Innovative Indoor Positioning Allowing for Safe Infrastructure

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Summary

Knowing the exact locations of the people staying in a building at any time constitutes crucial information during an industrial incident or a natural hazard. The computer aided disaster management system developed at Graz University of Technology offers indoor positioning capabilities, without the burden of having to rely on expensive and inflexible stationary infrastructure installed in the building. Furthermore, deploying inertial measurement units and utilising characteristic building information stored on small-scale mobile devices, provides seamless and autonomous indoor localisation. This paper gives an overview of the developed system, analyses positioning technologies already existing and describes the innovative map matching techniques designed to conduct the combination of time-dependent and time-independent information during deployment. Experimental results show the performance of the system.

Keywords: indoor positioning; disaster management; map matching; inertial navigation, building information model

1. Introduction

The percentage of the world population concentrated in urban areas is still growing. As a consequence, we are confronted with an increasing number of complex and widely ramified buildings like centres for public transport and education, shopping malls and office buildings. During extraordinary events like floods, earthquakes, fires or even terrorist attacks, it is hardly possible to keep track of the current status of the building, including the rescue teams' current positions, which is a precondition for efficient disaster management. On the other hand, efficient disaster management is compulsory in order to alleviate the consequences of natural hazards or industrial incidents in urban areas.

At Graz University of Technology a computer aided disaster management system (CADMS) is being developed. It has the task to fulfill the requirement of conveying up-to-date consistent information about the building's status to the rescue teams deployed onsite as well as to the control room to allow for efficient disaster mitigation and safe infrastructure. This information includes the current positions of the pedestrians staying in the building. The CADMS jointly gathers data from multiple sources and combines them in a concise, easy to use speech-driven interface. The rescue workers are equipped with a head-mounted display and a robust small-scale lightweight laptop or a smartphone. All the static information about the building in question is stored on the handheld thus allowing the CADMS to work autonomously and independently of the availability of wireless networks set up in the building. In order to conduct indoor positioning, an inertial measurement unit (IMU) is mounted on the rescue worker's foot and connected to the mobile device responsible for the integration of the measurement results and the time-independent information on the building.

This paper focuses on the innovative techniques allowing for map matching in indoor environments and describes the combination of IMU data and information on the building.

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2. Existing Positioning Techniques

Thanks to GPS, positioning and navigation for road traffic is an already solved problem today. Unless the microwave signals emitted by the satellite are attenuated too much by natural obstacles like mountains, nearly seamless navigation functionality is available. Approaching the city and entering the densely populated urban area, the satellite signals become more often attenuated by the built infrastructure forming our well known “urban canyons”. Inside buildings the GPS service cannot be beneficially utilised. Analysing the literature concerning existing positioning techniques, it can be concluded that there is no functioning indoor positioning system on the market that is tailored to the demanding requirements of disaster management. The following chapter describes the basic principles and innovative techniques of how indoor positioning and map matching are conducted in the CADMS.

3. Innovative Map Matching Techniques for Achieving Indoor Positioning

The CADMS uses room polygons stored in the underlying BIM instead of line segments defining paths in the building. The room polygons constitute the building’s walls. The main idea is that the walls must not be intersected by the pedestrian’s trajectory. Intersecting a room polygon indicates that the derived position deviates from the true location of the person. Processes re-calculating the position displayed to the user and minimising the error of position thus have to be conducted. The CADMS software incorporates a couple of sophisticated algorithms detecting and reducing the error of position in real-time. The first category of algorithms is carried out automatically should the deviation increase. These techniques re-calculate the position currently displayed on the screen without relying on any kind of user interaction. Hence, they perfectly support emergency forces that must not be detracted from their work. These algorithms exploit characteristic information on semantics describing the building’s elements like rooms and transitions between them (doors, stairs etc.). The second category of algorithms is dynamically invoked by the user onsite and sets the current position according to his observations. It is intended to use these techniques only to correct heavy measurement drift that cannot be compensated by the automatic methods. The paper concentrates on the algorithms belonging to the first category.

4. Experimental Results

The presented system is qualitatively evaluated by tracing a trail through an office building, which covers two floors. Screenshots of the CADMS show the functioning of the proposed techniques and compare the raw IMU data with the positions automatically corrected by the system.

5. Conclusion

In this paper we described a computer aided disaster management system including indoor positioning. We evaluated the system on the basis of experimental results. These promising results show that the CADMS is able to achieve the localisation of pedestrians over long distances without relying on stationary infrastructure installed in the building and without absolute re-positioning conducted by the means of user interaction. The result leads to a significant improvement of the chances and effectiveness of rescue teams during extraordinary situations. The error of position of the inertial subsystem in indoor environments can increase to approximately 5 % of the travelled distance due to disturbances of the earth’s magnetic field. For the localisation of people inside complex infrastructure this is not sufficient since their position cannot be assigned to the correct room. To alleviate this problem, our solution exploits characteristic building information extracted from well known CAFM-systems. Sophisticated map matching algorithms especially tailored to 3D-indoor environments, defined by room polygons and transition objects connecting them, are able to adjust the current position in real-time while taking the building’s geometric structure into account. Avoiding stationary infrastructure and using characteristic building information prestored in CAFM-databases promises broad acceptance and fast deployment of the CADMS.