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Offline indoor navigation via QR codes

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Abstract. This paper introduces a novel, cost-effective system for indoor navigation and localization that operates independently of satellite positioning services and data communication networks. The proposed solution leverages QR codes affixed within building interiors and an accompanying smartphone application, which, through integration with the device's inertial motion unit (IMU) sensors and the application of the Pedestrian Dead Reckoning (PDR) algorithm [1], accurately determines the user's position. This position data is then utilized by the Dijkstra navigation algorithm [2] to facilitate user navigation to their desired destination. Beyond navigation, this system offers significant utility in healthcare logistics, enabling efficient collection and transmission of triage decisions in emergency situations, even in the absence of a communication network.

Keywords: Indoor Navigation, QR Codes, Offline Navigation, First Response.

1 Introduction

The primary goal was to create a proof of concept demonstrating the feasibility of indoor navigation and localization using only passive tags. To achieve this, a smartphone navigation app was developed for use inside buildings, which operates without relying on satellite positioning services or communication networks. Satellite navigation systems (GPS, GLONASS, Galileo, BeiDou, QZSS, IRNSS) typically fail to function accurately inside buildings, particularly on lower floors, in basements, central areas, and away from windows due to a limited number of visible satellites. Similarly, communication networks (WiFi, LTE, 5G) may be unavailable in certain situations, such as during catastrophic incidents, power outages, or other emergencies, rendering localization systems based on these networks ineffective.

The smartphone app serves two main purposes. First, it aims to provide a reliable, user-friendly, and cost-effective indoor navigation system suitable for large buildings like hospitals, shopping malls, trade centers, and fairs where other positioning services are unavailable. Second, it aims to offer an indoor position reporting system for use in emergencies and mass-casualty incidents to report triage decisions to a server. Both functionalities rely on QR codes containing all the necessary information [3].

2 Methodology

To ensure comprehensive navigation data, two types of QR codes were created, each containing all necessary information.

1. Floor QR Codes placed at the entrance to each floor. These include:

- A compressed floor plan presented as an edge list (Fig. 1). A Python script was developed to automatically generate these edge lists from raster images of floor plans.
- The navigation graph, which includes the coordinates of destinations and navigation points, along with descriptive labels for all destinations (Fig. 2).

These QR codes are very dense [4], which can slow down the recognition process. If printed too small, the rows and columns are too close together, and under normal lighting conditions, the smartphone camera may not capture an image that the decoding routine, even with machine learning support, can robustly recognize. Experiments indicated that printing on A3 paper size is appropriate for these dense QR codes.

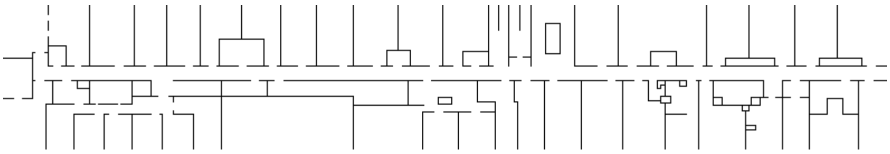

Fig. 1. A test floor plan saved in the floor QR after reconstruction.

2. Location QR Codes placed at destinations, intersections, and other navigation points. These codes include the location in GPS (latitude, longitude) and metric UTM (northing, easting) coordinates, as well as additional data about the location (room label, residents, etc.). The data size of these codes is much smaller—3 to 4 times smaller than the floor QR codes—making them less dense. Experiments showed that they can be printed on A4 or even A5 paper size for robust recognition.

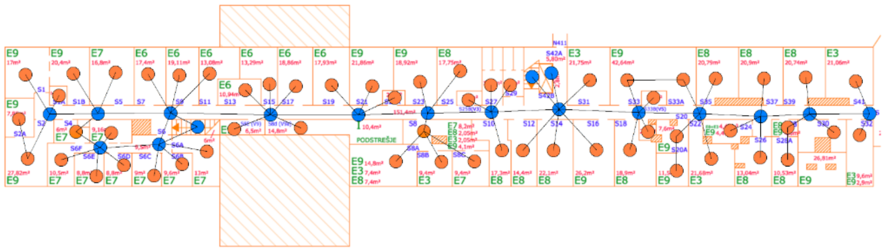

Fig. 2. Example of a navigation graph for a testing floor with all possible destinations (orange circles) and navigation points (blue circles) depicted on the original floor plan raster image.

3 Navigation and localization

Upon scanning a Floor QR code, users select their destination, and the app calculates the optimal route, visually represented on the device (Fig. 3). The app continuously updates the user's position using PDR, factoring in stride length and direction from IMU sensors. This system is not only effective for guiding users but also ensures that localization is aligned with global coordinate standards, facilitating integration with widely-used mapping services.

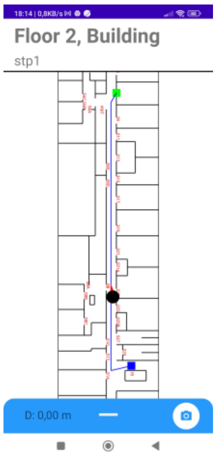

Fig. 3. Visualized path from the starting point (blue square) to the destination (green square), showing the user's current location and orientation (black circle with red pointer).

4 Healthcare logistics and triage support

A significant application of our system is in healthcare logistics, where it aids first responders in reporting triage decisions during mass-casualty incidents. By associating triage decisions with precise location data, the app enables efficient communication with emergency services, even in the absence of a reliable communication network. This feature is particularly valuable in disaster scenarios, ensuring that critical information is conveyed without delay.

The app supports the following triage scenario: First responders locate each casualty, determine the emergency level, and then use the app's menu to select the triage decision. This decision, along with the GPS coordinates of the location, is sent to the server using a REST API interface and GeoJSON data format (Fig. 4). If the communication network is unavailable, the data is saved to a local JSON-based database. Once communication is restored, the data is automatically sent to the cloud, and the user is notified, as shown in Fig. 5.

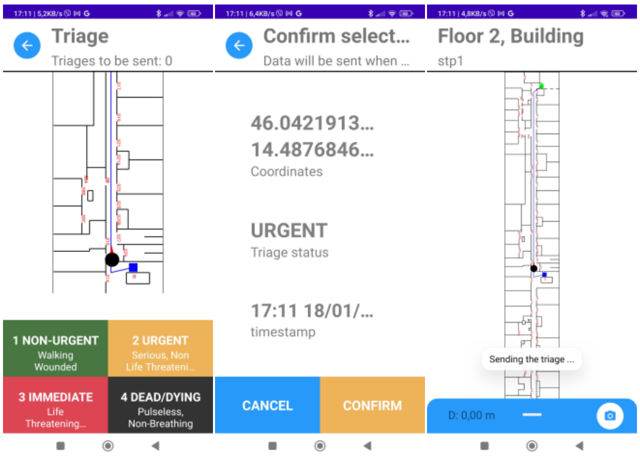

Fig. 4. The app's screens for triage decisions: selecting the triage decision (left), confirming the data to be sent (middle), and sending the data to the server (right).

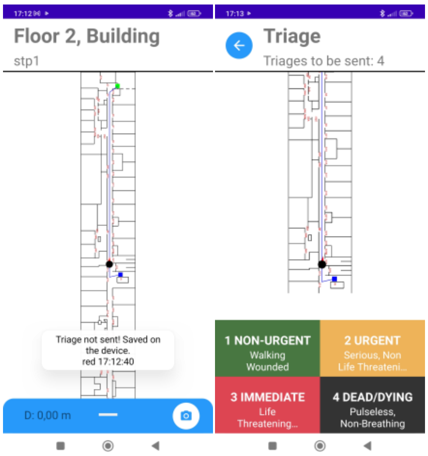

Fig. 5. If the triage message is not successfully sent (left), the status of unsent messages is displayed on the triage selection screen (right).

5 Future work

Future developments will focus on improving the system's ease of use and efficiency by pre-loading navigation data onto smartphones, eliminating the need for QR code scanning. This approach will provide users with immediate access to comprehensive maps and directions for entire buildings, ensuring a seamless navigation experience from the outset. Additionally, the system will incorporate real-time updates and dynamic route adjustments to enhance user guidance and adaptability. Enhanced user interface features will also be developed to provide a more intuitive and user-friendly experience.

6 Conclusions

We have successfully developed and tested an innovative indoor navigation and localization system that circumvents the limitations of conventional satellite and network-based solutions. By utilizing QR codes and smartphone technology, our system demonstrates a viable alternative for indoor navigation, with substantial implications for emergency response and healthcare logistics. Our findings suggest significant potential for further development and integration with existing technological infrastructures, promising to enhance indoor navigation capabilities substantially.

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