Beacons and BIM Models

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This research work uses a simplified approach to combine location information from a beacon's propagation signal interaction with a mobile device sensor (accelerometer and gyroscope) with local building information to give real-time location and guidance to a user inside a building. This is an interactive process with visualisation information that can help user's orientation inside unknown buildings and the data stored from different users can provide useful information about users' movements inside a public building. Beacons installed on the building at specific pre-defined positions emit signals that give a geographic position with an associated imprecision, related with Bluetooth's range. This uncertainty is handled by building layout and users' movement in a developed system that maps users' position, gives guidance, and stores user movements. This system is based on an App (Find Me!) for Android OS (Operating System) which captures the Bluetooth Low Energy (BLE) signal coming from the beacon(s) and shows, through a map, the location of the user's smartphone and guide him to the desired destination. Also, the beacons can deliver relevant context information. The application was tested by a panel of new and habitual campus users against traditional wayfinding alternatives yielding navigation times about 30% smaller, respectively.

Keywords: indoor location ; mobile app ; building information models ; BLE ; Beacon ; Path Finding ; A*

1. Introduction

This study employs two established technologies to develop a cost-effective solution. A mobile application that resorts to Bluetooth beacons for indoor user localization and Building Information Models (BIM) [1] for physical context. Bluetooth beacons broadcast a Bluetooth Low Energy (BLE) signal in a limited and configurable range. This signal can be interpreted by the mobile device as the location of the user in the building, without the need of internet connection. BIM models, the evolution of traditional Computer-Aided Design (CAD) drawings, associate both three-dimensional geometric and a database of all kinds of information: materials; spaces, or equipment and thus provide necessary context both for the location and navigation. Since most new construction today is based on BIM methodology, the effort for the development of a navigation application using the developed methodology is minimal.

A mobile application—Find Me! App—that integrates Bluetooth beacons and BIM models to show the user his location and the path to the destination was developed for Android smartphones. The most important parts of the Find Me! App are the user's current location (from the nearest beacon) and the Building Information Model, which holds room, beacon, stair, and elevator locations and navigation maps and delivers the location of the destination. Beacons are configured with identification data and are placed based on automatic analysis of the building geometry.

2. Proposed Approach

The primary goal of this project is the development of an indoor guidance app that uses Bluetooth beacons for location and BIM for physical context information. The secondary goal is to obtain information about building utilization patterns, which is not covered in the present research work.

In the proposed app, once the user's current location is obtained through the interception of a beacon region, the user has the option to insert the destination room. The mobile app then calculates the shortest path between the current location and the destination, using a Path Finding Algorithm. The calculated path is shown on the map and is updated step-by-step (when a new beacon is intersected) until the destination room is reached. If the user chooses not to follow the proposed path, the App will recalculate the way to the chosen destination.

Each user role has a defined role as described:

- **End User**: any facility user that installed the Find Me! App on an Android smartphone.

- **System and Database Administrator**: builds or adapts a 3D BIM the model of the building; generates maps and input data to the mobile App, e.g., facility geometry, room, and beacon location; configures and installs the beacons in the facility.

- **Developer**: develops and maintains the mobile App Find Me! code.

The Find Me! project has three main system modules:

- **Beacon Installation Process**: The initial installation starts by finding the minimum number of beacons and their location considering the facility layout extracted from the BIM model. The beacons must be configured, placed in the facility and inserted in the BIM model.

- **Front-end Mobile App**: The user interface (UI) side where the user inserts the Destination, configures Options and receives dynamic orientation: the Map with the optimized path; Crucial Orientation Photos to confirm the user is in the right way.

- **Back-end Mobile App**: Contains a Local Database that stores beacon and room location, automatically extracted from the BIM model. The Beacon Manager scans for beacons and manages data from each intersected beacon signal. The Map Manager manages and configures the map(s) returned to the user interface. Beacon, room, stair, and elevator location and map images are generated by the BIM model and stored locally when the app is installed on the user's smartphone. The Path Finding Algorithm calculates the shortest path between the user and the destination.

3. Evaluation

Every year, ISCTE-IUL receives an average of 1150 new students distributed in sixteen graduate courses and approximately 200 Postgraduate, Master, and Ph.D. degrees. A high percentage of these students do not know how the facilities are organized as a physical structure and when the moment to go to a specific room comes, they need to ask how to get there. After meetings with the ISCTE-IUL Technology and Information department, it was decided and confirmed that ISCTE-IUL is going to be used as a validation approach to this concept.

Building Sedas Nunes, used to test Beacon Placement and described in that section, was also used as a pilot for the navigation. Individual testing was performed from June to August 2018, where new students were asked to use and evaluate the App. We asked these students to find a room with and without the usage of the App. On average, the 50 tests cases show a 30%reduction of time to arrive at the room. Real tests are planned for the start of the next year, where around two thousand new students will arrive on campus and need guidance towards administration, classrooms, etc. At the campus, QR codes will alert the students for App download, and the App will also be used to send context information to the new students.

4. DEMO

In the app demo and promotion video available at https://vimeo.com/303014540 or https://goo.gl/VQt1wG. It is possible to verify the app performance with real-time guidance and environment images and the real-time path update/recalculation as user reaches new beacons in the corridor halls.

5. Major Findings

The major innovations on this work are the process of Bluetooth Beacon placement planning using the geometry of the building which is described by a BIM model, the combination of beacon location information with available buildings maps and information, reducing the tedious task of gathering room information and location. Another contribution of this research work is that user movement can be registered passively (without user identification). This critical information can be analysed to extract knowledge about users' movements inside public buildings. Also, this approach allows a simplified implementation process for indoor location and guidance, where location precision is based on beacon configured propagation radius and location uncertainty (zones without beacons coverage) is handled by building geometry using information of entry and exit points. Between two beacon signal zones, the solution assumes a regular walk based on pre-defined velocity or based on previous user walking velocity.

This approach can be easily replicated in other buildings with the introduction of new maps and calibration of beacons signal range to account to different propagation conditions. Also, there is the possibility of association of information services through the beacons, e.g., beacons near the library may advertise events, canteen menus, available

administrative services, or evacuation guidance for emergency situations. Building changes and constraints (areas under maintenance, room changes, closed exits, etc.) can be quickly generated from the BIM model and sent as an update to the app.

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References

1. Eastman, C.; Teicholz, P.; Sacks, R.; Liston, K. BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors; John Wiley & Sons: Hoboken, NJ, USA, 2011; Volume 2.