Abstract „RFID maintenance guidance system for fire prevention“

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Objective of research project

Fire prevention is one of the most important fields of building safety with high requirements on the quality of the maintenance processes for the built in technical fire safety objects. Therefore, especially in complex buildings the RFID technology provides new possibilities.

The item fire prevention includes all activities, which prevent the generation and spread of fire, and also the resulting personal and material damages. There is a differentiation between preventive fire protection and defensive fire protection (fire-fighting). Repelling fire protection is provided by the fire-fighting measures. Preventive fire protection includes the construction, the plant engineering and the operational and organizational safety of a building.

Accompanying the construction of a building the fire prevention is planned and the fire protection equipment is installed. This equipment and all operational and organizational measures for fire prevention and evacuation of persons must be checked regularly.

Due to cost savings and risk outsourcing many building managers, as a part of their operational responsibility, commission external companies to conduct the comprehensive maintenance and inspection of fire protection systems. Indeed, these foreign companies usually have explicit know-how of the legal requirements (laws and standards) to perform maintenance. However, they are mostly represented by maintenance personnel who are unfamiliar with the area. Sometimes they miss the necessary guidance in complex buildings, so the result is a time-consuming search of the fire safety objects.

Furthermore, there are deficits concerning the actual maintenance process. The documentation is done by the staff mostly on handwritten paper lists or forms, which are later transferred into a computer system. This poses a high risk of transcription errors. There is also currently a risk of confusion between maintenance objects by a non-existent unique identifier. This leads to the maintenance personnel often not having enough information about the maintenance history of the objects.

This shows that in terms of maintenance and controlling of fire objects there is an urgent need for research.

The aim of the research project "RFID maintenance guidance system for fire protection" is to develop methods which support the mostly external maintenance personnel in pathfinding in complex buildings and improve the quality of the maintenance processes. This would make it possible for the maintenance personnel to create maintenance routes by being connected to a mobile device with navigable, digital building plans (generated from CAD building information), which calculate the shortest path between the fire objects. So-called round trips should reduce the expenditure of time and bring a higher quality assurance because the maintenance staff cannot forget a maintenance object or mistakenly confuse objects.

The System “Context sensitive RFID building guidance system”, which was developed in the first phase of the project, should be expanded with path calculation methods in buildings and for maintenance of building safety systems for preventive fire protection. This should ensure a complete digital documentation of the maintenance and a verification of the actual presence of the maintenance staff by using RFID-tags. In addition, maintenance personnel who are unfamiliar with the building such as the one from external companies can be guided directly to the operating place using indoor navigation.

Maintenance personnel should also be able to acquire information about components via RFID (e.g., cable or pipe duct). Here the information from the project “RFID-Intellibau” from the “ARGE RFID im Bauwesen” can be used.

Practice partners in this research project are the airport fire brigade of Fraport AG, Bureau Veritas Brandschutzservices GmbH, Identec Solutions AG and innoTec GmbH.

Accomplishment of research project

Legal requirements of the maintenance of fire protection objects

To mitigate or even to prevent fire disasters and its consequences early, appropriate fire protection measures have to be taken and controlled steadily. Decisive for the present application of maintenance of fire protection objects, is especially the preventive fire protection in combination with the plant-specific fire protection. This includes all the technical devices used to detect, notify and extinguish fires and to support measures for the evacuation and rescue of persons [Zwinger, 2010]. Typical technical systems for fire protection in buildings are facilities for storage and supply of fire water, fire alarm systems, automatic fire-extinguishing systems, smoke and heat extraction systems, escape and emergency lighting, manual fire extinguishers, fire hydrants, bulkheads and fire dampers.

For the maintenance of all these facilities a lot of laws, rules and regulations should be considered:

- DIN-Normen (e.g. DIN 14406-4, DIN 14675, DIN EN 3, DIN EN 12101, DIN EN 12845)
- VDE-Normen (e.g. DIN VDE 0833-1, DIN VDE 0833-2)
- VdS-Richtlinien (e.g. VdS 2490, VdS 2864, VdS 3444)
- CEA-Richtlinien (e.g. CEA 4001)
- GEFMA-Richtlinien
- Druckbehälterverordnung (DruckbehV)
- Betriebssicherheitsverordnung (BetrSichV)

To enable an all time working state of the fire protection equipment a careful maintenance has to be done. The term maintenance can be seen as a generic term for the areas of inspection, service, repair and improvement.

There are also a lot of requirements regarding the maintenance staff. For example, DIN VDE 0833-1 obligates the operators of alarm systems to regular inspections, but these may not be performed by any staff member. For example, only employees by a professional firm or service staff with special qualifications are allowed to carry out the inspections.

Navigation inside buildings

In the first phase of the research project a multi-method approach for indoor locating based on WLAN, UWB and RFID-tracking was developed. In the second phase to the already developed Indoor-Navigation-Integration-Platform (InNavI) another indoor locating system (INTELLI**FIND**^{RTLS} by Identec Solutions) was added. This is a tracking system with fixes installed readers distributed in the locating area, which allows the localization of mobile transponders. Up to now, this system has been used primarily for outdoor applications and there are only a few experiences so far for detecting people who are moving in the indoor area.

To implement a navigation system for indoor use, a comprehensive data base of the building's geometry and the associated possible trails is essential. For this purpose, a Building Information Model (BIM) was developed by the IIB, which gets its data directly from CAD-systems.

By the use of one developed software component (routing grid generator), it is possible to create an automated path graph, which includes all usable paths on the basis of BIM with the details on walls, doors, etc. [Stübbe, 2010]. This path graph is a network of nodes and edges, which makes it possible, with the help of suitable algorithms, to calculate paths from any point in the path network to another arbitrary point. For this purpose, various methods such as uniform screening, quadtrees, Delaunay-Triangulation/Voronoi-Diagramm and Straight Skeleton were examined. With regard to the computation time and the performance, Straight Skeleton provided the best results for the present application [Kreger, 2011].

The use of navigation in the context of maintenance processes especially requires a circular route calculation whose starting and end point are mostly identical (e.g., building entrance). This limits the choice of a routing algorithm

which calculates a shortest path between two given points based on the network of nodes and edges. The Nearest-Neighbor-Heuristic, Simulated Annealing and Ant-Algorithm proved to be useful heuristic algorithms.

Sometimes in the process of maintenance it may be necessary to use alternative routes, so it would be useful to provide them from the outset. In this regard, the present navigation software includes an internal so-called distance matrix, which allows for a fast efficient performance of alternative routes on mobile devices for later use. However, this is only possible through a continuous monitoring of the course and the current position.

Prototypical implementation

For creating the runtime-based indoor navigation application for the maintenance of fire protection objects a detailed analysis of the requirements was carried out first. For this purpose, the legal and normative requirements for maintenance and inspection services, their documentation and the special needs of future users were studied.

Figure 1 shows a use case diagram on behalf of the users' needs, in which the interactions between users and the system and the dependencies within the system are roughly sketched.

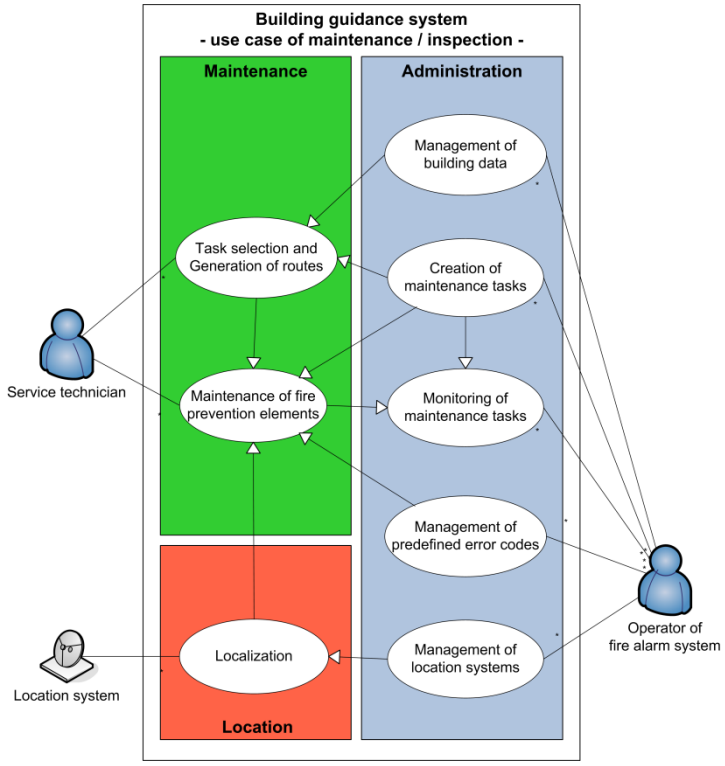

Figure 1: Use cases of an maintenance guidance system [Kreger, 2011]

Figure 2 illustrates the distributed components in the network using a network diagram.

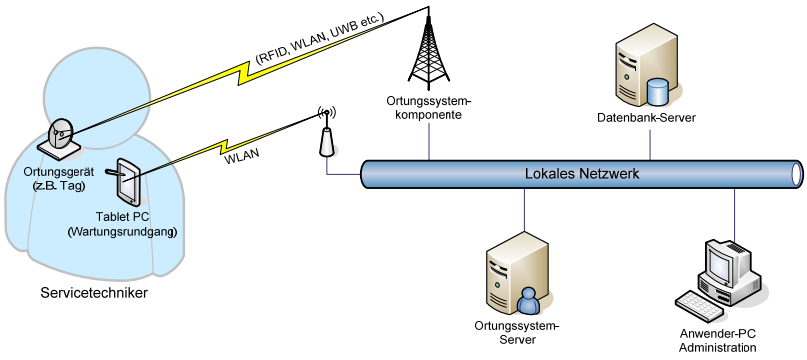

Figure 2: Network design for a maintenance guidance system [Kreger, 2011]

Based on the existing Indoor-Navigation-Integration-Platform (InNavI) of IIB from phase 2 a runtime-based indoor navigation system for the maintenance of fire protection equipment was created. Because of different user groups and to enable differentiated delivery of information in a variety of details, different use and a different program flow, a separation of the application software was implemented. Therefore, for the two main groups of users, administrators and service technicians, an own application was developed.

Application for administration

The application for administrators allows them to manage the data base and amongst others includes features for creation, reviewing, editing and deleting of maintenance orders. It is equipped with a detailed view for data and map.

Figure 3 represents the view of maintenance and inspection of the maintenance guidance system.

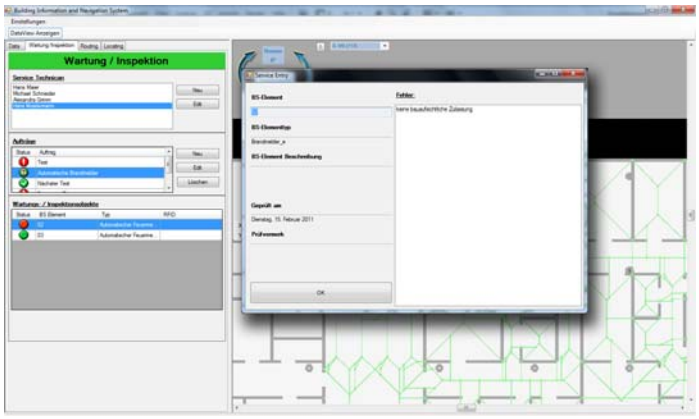

Figure 3: View of maintenance and inspection
(Application for administrators)

Mobile Application

The application for service technicians has been optimized for a screen resolution of 800 x 600 pixels and simple handling. During the execution of the program, when reaching a service object, an automatic change from map to documentation view was implemented. It can be hidden again after the work has been completed on the service object. With the help of a verification (via RFID or bar code) on fire prevention elements by the service technician it can be prevented that a fire protection element is confused or forgotten [Kreger, 2011]. With the use of predefined error codes the maintenance process can be logged in a generally understandable way.

By providing the history for the current object to be processed, the service technician can view all information about past inspections and maintenance issues directly and respond to possible weaknesses.

Figure 4 represents the documentation view of the maintenance application (mobile application).

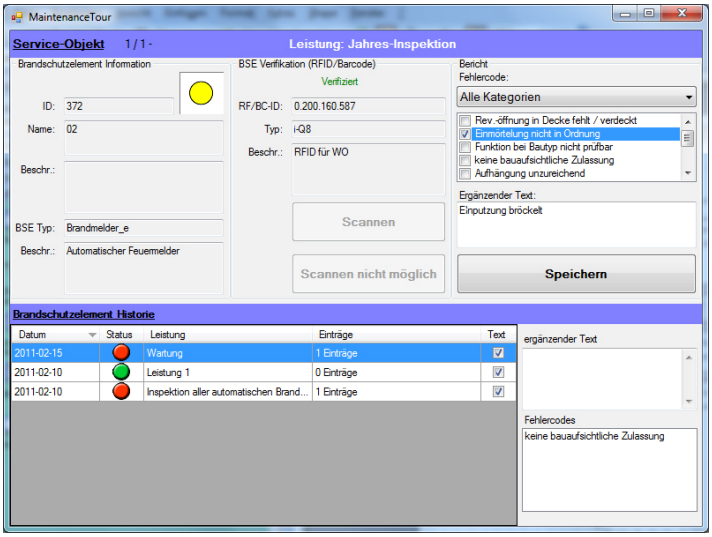

Figure 4: Documentation view
(Mobile application)

Evaluations

In this research project, different tests were performed. These included:

- Determination of the effects of different building materials to the location with RFID (Test run on the grounds of the TU Darmstadt)

Figure 5: Measurement experiment regarding "tunnel effect"

- Determination of the range in relation to detection accuracy
  (Test run at the Frankfurt airport, participation of the partners Fraport fire brigade and Identec Solutions)

Figure 6: Test equipment for range / accuracy measurement
(left: Truck stocked with RFID-tags; rights: Turntable ladder stocked with i-SATs)
(Image source: Hr. Fabian, Identec Solutions)

- Evaluation of the prototype
  (Test run on the grounds of the TU Darmstadt)

The practical test of the prototype was conducted in the institute's premises. This is a seven-story building where the institute is located on the second floor. These premises appear to be suitable, because of a variety of different types of interior walls (e.g., concrete, masonry, lightweight) and the possibility to use existing technical infrastructure, but also easily including other necessary additional infrastructure.

The test site is divided into a long hallway branching, adjacent to the side office, technical and sanitary rooms of different size. In this area the RFID tracking system INTELLI**FIND**^{RTLS}, developed by Identec Solutions, was included. It has been run through the following test scenario:

A maintenance employee of a foreign company who is unfamiliar with the building was assigned with the maintenance of 5 fire protection objects (1 fire extinguisher, 2 smoke detectors, 1 wall hydrant, 1 sprinkler head). To conduct his activities, he was equipped with a mobile computer, an active RFID tag (for tracking) and with the prototype software for maintenance developed in this research project.

The RFID maintenance guidance system for fire prevention supported him regarding the orientation, provided the shortest round trip and determined and showed his current position to quickly arrive the maintenance objects. As part of the actual maintenance process the service technician is supported by the system with a digital maintenance form and an automatic detection and localization of the actual to be maintained fire protection object.

Conclusion and results

As part of fire protection concepts, operators of larger and public buildings, but also those of industrial buildings, are usually required to integrate a fire alarm system to warn the persons who are located in the building early enough in case of danger and to contact a central alarm office and thus to summon appropriate emergency services. Because such a system requires a very extensive maintenance, which includes a considerably large amount of legal regulations, many operators outsource the maintenance tasks of fire prevention objects to external companies. Indeed, these have partly qualified and certified maintenance personnel, but they are usually unfamiliar with the building. Difficulties relating to the orientation in large complex buildings and a subsequent extensive search for the serviceable items are thus inevitable.

In this research project the main issue was to improve the performance of maintenance contracts in complex buildings by the example of fire protection objects. An IT-based system was developed to replace the previous paper-based logging, accompanied by providing positioning and navigation functions, which accompany and conduct the service technician in their work, but also provide a maintenance support during the actual operation. For this purpose, inter alia standardized damage codes and an RFID- and barcode-based service object identification was integrated.

Furthermore, a new RFID-based tracking technique for locating service technicians in complex buildings was examined and it was shown that by use of a combination of positioning and navigation the maintenance orders can be improved and accelerated.

The developed concept of the RFID maintenance guidance system for fire prevention has been prototypically implemented and evaluated with the practice partners at different test runs.

The evaluation of the system showed that only the usage of a digital system makes the management and execution of maintenance orders perfectly feasible. The previous paper-based maintenance process had too many media breaks and thus a very high number of potential errors. In this regard the following benefits were arisen from the practice tests and interviews with the practice partners.

Benefits regarding the procedure of the maintenance task:

- Because of the combination of location and navigation the service tours are optimized.
- Increase of the quality of maintenance by control functions for the successful mission execution.
- Verification of the actual presence of the service technician to the appropriate object (fulfillment of obligation to produce proof).
- Use of constantly updated building data by using interfaces for import data from facility management and CAD software systems.
- The combination of maintenance-related information on building data and maintenance protocols allows an optimal use.

Benefits regarding the processes of maintenance:

- Confusion of serviceable objects can be virtually eliminated.
- Digital documentation of the inspection and maintenance operations reduces the amount of work and ensures the timely delivery of maintenance orders by using mobile devices.
- The service technician has all the important data of the objects at any time.

Furthermore, it offers the following advantages:

- Improved overview of maintenance items and their maintenance intervals.
- Based on the RFID computer-based inventory management the monitoring of refresh cycles can be improved and significantly shortened. The maintenance data are immediately available in the system.
- Reduced errors by eliminating the transfer of paper lists into computer systems.
- Additional information can be directly stored digitally in the RFID tag, which is attached in the maintenance object.

The work on the research project and the obtained results have shown that more research is needed in the areas of positioning and navigation, but also at the implementation of maintenance processes in order to provide even better support for service technicians and to increase the quality of maintenance continuously.

Above all, it became clear that an investigation in the field of mobile positioning, iwithout a fixed installed location technology, makes sense, because the subsequent installation of appropriate positioning equipment in existing buildings can be very extensive based on the building geometry and internals. In this regard it is useful to assess how viable a mobile ad-hoc tracking infrastructure is.

For digital building models many new applications and uses have been shown in this research project. Thus, it will be also useful to research in the field of building information modeling (BIM) to enrich and connect them with other useful information.

The previous research in the areas of a "Context sensitive RFID building guidance system" and "RFID maintenance guidance system for fire prevention" has shown that there is a great need for support to the service technician for maintenance. The response on conferences and trade fairs was very positive. Above all, the interest of the economy, but also by representatives of security und emergency organizations (BOS) was great, which shows the great interest in the implementation of the developed methods.

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