FRANKFURT AIRPORT FIRE SAFETY: CONTEXT SENSITIVE EMERGENCY NAVIGATION IN COMPLEX BUILDINGS

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Key words: safety management, fire prevention, airport, indoor navigation, terrorism and security

Abstract

Introduction
About twenty fire fighters loose their lives and more than 16.000 accidents happen on duty every year in Germany. One of the main problems is the orientation inside of complex buildings during operations. Route cards (printed on paper) to find fire detectors are often not on an up to date level. Fire detectors can be located in suspended ceilings and are very difficult to find. Especially, fire brigades of airports have to cope with a high number of fire alarms every day. Because of reconstruction work the orientation in these buildings is insufficient and very time consuming. In case of real fire this can endanger human lives of passengers and fire fighters.

Theory and method
The aim of the research project “Context Sensitive Emergency-Navigation-System for Complex Buildings” is to improve disaster preparedness by providing better orientation with the development of an indoor positioning system for fire fighters. As satellite based navigation systems are not usable inside of buildings, a Navigation Integration Platform has been developed which combines three indoor positioning methods. This multi method approach uses the technical equipment that already exists in the building and requires additional installations only where necessary.

Results
To set up the Navigation Integration Platform, positioning systems and methods based on Wireless LAN (WLAN), Ultra Wide Band (UWB) and Radio Frequency Identification (RFID) have been developed and adapted for indoor positioning. CAD building data is exported to use the information on fire protection and building elements to be displayed in the spatial context of the fire fighter.

Introduction

The Frankfurt Airport is one of the most frequented Airports in Europe. 2.5 million square meters of buildings and many thousand passengers and employees per day are a challenge for the fire brigade to ensure fire safety in the buildings and on the apron. In order to save human lives and material assets complex buildings are equipped with different safety and security systems. The Frankfurt Airport has about 50.000 automatic fire detectors, which cause about

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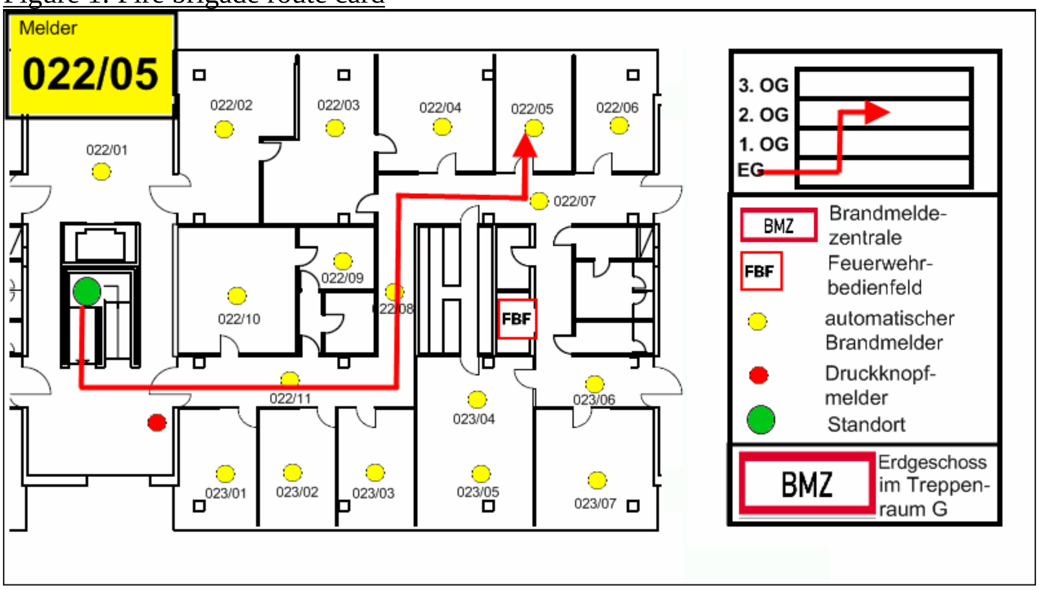
5.000 alarms per year. 95 per cent of them are so-called “false alarms” but in each case concentrated efforts of the fire brigade are necessary: Fire detectors and extinguishing systems have to be checked immediately. In alarm cases at least six fire fighters are involved for 30 to 45 minutes only to locate the fire detector and to return to the fire station. This is very time consuming and the orientation within the buildings is often insufficient. The exact position of the fire detector is often difficult to find because they can be located in suspended ceilings. For the officer in charge it is nearly impossible to keep track of all activities and the particular positions of the rescuers within the building.

The aim of the research project “Context Sensitive Emergency-Navigation-System for Complex Buildings” – which is founded by the German Federal Ministry of Transport, Building and Urban Affairs – is to improve disaster preparedness by providing better orientation with the development of an indoor positioning system for fire fighters. Partner in this project are the fire brigade of the Frankfurt Airport and a fire prevention planning office. In this paper the operation sequence of the fire brigade in case of a triggered fire detector, related works, the requirements of the fire brigade, the use of different technologies for indoor position sensing (multi method approach) and the system architecture will be described. Providing information in the spatial context is one of the advantages of this system. Context awareness for mobile devices is explicated in detail.

Work sequence of the fire brigade

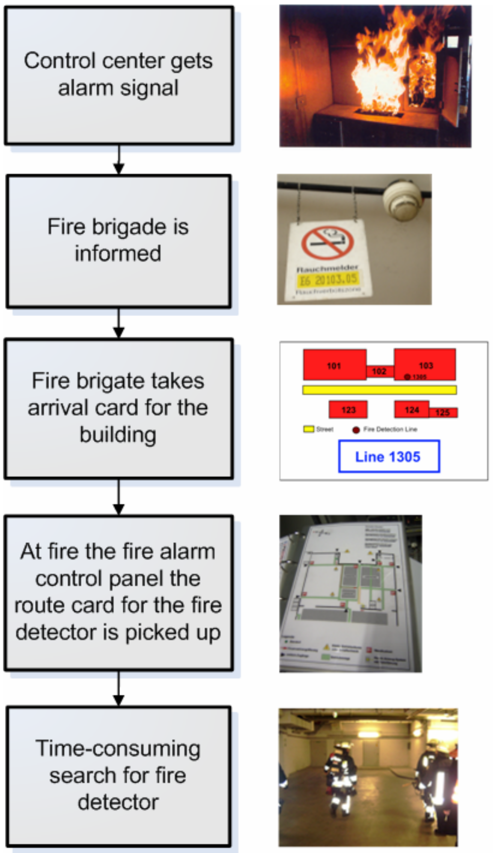
On average 10-12 times a day one of the 50.000 automatic fire detectors of the Frankfurt Airport trigger due to, for example, dust from reconstruction work, smokers in none smoking areas or a paper basket burning. In most cases there is no dangerous situation, but the fire brigade has to analyze the reason leading to the alert. In case of an alarm one of the three fire stations is informed by the control center to march out. Fire detectors are connected to alerting lines. If a fire detector triggers the fire brigade is informed, takes an arrival instruction for that alerting line and starts for the building in which the alarm has been activated. The arrival instruction contains only few information about the building. Usually, only the building number, the number of the fire detection line and the way to the fire alarm control panel is drawn on a small map. The Frankfurt Airport has many different fire detection systems, which are often at the state of technology of the time the system has been installed. Modern systems send the detector number direct to the control center; older systems only send the line number. Reaching the building a fire alarm control panel displays the fire detection line and the exact fire detector that has caused the alarm. At these terminals building maps are available printed on paper (route cards) (see Figure 1).

Figure 1: Fire brigade route card



Using these route cards the fire brigade has to find the fire detector. The operating sequence is shown in Figure 2.

Figure 2: Work sequence of fire brigade



In complex buildings and large halls it is very difficult to find the exact fire detector because of insufficient orientation. Due to changes in usage airports often undergo reconstruction work. It takes enormous efforts to keep these building maps on an up-to-date level and to distribute them to the different fire alarm control panels. The current situation is not only time consuming. In cases of real fire the orientation within a building and information about the direct way to the fire detector, the exact position of the fire detector and the areas where passengers and employees are located is very important to safe human lives. For the officer in charge it is nearly impossible to keep track of all activities and the particular positions of the rescuers within the building.

In the research project “Context Sensitive Emergency-Navigation-System for Complex Buildings” different technologies for indoor localization and a CAD-data-export are used to enable indoor navigation including route calculation to improve orientation and safety for rescuers in buildings.

Related works

Satellite navigation systems like GPS and Galileo (in the future) allow rotational position sensing within the accuracy of a few meters outdoor. Using small GPS-antennas for mobile devices it is actually only possible to detect positions in accuracy of a few meters directly under the roof of a building [Eisfeller et. al. 2005]. On lower levels signals are absorbed by or reflected on walls and metal surfaces which prevent position sensing in an adequate precision and feasible time. For this reason different technologies like WLAN, Radio Frequency Identification (RFID) and Ultra-Wide-Band (UWB) have been developed. A description of different Real Time Location Systems (RTLS) is given in [Rueppel and Stuebbe, 2007] but each system has its own application range where it is best for usage.

The importance of indoor navigation to first responders in order to improve orientation and the availability of building information during the rescue mission is emphasized by the existence of several research approaches in that domain. Different approaches mainly focus on one technology are shown in the literature. [Europcom, 2006] presents a system for positioning and communication for emergency situations based on Ultra Wide Band (UWB). [Walder, 2006] focuses on inertial tracking, laser distance measurement and user interaction for position sensing inside of buildings. [Akinchi, 2008] has developed an indoor navigation system based on Radio Frequency Identification (RFID) using active RFID-tags.

Not only indoor navigation is subject to research, also the communication and context-aware computing is in progress. [Jiang et. al, 2004] presents a system for context-aware messaging in the firefighting domain. The fire brigade of the Technical University Munich has developed a system using mobile devices to provide building plans of laboratories and fire protection manuals in site. These two systems focus on communication and do not include indoor RTLS.

With reference to indoor navigation all of these systems do only apply to special kinds of buildings. An airport like Frankfurt has different environments: large halls, office areas, underground car parkings and cellar rooms. One of the described systems does not fit all requirements of these different environments. Due to this reason the Institute of Numerical Methods and Informatics in Civil Engineering has developed a multi method approach to integrate adaquate indoor positioning technologies.

Requirements of the Frankfurt Airport and RTLS overview

Before setting up a system architecture for the Context Sensitive Indoor-Emergency-Navigation-System the requirements of the fire brigade of the Frankfurt Airport have been analysed. The results are as follows:

- All firefighters shall be equipped with mobile devices
- Small device (e.g. PDA) for fire fighter
- Larger device (e.g. Tablet PC) for squad leader
- Inputs shall be made by hand with protective gloves on a touchscreen
- Easy login and logoff
- Detection of the actual position of the firefigther
- Calculation of the shortest waypath to fire the detector
- Personal view and overview (all fire fighers) of the situation
- Information within the spatial context of the firefighter and the situation

In general the fire brigade of the Frankfurt Airports needs a system which is easy to use, does not restrict the rescuers in motion and supports the workflow with a minimun of user interaction. User interaction has to be possible by using protective gloves, this must be considered while designing the user interface. Squad leaders and fire fighters will equipped with mobile devices that have touch screens for easy and intuive handling. The displays shall not be too small as building plans with the calculated route to the alarming fire dectors shall be displayed.

As calculating a route through a building postulates a known position as a startpoint, a survey of different indoor positions systems is given. Information within the spatial context (context sensitive) will be described in detail in section 6.

As mentioned above the airport has different environments. To compose the best fitting RTLS components a choice has to been done. The following table gives an overview on RTLS. The column *Technology* contains the unterlying technology. Indoor/outdoor indicates if the system is suitable for indoor use, outdoor use or both. *Best fitting environments* categorises the best fitting environment of the Frankfurt Airport. Big rooms and halls like checkin-halls and luggage halls are combined to halls. Offices are asumed to be equipped with wireless LAN. *Celars* and *undergrund car parking* can be assumed as rooms with few technical infrastructure.

Table 1: Overview Indoor Positioning Systems

Technology	Accuracy	Indoor / Outdoor	Best fitting environments	Comments
GPS	< 10 m	outdoor	-	-
Cellphone	50-300 m	both	all environments	not precise enough
WLAN	<3m	both	offices, halls	existing WLAN-hotspots can be integrated
Ultrasound	~ 15 cm	indoor	offices, halls, underground car parking	large fixed-sensor infrastucture throughout the ceiling
Infra Red (IR)	~ 10 cm	indoor	offices, halls, underground car parking	direct line-of-sight, influenced by sunlight
UWB	~ 30 cm	indoor	halls	few sensors for a large area
RFID (active tags)	< 4 m	indoor	underground car parking, cellars	reading distances up to 10 m (mobile readers)

A detailed descripting of the different technologies ist given in [Rueppel and Stuebbe, 2007]. In the next section the selection of RTLS and the integration into our Indoor Navigation Integration Plattform is exemplified.

Indoor Navigation Integration Platform

As mentioned in the last section the Frankfurt Airport has many different environments and one single indoor positioning system does not work for all environments. Due to this reason three systems have been chosen. This multi method approach uses most of the existing technical infrastructure and requires additional navigation infrastructure only where necessary.

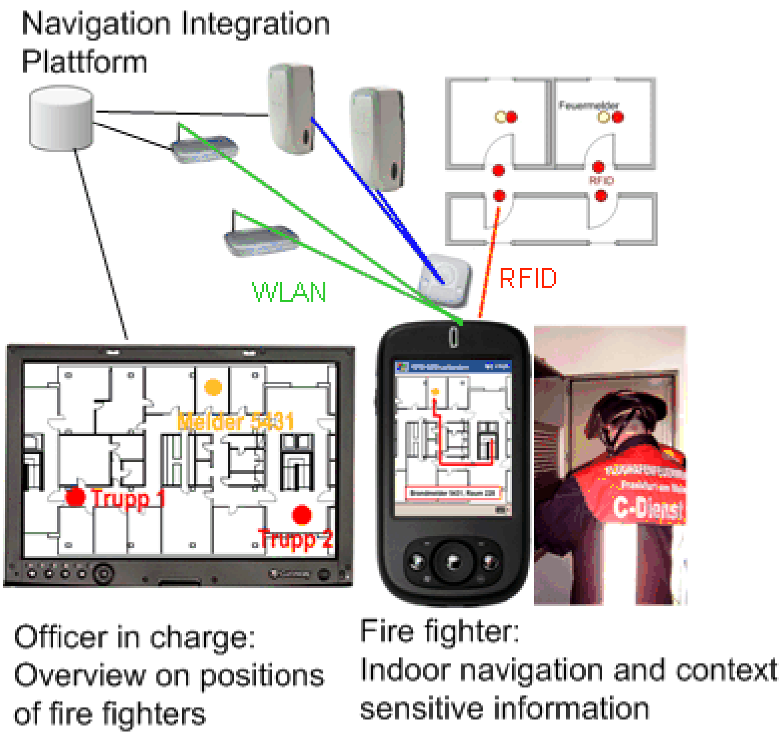
Ultra Wide Band (UWB) is appropriate for position sensing in halls. UWB is less influenced by metals and high humidity than other radio communication technologies and is therefore the choice for passenger and baggage halls. By use of high sensitive antennas only few sensors are needed to enable position sensing in halls.

Existing Wireless LAN networks can be used for position sensing in office areas. Wireless LAN is capable of being influenced by human beings walking by or by structural measures. On this account active RFID-tags will be added to recalibrate the system.

Cellars and underground car parking will be equipped with active RFID-Tags using the UHF-frequency (868 MHz). These tags will be placed at central points. If a fireman is in footprint of a RFID-tag the system detects its position. Antennas of active RFID-tags allow the detection of tags while walking by without adjustment of the antenna in the direction of the RFID-tag. As bar antennas of active RFID-tags are small they are suitable for easy handling with mobile devices.

The Navigation Integration Platform administrates the actual positions of the rescuers (see Fig. 2), the organizational structure including work schedules, the building information exported from CAD, generated routing networks for navigation and information on fire protection and building elements. The communication between the mobile devices and a web service of the Navigation Integration Platform can be established by WLAN, GPRS, UMTS or other possibilities for internet access.

Figure 2: Navigation Integration Platform



Information on fire protection and building elements will be displayed in the spatial context of the fire fighter, e.g., gas pipes or high voltage panels.

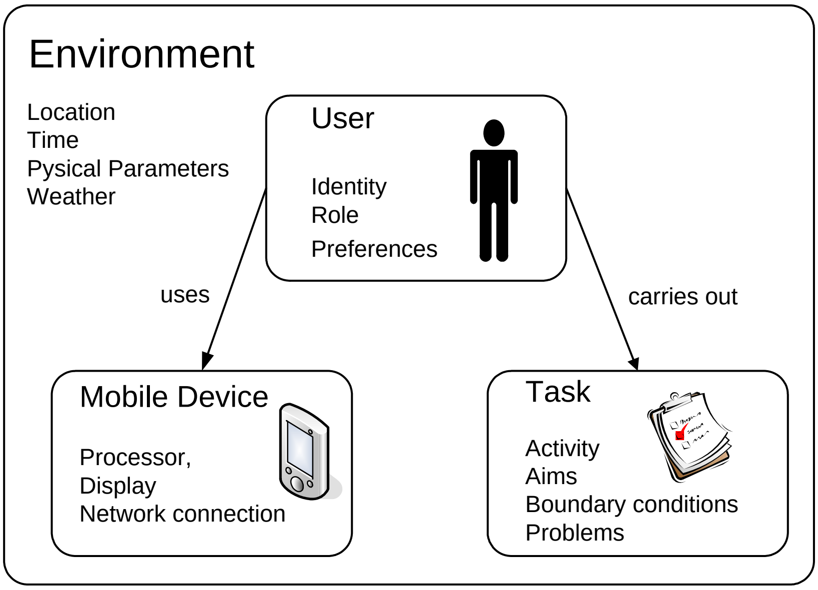
Context sensitive information

In the previous sections it has been mentioned that context sensitive information will be provided to the rescuers. Before describing how this is implemented a definition of context and context aware computing is given.

Definition of context and context aware computing

Implicit situations (or context) are used when humans talk with humans. They use implicit situations to transfer information. This does not work well when interacting with computers.
To improve this, context has to be defined in sense of interacting with computers. A good definition is given by [Dey and Abowd, 2000]: “Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.” There are certain types of context that are more important than others. These are location, identity, activity and time. Criteria for describing context are categorized in the following figure.

Figure 3: Criteria for contexts



Most applications use one of these types to provide the user of an application with information which is interesting for him in this context. According to [Dey and Abowd, 2000] a context-aware application can be defined as a system which uses context to provide relevant information and/or services to the user where relevancy depends on the user's task.

Context aware computing for fire fighters

In case of an alarm fire fighters are equipped with helmets, protecting clothes, breathing apparatus and other equipment. When walking through buildings they need an application that supports their orientation and provides information mainly in the spatial context according to their position in the building. This needs to work with a minimum of user interaction.

Beside the actual position of the fire fighter and the way to the fire detector other information in case of a real emergency is important, e.g.,

- Explosive goods
- High voltage panels
- Toxic materials
- Information on CO2 or inert gas extinguishing systems
- Control panels of fire alarm systems

For the Context Sensitive Indoor-Emergency-Navigation-System for Complex Buildings two context types are most important: location (position in the building) and time. According to the position the system sets a request on the database to get information on, e. g., explosive goods or high voltage panels in a circumference to the actual position (see Figure 4).

Figure 4: Context sensitive Information

Additionally, it is possible to monitor the motion of a rescuer. Each rescuer can push an emergency button on his mobile device to alert the officer in charge and all other rescuers can see the alert and the actual position on their display. It is also possible to automatically generate alarms, if the position of a rescuer has not changed for a certain time. In this case the rescuer could be hurt and may not be able to raise an alarm.

Results / Discussion

The orientation inside complex buildings and the possibilities to control and overview operations is not yet satisfactory. Basic technologies for indoor navigation and digital supply of building maps are available but have not yet been combined to a system that can be used in practice. Building maps printed on paper and distributed to the fire alarm stations are often not on an up-to-date level. It takes much time and effort to administrate these maps.

The Context Sensitive Emergency-Navigation-System for Complex Buildings supports rescuers in finding the shortest and fastest way in a complex building. With a multi method approach Wireless LAN, RFID and UWB RTLS are combined to fit for different environments in buildings. Maps on paper will be replaced by digital plans which are able to provide additional information within the spatial context of the rescuer. The system described in this paper enables a better overview over the situation and will achieve a distinct improvement of efficiency of rescue operations.

The different indoor positioning systems have been connected to the Indoor-Navigation-Integration-Platform and are now being calibrated to improve accuracy. The central database has been set up and first tests of the system have been made at our institute.

In our future work we will evaluate the system introduced in this paper by practical tests at the Frankfurt Airport and we will extend it to the detection of passengers in buildings to facilitate direct supporting measures to save human lives.

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Acknowledgement

The research project “Context Sensitive Indoor-Emergency-Navigation-System for Complex Buildings” is funded by the German Federal Ministry of Transport, Building and Urban Affairs.

Author biography

Uwe Rueppel is professor for Informatics in Civil Engineering at the Technische Universitaet Darmstadt. Under his direction several research projects concerning CAD-building models with integrated examination of German fire protection regulations, disaster management systems for flood disaster and GIS systems for ground water monitoring have been carried out. He is currently working on research projects in the domain of disaster management and building safety together with public authorities and operators of critical infrastructures.

Kai Marcus Stuebbe has made his diploma in Civil Engineering at the Technische Universitaet Darmstadt. He is specialized in indoor localization, CAD and GIS-systems for mobile devices and is currently doing his dissertation within the research project “Context Sensitive Emergency-Navigation-System for Complex Buildings”.