMS. The on-site emergency crews need to know for example which hazardous substances are kept on the site and where those are located. Further it is vital to know how many people are in the entire building and which offices they utilise so that they can be rescued if needs be. All these information can instantly be extracted from the CAFM-system and then superimposed on the plans used by the emergency crews.

The types and formats of graphical and alphanumerical base data utilised in CAFM-system is governed by GEFMA guidelines (GEFMA 430) though, actual norms have not yet been published. The GEFMA 430 guideline itself does utilise various other existing norms and guidelines when it comes to classifying and structuring the data. Further, all interfaces to other software and systems that come in contact with these base data, are governed by the GEFMA 410 guideline.

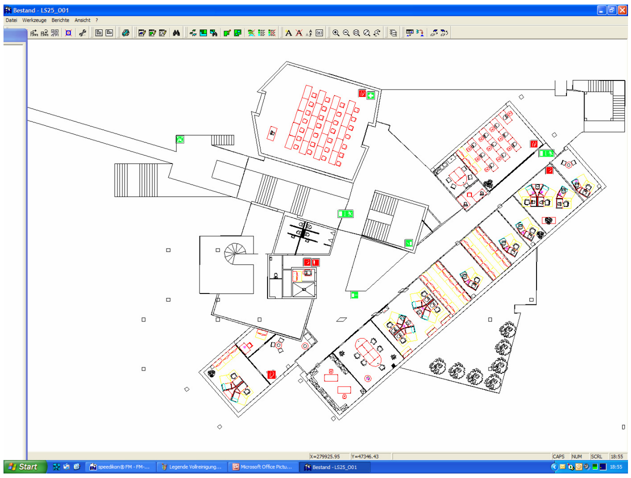

Figure 1. CAFM Representation of Graphical and Alphanumerical Data (Source: speedikon®FM).

Due to the wide distribution of GPS for cars, ships and planes, international standards for the format of the maps and their displaying have been developed (such as Flash or SVG (Scalable Vector Graphics)). For the description of infrastructure and buildings in 2D or 3D producer-defined formats (dwg, dgn) or open source model definitions (IFC) are common in engineering and architecture, though they have not yet been adopted apart from the use as data exchange formats.

Today it is not necessary to discuss whether or not a virtual 3D building model should be used. Firstly the necessary data is simply not available and secondly in the event of emergency situations information outside the current field of vision is needed. In those situations 2D floor plans provide the best possible orientation. They can easily be adapted to the constantly changing circumstances and needs and may be extended by superimposing additional data.

Since an increasing number of CAFM-systems make the graphical building data available via the Web using standards such as SVG or at least similar XML-formats, those formats are to become generally accepted in the very near future. In this CADMS project the CAFM-system speedikon®FM is used as the underlying base system. The software supports the presentation of floor plans on the Web using the XML-technology. Using an XML-format for the representation has a number of significant advantages over other potential methods. Firstly, an XML-document can easily be edited. Further the data contained in an XML-document can be highly compressed using standard tools such as ZIP. This is very important since the smaller the data-volumes are the easier and faster it is to transfer them between mobile devices. In addition, with the XML-format any sensor data can easily be integrated and displayed in form of symbols such as directional arrows and lines of sight to mention two. Finally, several tools for an efficient graphical user interface are already available.

Furthermore, the graphical representation is actively connected to a database. Thereby room and object attributes can be displayed as coloured areas, highlighted objects or text boxes. The user interface can easily be adapted to the users' requirements and also allows for defining and editing data via the web-application. Zoom and pan functions, displaying and hiding layers, as well as linking sounds, images, videos and documents to the objects are possible. If the system is accessible to the in-house fire brigade for example, the data from the building control system and the access control devices can be displayed in real-time. Though, this is only the case as long as the sensor components and communications within the building are still intact.

3 INTEGRATION OF REALTIME DATA AT THE EXAMPLE OF INDOOR POSITIONING

A number of different technologies are available for positioning. Only methods that calculate the position relative to a known environment can be used for indoor positioning. This is due to the technical limitations of systems that use either an absolute position (GNSS) or one relative to the location of external transmitters (GSM, UMTS). Generally, one can distinguish between two different solutions.

3.1 *Inertial tracking*

The exact location of an individual is traced from a point of origin using a 3-axis gyroscope and 3 accelerometers so that the position can be displayed in a geometric reference model. This model may be a map, a 3D building model or a 2 1/2D model made up of superimposed floor plans. For the positioning the angles of all 3 axes are constantly measured and from the acceleration the covered distance is calculated using double integration. The precision of the results depends on a number of factors, especially measurement errors by the sensors, the mechanical inaccuracy of the setup of the sensors and the accuracy of the measurements themselves (Barbour et al. 1992). Further sources of errors are temperature changes and noise. Most of these errors are inconsistent but occur stochastically. Own experiments proved that the goniometry of small, low-cost gyroscopes is only precise enough to allow for the orientation inside a room for a very short period of time under extreme conditions. Therefore, tracking the covered distance fails due to the drift within the inertial system. To overcome these difficulties, our test system which could be used in terms of size and weight uses a novel inertial tracking algorithm based on the movement recognition of the individual. The accuracy of the measurements can be improved by using a Kalman-Filter and periodically repositioning the moving system using known fix-points.

3.2 *Additional sensor systems*

The moving individual continuously positions itself in relation to a point of origin using different sensors. The point of origin is repositioned periodically through measurements and user interaction relative to known points and walls within the building (Retscher & Thienelt, 2004).

The choice of the most adequate solution depends on the circumstances under which the system will be applied. It has to be assumed that in extraordinary situations the local infrastructure does not exist anymore and there is no time to set up a new or additional infrastructure. Therefore both solutions could be used for a CADMS. Though, the second solution has some uncertainties as well. Up-to-date floor plans are required, in order to perform constant adjustments of the origin (new fixed points) and calculations of the positions based on the measurements. Problems could arise as these floor plans may have become obsolete because of destructions.

Further means of measurement, such as the laser distance measurements, may be influenced by thick smoke, water from sprinklers or new obstacles (debris for example). Moreover, for the positioning it is necessary that the path can be tracked without interruptions, as the overall position within a building cannot only be determined from the position within a room. The first solution allows less user interaction than the second but relies on periodical repositioning. The need for repositioning is caused by the relatively poor performance of the gyroscopes (heading drift). One possible solution for repositioning may be the use of magnetometers which measure the terrestrial magnetic field.

All other errors could be overcome by using very short periods of time for the double integration. The shortest possible period of time is one footstep. Therefore the inertial sensor of our test system is mounted on the users' shoe. The results of a walk along the y-axis (Distance Y) are depicted in Figure 2. By summing up the lengths of all the individual footsteps, the whole length of approximately 10 meters could be obtained. The results below show that an inertial tracking system can be used for indoor positioning. However the problem concerning the repositioning still has to be solved.

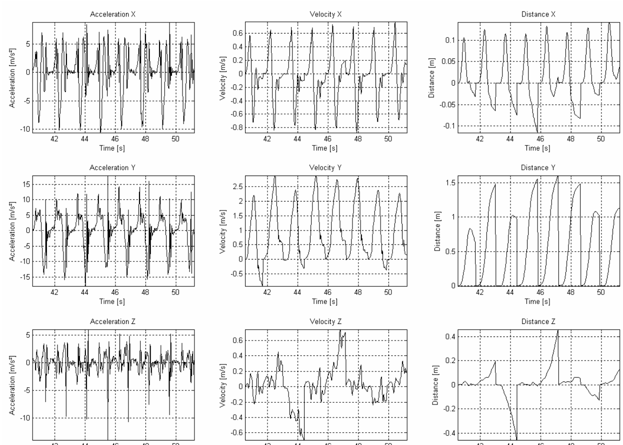

Figure 2. Inertial sensor mounted on the user's shoe (10 meters / 8 footsteps along a straight line) - results: a_x, a_y, a_z, v_x, v_y, v_z, d_x, d_y, d_z.

4 USER INTERACTION

The usability of a CADMS in a real-life scenario such as a fire will ultimately be determined by its accuracy and user friendliness. The latter mainly depends on the user interaction. The required information has to be available and displayed in real-time. The system to be created has to ensure that there is a significant advantage in comparison to the orientation with plans and maps used today. Even though the development of the graphical interface is still at its early stages several major ideas can already be outlined.

The user interface and users' interaction with a CADMS have to be optimised for the different users of the system. This is particularly important as for example the squad leader in the control room will most certainly require different information and possibilities for interventions than the on-site rescue team.

The main activity at the command centre is controlling, commanding and guiding the rescue teams. The most important information therefore is a 'bird's eye' view over all the events happening on-site. Therefore all the graphical information is displayed using a layer technique. The basic floor plan will be displayed on one layer and is used as a kind of frame for all other information. Further layers containing additional information can then be superimposed on top of the base layer. These superimposed layers could contain crucial information such as the locations of technical installations, hazardous materials and furniture within rooms. In addition to already existing data from the data base can be displayed using shadings, symbols and highlighted texts. Furthermore vital information from the document management system can be visualised. Since the emergency crews and the control room will need a lot of information all the layers mentioned above can be displayed at the same time. This guarantees that the largest possible amount of information can be visualised and therefore be taken into account by the staff in charge. In order to allow for effective communications and of course the safety of the on-site staff the current positions of the rescue teams are constantly updated. Several positions of teams can be displayed simultaneously. The user interface and the main menus correspond to the client-server version of the CAFM-system speedikon®FM.

The user interface of the mobile devices will have to adhere to certain boundary conditions. First of all the interaction can only be in form of voice entry. It has to be assumed that the emergency crews will wear gloves and of course need their hands for the rescue-related tasks. Therefore the user-interaction will have to take the form of speech recognition for the rescue crews to use the system.

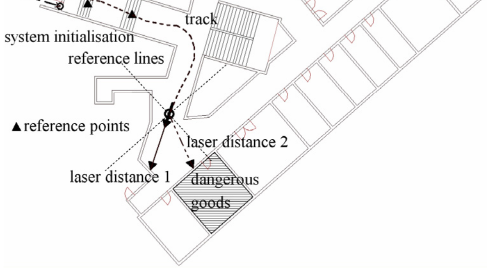

Figure 3. Track and position representation of an emergency crew.

In order to avoid an 'information overload' meaning too much information to handle at any given moment in time, only data crucial for the current situation and tasks on hand is to be displayed (Figure 3). Furthermore all vital commands such as zoom, pan, displaying and hiding layers as well as other standard functions need to be triggered using simple verbal commands.

Displaying the sensor information in real-time is one of the major challenges. In addition to the inertial data the environment will be scanned using a laser rage metre and the results of the measurements will be displayed on the floor plan. The measurement results of the current position as well as the reference points will be represented in the floor plan using colours and symbols.

Finally any important observations made by the rescue teams also have to be displayed in the floor plan almost instantly. In order to allow for this, a voice-controlled redlining function will be implemented.

In case of an extraordinary situation, the emergency crews using the CADMS will have to make numerous other very important decisions. Therefore the user-interaction by voice control has to be as simple as possible in order not to distract the staff from their main tasks. It has to be ensured that commands which are very likely to be used in the situation have to be on a high level in the control hierarchy. A two-layer command structure for controlling the GUI could be a possibility with commands like "display – zoom in" and "display / next exit" for example.

In terms of the hardware, the current aim is to use a so called Head Mounted Display (HMD) for displaying the graphical user interface. In addition the HMD is to be equipped with a microphone to allow for the voice control as well as all other crucial verbal communications. Again, a number of crucial factors arise and have to be taken account of.

To ensure the usability of the system it has to be created in such a way that it is like any other existing piece of equipment the emergency crews already have in use (Figure 4). In the end the CADMS is there to help and must not interfere with any of the tasks on hand.

Figure 4. Head Mounted Display in combination with a helmet [©Liteye Systems, Inc.].

The HMD has to be suitable to the extreme circumstances under which it will be used. Any malfunctions of the system or even complete failures can lead to potentially life-threatening situations for the on-site emergency crews. Another problem that ties in with the suitability is the microphone. It has to effectively filter all the background noises in order to minimise the possibility of system malfunctions and to ensure that the verbal commands can be recognised by the system.

5 SYSTEM ARCHITECTURE

In order to make a CADMS useful and attractive for emergency services, not only problems related how to display data, handle real-time positioning and provide user interaction adapted to extraordinary situations have to be solved. In fact, important issues with far reaching consequences for the whole system like choosing proper hardware devices, developing the overall system architecture and guaranteeing digital communication between the on-site staff and the control rooms have to be considered. Not only the user-friendliness and robustness of the system under extreme conditions have to be taken into account, but also budget constraints have to be kept in mind.

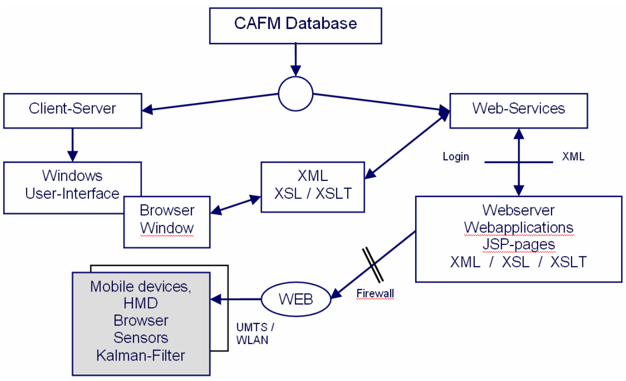

Figure 5. CADMS System Architecture.

The system architecture consisting of components placed in the control room on the one hand and mobile elements on-site on the other hand is displayed in

Figure 5. The CAFM-database constitutes the core of the system. It stores the floor plans and alphanumerical data of the CAFM-system that will be combined with positioning data to be generated. The file format of the database depends on the chosen CAFM-system. In the case of speedikon®FM the data is stored in an object based format in a database management system (Oracle or SQL-Server).

Two ways of making this information available for the user or the rescue worker in this special situation, respectively, could be theoretically conceivable. Either it can be presented by a conventional client-server application running on the same device as the CAFM-database management system, or the facility management data can be translated into the well known XML format and be transferred to the on-site staff by a wireless network connection.

The first approach is not practical for the following reasons: In the case of a client-server programme a fully-fledged and memory consuming CAFM-system has to be installed on the mobile devices, which may overburden the scarce resources of the computers on-site. Furthermore it is much more complicated to integrate dynamically generated positioning data into a proprietary CAFM-system only available in terms of executable files than into an open format like XML. Therefore we decided to focus on the latter approach, which implies the advantage that a lightweight web-based application can be run in the internet browser of the rescue workers' mobile devices offering only the functionality necessary for the staff deployed in emergencies. For this purpose speedikon®FM Webdesk is adopted for presenting graphical data in combination with sensor data from different sources.

To accomplish the task of converting data from the CAFM-database to the web-compatible XML format and of making this information utilizable in browser windows, a web server application is needed. This component has access to the database, handles incoming (local or remote) requests and forwards the demanded information to the browser running on the corresponding client.

An http-driven network completes the transfer of the XML files to the mobile devices. This kind of equipment must fulfil certain requirements to be adequately usable for rescue workers to not put their health at risk in emergencies. The mobile devices must be able to run at least a web browser application, while they should offer low power consumption and acceptable battery running time for long-lasting missions. Furthermore they must be robust and it has to be assured that the impact of the on-site staff's fast movements and abutting upon walls and other barriers do not cause a fatal computer crash.

The decision, which operating system should be installed on the mobile devices primarily depends on the chosen hardware devices and their capabilities, but it is unaffected by the operating system that the native client-server based CAFM-system relies on. It is the mobile devices' job to combine the received floor plans and the positioning information gathered from the sensor to a graphical output. For this reason they need proper interfaces to guarantee the ability to communicate with the sensor device mounted on the rescue worker's foot.

The system architecture depicted in

Figure 5 assumes a permanent web-connection between the on-site staff's computer equipment and the server(s) in the command centre. There are two possibilities where the central database can be stored heavily influencing the way of communication and collaboration between the equipment in the control room and on-site:

- The CAFM-database as the crucial component of the system is installed only at a safe location and, despite the system cache, the mobile devices receive all the necessary data to display status information and floor plans over the wireless network connection leading to a high transmission rate. This situation is schematically depicted in Figure 6b. Attenuation and more than ever deep fades causing the break of communication lead to a situation where it is not possible to display floor plans and the current location of the rescue worker on the local display any longer. However, the process of setting up the terminals is less complicated in this case because there is no need for a locally installed web server and the latest version of the graphical and alphanumerical data stored in the CAFM-database.
- It is also possible to install the complete system on the mobile devices, like it is shown in Figure 6a. As a re-

sult, the rescue worker has all the information he needs about the building stored on his computer and does not depend on a network connection that may possibly break down because of various reasons at least temporarily. This would be the safer way to ensure autonomous digital navigation for the individual rescue worker. Since the amount of information transmitted over the network is much lower with this kind of system architecture, the requirements concerning the maximum and the mean transmission rate of the wireless network are also easier to satisfy.

The installation of the mobile computers is more complex due to the fact that the complete system including CAFM, database and web server has to be set up and configured correctly. Regarding our prototype all the software is installed on the mobile tablet-PC.

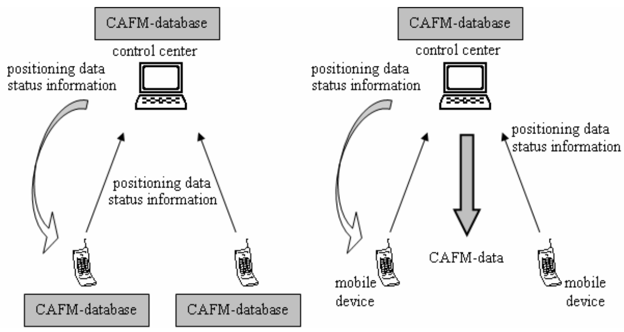

Figure 6. System architecture with autonomous mobile devices (a) and with remote access to the central database (b).

Provided that there is a functioning web-connection between the mobile devices and the control room the current position of the on-site staff is transferred back to the operation controllers to allow an effective organization of the whole deployment. Conversely, the local terminals receive the position coordinates of the other rescue workers enveloped in XML files.

The system is designed to work without technical infrastructure that was installed especially for the case of emergency, but it is constrained to fixed infrastructure like access points inside the building and base transceiver stations outside the building that may be existent and usable or not. As a consequence, the system must be flexible and adaptable to changing conditions. An on-site participant of the service may receive varying signal strength while moving through the real-estate and it may not always be possible to connect to the control room to gather information about the other rescue workers' locations. The system should implement some algorithms to interpolate the position of his colleagues for at least some seconds until the network connection can be rebuilt again ideally.

Facing low transmission rates and congested links it is recommendable to have some kind of internal Quality of Service strategy. The type of information transmitted by the network can be categorized into CAFM base data originating from the central database, position information, verbal communication among the rescue workers and the control centre and status information inducted by the on-site staff. This data can be handled in different formats and comprises information about impassable doors and walks, injured or enclosed persons and photographs taken of the building site with cameras mounted on the helmet. The transmission time of the network packets should correspond to their priority. Hence, positioning data should be transferred first to achieve approximately real-time service while pictures can await better transmission conditions. Following this argumentation the system discards positioning data that was not able to be transmitted and that became obsolete in the meantime after some seconds.

If the potential deployment locations are previously known, such as all public buildings in a city, the necessary alphanumerical and graphical data should be kept and updated on the servers in the command centres. If this is not the case, all the data is to be made available on-site and transferred by Bluetooth, USB stick or CD from a so called 'data hydrant' via a defined interface to the server and/or mobile devices. It has to be ensured that the provided information contains at least closed room polygons. Furthermore all existing alphanumerical data (such as data concerning the storage of dangerous substances) should be allocated to the rooms in such a way that an import of this data into the database is possible.

Initializing the indoor positioning system provides another challenge. Prior to usage, the horizontal and vertical angles of the gyroscope have to be adjusted to the local coordinate system of the building and to the orientation of the displayed geometry. The rotation of the floor plan against the real object has to be known and the gyroscope can be initialized by a bearing between two defined fixed points (such as markings on the floor and façade).

6 CONCLUSIONS

At this point in time the command and control of rescue teams in extraordinary situations in buildings or underground structures is not yet satisfactory. The basic technologies for an integrated command and communication system providing an indoor positioning are available but not yet combined to a system that works in practice. The development of a completely new system of this kind for civil use only would be very extensive, especially considering the amount of years needed for the development of the CAFM system components. It is therefore advisable to base the development on existing building information systems and to push the research into indoor positioning and into definitions of standards for the necessary data formats as well as for the interfaces simultaneously.

As a part of the CADMS-project the existing prototype for indoor positioning is currently further developed in cooperation with the industry. The fast developments within the market for mobile devices (such as HMD from the computer and video game industry) have to be considered and used beneficially where ever possible. The architecture of the whole system must fulfil the conditions of robustness and flexibility. A tradeoff between lightweight mobile devices and reliability of positioning service has to be made. The main goal still is the reduction of injuries and damage in case of extraordinary events.

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