Integration of Computer Aided Facility Management Data and Real-time Information in Disaster Management

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ABSTRACT: In case of disasters like fire, terror attacks or floods up-to-date information about the affected site as well as the positions and activities of deployed rescue teams should be available. For most major buildings situated in developed countries geometry data is available in digital form, at least as 2D-CAD drawings. Very often these drawings are already linked to the database of a CAFM-system. Tracking rescue teams within buildings or underground constructions and displaying their locations in real-time is a major problem. The objective is to develop an easy to use, safe tracking system which allows for the permanent real-time representation of the position of rescuers in buildings and underground structures on the basis of CAFM data. Different technologies of tracking people and objects in buildings are discussed and first results of a test with a multi-sensor tracker based on a gyroscope and laser distance measurement are presented. Special attention is given to a simple user interface for the mobile components. In future rescue organizations shall take advantage of an integrated system, which supports the management of disasters based on commonly used CAFM-data and data gained through sensors.

1 INTRODUCTION

In the future the tendency to even more densely populated cities and suburbs will continue and increase. Work, production and leisure activities are being brought together in large subsurface or roofed facilities connected to large underground traffic systems. Thereby the risk to the individuals rises within such environments through natural catastrophes, malfunctioning technologies, sabotage or even terror attacks. Large and complex underground structures complicate the coordination and deployment of rescue teams in case of a disaster. The same problem is encountered in shopping malls, stadiums and production facilities as well as hotel complexes, museums, etc.

Deployment teams usually gather their knowledge about vulnerable locations through inspections or onsite training exercises. Furthermore, more or less up-to-date building plans are at hand in case of emergency. Integrated command and control systems exist only for military purposes, but still reach their limits in urban areas and in underground facilities they don't work at all. This is due to the fact that the positioning systems in use work on the basis of GNSS (global navigation satellite system). Furthermore military systems are extremely expensive and require a complex communication infrastructure.

The increasing use of computer aided facility management (CAFM) systems within public administrations, real estate companies and large property owners significantly improved the situation concerning the availability of up to date information about heavily frequented buildings. Large cities such as Zurich are working on documenting all their buildings graphically and further managing them with a CAFM system. Graphic data formats are defined by various codes and the connection to facility management systems is state-of-the-art, however until today no standardization for the overall data management has been established. At present the use of sensors in connection with CAFM is limited to the integration of data obtained from building control systems. This information can be very helpful in emergency situations, especially to get information from fire alarm and access control systems.

Thanks to the efforts of large international organisations such as the IAI (International Alliance for Interoperability) it may be assumed that an accepted standard for the description and management of buildings and technical equipment will soon be put in place and be used at least as an interface description for the data exchange between different CAFM systems. Still this will not solve the problems with gathering real-time data especially from mobile applications.

As mentioned earlier, large parts of the sensitive infrastructure of a country as well as the major part of the modern living space can not be covered by GNSS-Signals, i.e. localizing people or moving objects within such facilities is still not possible. Trapped people can often not be rescued in time, especially in case of low visibility due to smoke, electrical power failure, etc. Over recent years a number of disasters with many victims showed how important real-time data about the equipment and the construction of buildings, as well as the current positions of rescue teams, residents and visitors would have been. By knowing the exact location of people and the place of the occurrence of damages within a building, the best escape routs and rescue plans could be calculated.

Intensive research into positioning systems for people and objects within buildings has been carried out within the last years. Generally speaking, the main efforts have been undertaken in two major directions: systems based on the existing infrastructure of the building, and those which use mobile sensor devices. The first kind is already in use e.g. in hospitals for identifying patients as well as tracking beds and medical equipment. Gartner et al. (2005) provide a good overview of the current technologies and extensive references concerning this topic. In case of an emergency only systems which do not relay on previously installed facilities can be used, since the underlying infrastructure may have been destroyed during the event.

In the following, the research project CADMS (Computer Aided Disaster Management System) 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 mobile devices used in emergency situations.

2 GRAPHICAL AND ALPHANUMERICAL BASE DATA

The basis of all command and information systems is the geometric base data in the form of maps or floor plans. Due to the wide distribution of GPS-systems for cars, ships and planes, international standards for the format of the maps and their displaying have been developed (e.g. 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 widespread 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, during 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 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 and standards such as SVG or at least similar XML-formats are to become generally accepted, in this CADMS project a CAFM system (speedikon®FM) is used as the basic system, which already supports the presentation of floor plans on the Web using the XML-technology for several years. The advantages can be summarised as follows:

- The XML format can easily be edited.
- The data can be highly compressed for the distribution using standard tools (ZIP).
- Sensor data in form of symbols (directional arrows, lines of sight, etc.) can easily be integrated and displayed.
- Several tools for an efficient graphical user interface are available.

Furthermore, the graphical representation is actively connected to a database. Thereby room and object attributes can be displayed as colored 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-client. 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 e.g. to the in-house fire brigade, the data from the building control system and the access control devices can be displayed in real-time – at least as long as the sensor components and communications are still functioning.

Figure 1. Prototype of a "gyro-laser-tracker" based on an HP Tablet PC with a gyroscope and laser range meter

3 INDOOR POSITIONING

For indoor positioning a number of different technologies are available. 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), only methods that calculate the position relative to a known environment can be used for indoor positioning. Generally three different solutions can be distinguished:

3.1 *Inertial Tracking*

The exact location of an object 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 about all 3 axes are constantly measured and from the acceleration the covered distance is integrated. 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 measurement itself (Barbour et al. 1992). Further non-negligible sources of errors are temperature changes and noise. Most of these errors are not uniform but occur stochastically. The accuracy of the measurements can be improved by using a Kalmann-Filter and a periodical repositioning of the moving system using known fix-points. Own experiments proved that the goniometry even of small gyroscopes is precise enough to allow for the orientation inside a room for a certain period under extreme conditions. However, tracking the covered distance fails due to the drift within the inertial system. Our test system and alternative systems which could be used in terms of size and weight have an inaccuracy of more than 100 m/h.

3.2 *Buildings with active sensors*

The building is equipped with transmitters or receivers that can interact with the sensors of the moving object (e.g. RFID, Active Badge, Bluetooth, etc.). The other possibility is to use the signals of systems that are already installed in the building, like WLAN (Niculescu & Nath, 2004) or LPS (Local Positioning System). Basically there are two ways for determining the position. Firstly, it can be done using triangulation where the angle to a transmitter is determined and the strength of the signal is used to calculate the distance. Secondly, the moving object can be positioned using points in the building for which the respective signal strength has been defined (so called 'Fingerprint Method', Kaemarungsi & Krishnamurthy, 2004). Due to multi-path propagation and heavy shadow fading, the accuracy can hardly be foreseen. Experiments mentioned by Gartner et al. (2005) showed that the accuracy may vary between 1 and 3 metres. Alternatively UWB (Ultra Wide Band) can be used since the bandwidth of above 1GHz avoids multi-path fading. Since for the calculation of the position the time of arrival of the signals is used, at least three transmitters have to be placed in the surrounding of the building making the implementation of such a system rather complex. Finally using image recognition by monitoring cameras have to be mentioned as a further method.

3.3 *Multi-Sensor Systems*

The moving object 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).

3.4 *System Evaluation*

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 only the third solution can be used for a CADMS. Naturally this solution has some uncertainties as well. In order to perform the constant adjustment of the origin (new fixed points) and the calculation of the position based on the measurements, up-to-date floor plans are required. Those floor plans may become obsolete by destruction, further the means of measurement, such as the laser distance measurements may be influenced by thick smoke, water from sprinklers or new obstacles (e.g. debris). 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.

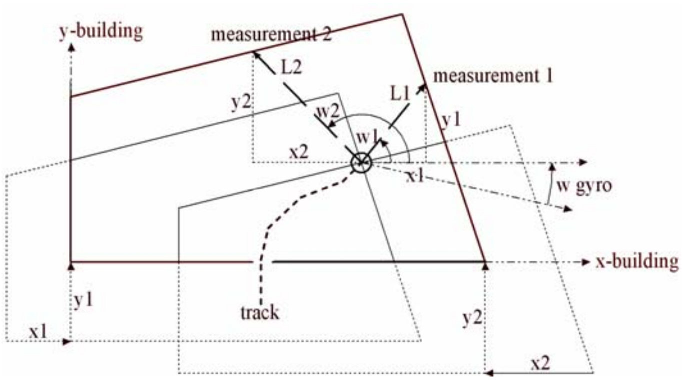

Figure 2. Plane projection of position calculation within a room

Especially in very large rooms, the selection of new reference points may be difficult since the inaccuracy of the measurements could e.g. complicate the automatic recognition of a new room in case of two doors being situated very close to each other. In this case the necessary user interaction has to be simple enough in order to be still effective with users being under pressure and with complicated circumstances.

To judge and estimate those uncertainties, our institute is carrying out experiments using a test facility (Fig. 1) with the following specifications:

- As an inertial system an X-Sense Motion Tracker MT9A is used. The accuracy of the gyroscope is 1 to 3 deg. The available measurement of the accelerations is not directly used to calculate the track but only to verify the absolute track length if the position calculated through laser distance measurements is not distinct within a room. Further, we are evaluating the possibility of using the vertical acceleration to determine the correct floor levels while moving along a staircase. Thereby a barometer would no longer be required since this is heavily influenced by fluctuations of temperature and pressure.
- The position within a room is determined by at least two bearings to non-parallel walls with a laser range meter.
- The current room polygon which has to be used is determined by tracking the path and the recognition of wall openings which the user went through. This recognition will be supported in the final system by the user.
- All the graphical data and database information can be uploaded onto the mobile device prior to the deployment and the sensor-data can be evaluated on the mobile device itself. This ensures a continuous tracking in the case of communication interrupts. The current prototype displaying the data on a portable screen will be replaced by a head mounted display (HMD, Eyebud 800).
- The user's interaction is currently carried out via a touch screen but will be replaced by voice recognition input.

The positioning within a room is calculated as intersection of the walls of two parallel displaced room polygons resulting on the measurements of the distances at any bearing to at least two non-parallel walls (Fig. 2). The attached gyroscope simultaneously provides the bearing to the origin. Currently the measurements are triggered manually but may well be continuous in the future. In order to prevent time-differences between the measurements, it is planned to equip the system with two laser range meters. The bearing and the corresponding view direction of the person to be tracked will be displayed in the HMD. Accordingly the "gyro-laser-tracker" is to be integrated in a helmet. By the means of field experiments in cooperation with the fire brigade, the optimal configuration of the "gyro-laser-tracker" is to be determined.

4 USER INTERACTION

The practical usability of a CADMS 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 in real-time and displayed in such a way that there is an obvious advantage in comparison to orientation with plans and maps used today. A few ideas concerning the graphical interface are listed below.

The user interface and user's interaction with a CADMS have to be optimised for different users of the system, e.g. the squad leader requires different information and possibilities for interventions than the rescue team on the site.

The main activity at the command centre is the control and command of the rescue teams. The most important information therefore is a 'bird's eye' view over all actions. Therefore all the graphical information is displayed using a layer technique. Apart from the construction floor plan layer, other layers (if available) can be visualized containing information about the different facilities (such as HVACR or furniture). In addition current data from the data base can be displayed using shadings, symbols and highlighted texts as well as information from the document management system. The current positions of the rescue teams are constantly updated. Several layers can be displayed simultaneously. The user interface and the menus correspond to the client-server version of the CAFM-system speedikon®FM.

The user interface of the mobile devices has to fulfil certain boundary conditions:

- The interaction can only be in form of voice entry since the hands are needed for the actual tasks.

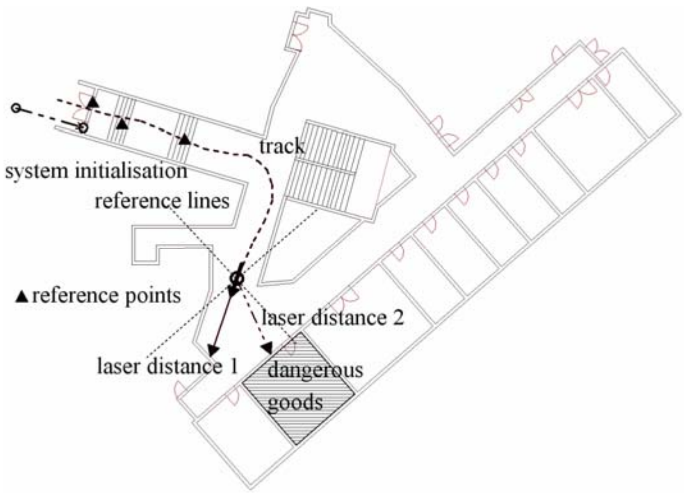

Figure 3. Track and position representation of an emergency crew

- Only information crucial for the current situation is to be displayed (Fig.3). Zoom, Pan, displaying and hiding layers as well as other standard functions must work by simple oral commands.
- Displaying the sensor information in real-time is one of the major challenges. The scanning of the environment with the laser rays is to be displayed on the floor plan together with the current position and the reference points presented by colors and symbols.
- Observations made by the rescue team have to be instantly implemented in the floor plan by voice controlled red-lining functions.

5 SYSTEM ARCHITECTURE

In order to make a CADMS useful and attractive for emergency services, not only problems how to display data, real-time positioning and the user interaction, but also problems concerning the hardware, system-architecture and communication have to be solved. Not only the user-friendliness and the robustness of the system under extreme conditions have to be considered, but also budget constraints are to be taken into account.

The system architecture displayed in Figure 4 assumes a web-connection between the mobile devices on site and the server(s) in the command centre. In this case all the crucial components of the system can be administered from a safe location. But it is also possible to install the complete system on the mobile device so that the way of communication with the command centre can be reversed. In the case of our prototype all software is installed on the mobile tablet-PC.

If the potential deployment locations are previously known, e.g. 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 or mobile devices. It has to be ensured that the provided data contain 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.

Initialising 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).

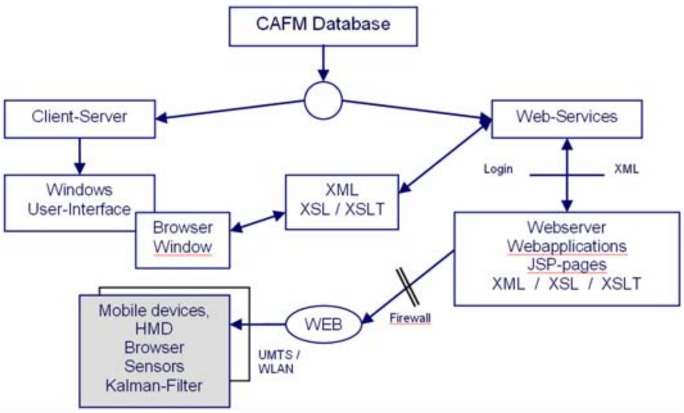

Figure 4. CADMS System Architecture

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 main goal still is the reduction of injuries and damage in case of extraordinary events.

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