i-Locate. A comprehensive solution for indoor/outdoor localization

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Abstract

Indoor localization continues to be a subject of a growing importance. Recent studies prove that on average, we spend about 90% of our time indoors, often in unfamiliar environments. Reaching to a precise target location is a crucial aspect in this process and has a great influence on many simple or complex social daily tasks. The goal of i-Locate project is to enable guidance and other location-based services in indoor environments such as office buildings, airport terminals, hospitals, museums, shopping-malls, etc. To accomplish this, several software components were developed. Indoor positioning technologies were identified, tested, and integrated. The technology was piloted in various locations and contexts in order to ensure a horizontal progress route from concept to service. This article briefly describes the overall perspective of the project architecture and how each component addresses specific issues.

Keywords: indoor; localization; geodata.

1. Introduction

The average time spent indoor in Europe, Canada and US is around 15.7h/day [1]. Even if people are devoted to indoor activities, maps, open data services, location based services and positioning technology are available mostly for outdoor areas. The majority of public indoor areas are large and complex enough to require technological help in navigating and managing locations and places. There are already a few hardware and software systems that that address these aspects, but there are also a number of missing mechanisms or approaches that require serious improvement. The solution proposed by the i-Locate project [2] aims to narrow this outdoor-indoor gap through a complex set of tools. An important component is the map data. It is well known that most buildings do not have available digital maps. To serve this this purpose, we propose a portal for indoor maps, where anyone can upload new maps as well as analyze locations and easily navigate using them. Another important issue is that there are few or no standardized mapping procedures. In those cases, where digital maps are available, they cannot be properly used with the available software, and reading positioning data from sensors is often difficult. By bringing all the pieces together, i-Locate intents to demonstrate the viability of certain methods and formats as well as to set them as standards. Another missing aspect that is not covered by other software solutions is an ecosystem-interoperable component, software and hardware solution, and the associated experience.

By developing, deploying and testing comprehensive indoor location systems, the project brings significant improvement in this area.

The "i-Locate" project has an overall duration of three years starting from 1st of January 2014, and is co-financed by the European Commission through the ICT-PSP programme. The project involves 24 partners from 9 European countries (HR, GB, DE, GR, IT, LU, MT, NL, RO) as seen in Fig 1.
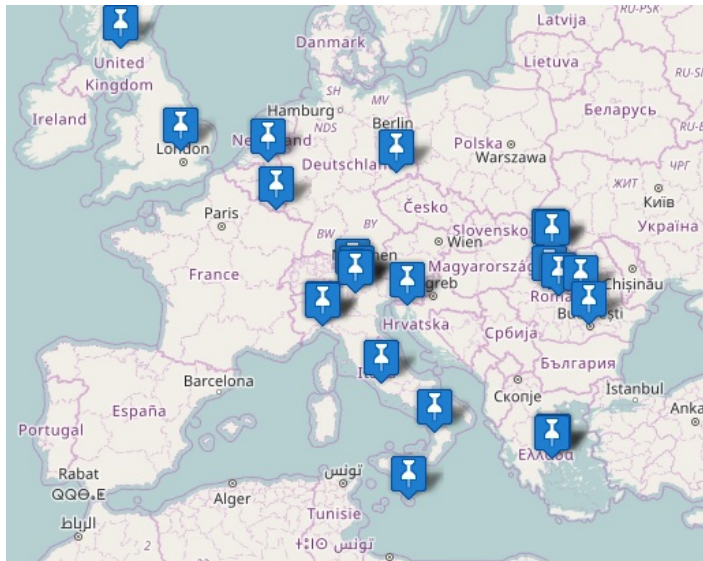

Fig. 1. Consortium partners [2]

The project is now close to the end of the three-year period. Maps have been created, software developed, antenna tags, routers and cables have been installed, interoperability has been achieved and experience has been enhanced.

2. **Components**
2.1. The portal
The portal allows visualization of indoor maps and creation of new ones by users. Visualization can be done through a typical map interface, overlaid on original street map. Furthermore, the location of existing interior maps is highlighted at lower zoom levels. By zooming in sufficiently towards a highlighted spot, a user can see the indoor map of a building stored in the portal. There are separate maps for each floor of the building and the interface allows the user to select which floor to display. This is a compromise between the 3d nature of buildings and the 2d nature of the display screens used when accessing the portal. Visualization of the maps is available to any user, without requiring any authentication or access to an account. Therefore, this information is public.

In order to add new maps to the portal, a user account is needed. There is a sign-up page, but the final step in the process requires the approval of an administrator.

After logging in with a valid account, a user may create a site. A site represents a group of maps, such as all the floors of a building or a group of related buildings. Each user of the portal can create and remove maps from sites created by him. However, sites created by other users cannot be modified.

Maps can be uploaded in the portal in the industry-standard "shapefile" format. This format describes geo-referenced polygons (with geographic coordinates like latitude and longitude), and is therefore the suitable for representing digital maps. The creation of the shapefile maps needs to be done by a user outside the portal, using existing software. Both commercial and open-source software already exist. Uploading and deleting maps is done in a "staging" area of the portal, which allows the user to preview the results without being available to the general public. After ensuring everything is in the correct place, the maps can be published to the "production" area, which means they can be seen by anyone.

In addition to the maps of the buildings, which show the configuration of rooms, hallways, doors, walls, etc., a user can create navigation graphs. These are necessary if the user needs guidance inside the specific buildings. The portal also contains an editor that allows creation of nodes and segments, as well as setting various properties to create a navigation graph on top of a building's map. It also allows file import and export using the IndoorGML [4] format, based on XML and approved by Open Geospatial Consortium. This integration facility allows interoperation with other standardized solutions like CityGML[5, 6] in order to achieve semantic based virtual city models[7].

In the context of IndoorGML, Fig 2. shows an example of semantic description used to qualify the navigational properties of the building elements.
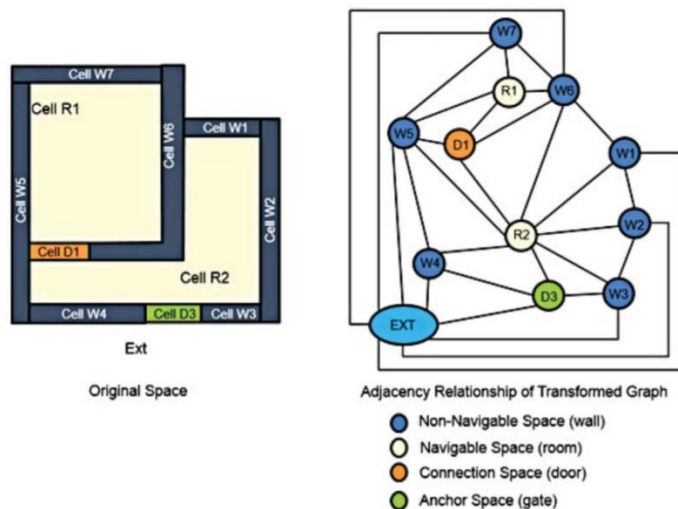

Fig. 2. Example of semantic description inside a building

Besides the user interface, the portal provides web services that are integrated into other components of the i-Locate project. These services allow other software solutions to use indoor maps, navigation data and metadata. An upload/download component is present as well, allowing an application developer to attach arbitrary data to a site and use it on his own purpose.

2.2 Toolkit

The toolkit is another central element of the i-Locate project. The main idea is to provide all the necessary components for building software solutions that offer indoor location-based services like navigation, asset management, etc. The toolkit itself has a number of components, which are all linked together through a communication bus. Noteworthy components are configuration management, indoor and outdoor localization services, a proxy, a routing service and a geo-referencing module.

Indoor and outdoor localization services provide information from various systems. For instance, GPS, Galileo, Glonass offer outdoor location information [8], whereas the Wi-Fi, eeRTLS(Energy Efficient Real Time Locating System) [9] , provide indoor positioning details. Other localization providers can be easily added without changing the code.

The configuration management module provides a way to store and access centralized configuration information concerning all components. This can be useful because the components of a system using i-Locate may not be all on a server, but spread on different servers in different locations, may run on client pcs or on mobile phones, and can include specialized hardware solutions such as a gateway that collects signal data from Wi-Fi or eeRTLS antennas.

The proxy component provides a unique access point and standard interface for all location data, regardless of the type or source: local device, devices installed on-premises, others.

The routing service generates a route plan and corresponding turn-by-turn directions for a trip with given origin and destination location. This can be done seamlessly even if the origin and destination locations are both outdoor and indoor, combining navigation information and simplifying the user experience. It has the ability to generate routes for vehicles, pedestrians, and even combine walking routes with public transportation ones if the necessary data is available.

A geo-referencing module which verifies spatial rules has already been created using certain location information (e.g. entry or exit from a designated area). A location analytics module computes a number of statistics related to the occupancy of indoor spaces. Computed indicators include total dwell time, frequency of visits to a given area, time spent within a given area, transitions among indoor areas etc.

2.3 Mobile app

In order to demonstrate the toolkit's use and the capabilities, as well as to test and improve it, a mobile navigation application was developed. The central goal of the app is to allow users outside the project, such as visitors of a museum, patients of a hospital, or citizens paying taxes at city hall, to see the indoor map of the building they are physically located in, and receive navigation instructions. The app was originally developed as a prototype, and custom versions have been built for each pilot participating in the project.

The functionality of the mobile app has the basic elements needed for navigation. It displays a map with the current location of the user, allowing zoom and pan operations. The map is the freely available open street map, on which indoor maps of sites from i-Locate portal are overlaid. It is possible for the user to search for a given location, either by typing a name for the location, or by choosing from a catalogue of locations specific to the pilot site. For example, all the various rooms in a museum might appear, including the ticket booth, administrative offices, and so on.

Once a destination is selected, the app can search for a route from the current position, either for walking, public transit or driving. Once generated, the route is displayed on the screen overlaid on the map, and step-by-step instructions are given, even voice instructions as the user is traveling along. Step-by-step instructions include notifications that the user should enter a building, go up or down stairs or take elevators. An example of how the user flows for outdoor to indoor is displayed on the smartphone can be seen in Fig. 3
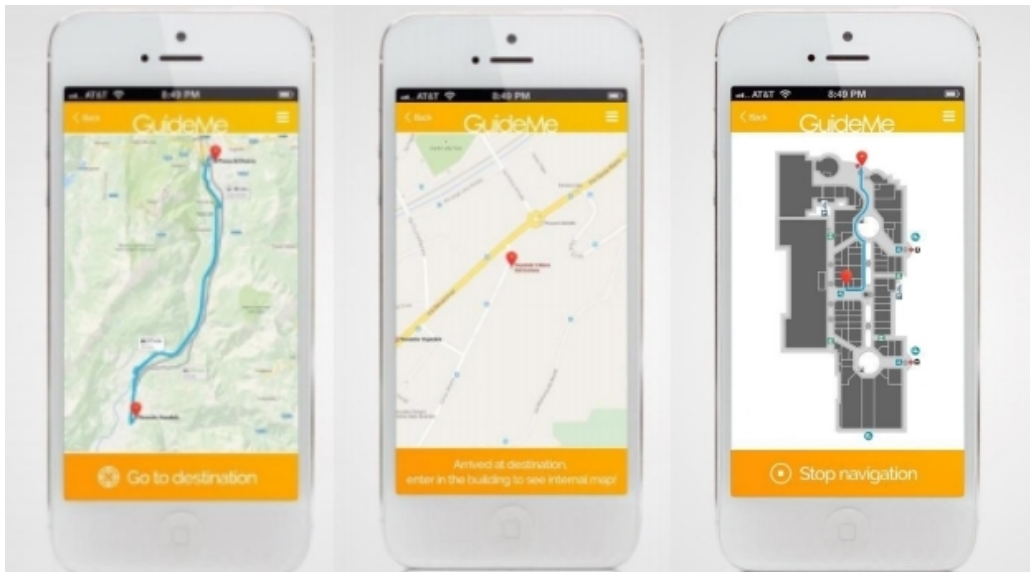

Fig. 3 From left to right: outdoor localization, indoor entrance localization, indoor map

To achieve these functionalities, the mobile application is built by leveraging the other toolkit components: proxy, outdoor and indoor localization, routing.

After a technical analysis on the available tools [11], the mobile app was developed using the Titanium Appcelerator SDK (v.3.4.0) [10], to ensure cross-platform support. In the initial phase of development, and given operating system-level restriction in terms of access to raw GPS and Wi-Fi data (see Outdoor Localization component description above), the development team has decided to focus on Android as target operating system.

2.4 Asset management module

One of the use-cases discussed during the planning stages of the project is an enhanced asset management by adding indoor location data. Web applications that have this feature have been developed for the pilots. The asset management web application displays the indoor map of the building, and overlays the position of assets being tracked in real time. This way, a person can visually identify the location of a needed asset, instead of actually searching for something through the building.

Obviously, this is only useful for mobile assets. The toolkit also offers support by generating alerts when equipment is being moved from a predetermined area, through geofencing. Though not implemented, through the analytics module, the system creates the possibility of retaining a time history of each asset's position.

An asset management service module developed in the context of i-Locate demonstrates how to integrate the service interface into an existing third party solution. The integration allows management of any type of asset, description of procedures and tracking of their execution. The specific integrated legacy solution has two service layers at different levels of abstraction: the lower one provides access to basic objects and it manages persistence, while the second provides further services in terms of intelligence and interaction. Most interestingly, the legacy solution and i-Locate use different technologies and operative systems. Moreover, they have different login systems. For this reason, a specific wrapper has been developed to align both interfaces and authentication processes. This version of the asset management module implements the read-access to class objects, the complete management of asset objects, the authentication module and the access to the indoor localization module. All these functionalities are in fact made available through the version 2.0 of the i-Locate toolkit.

3. Implementations

3.1 Brukenthal Museum

The Brukenthal Museum is one of the pilot locations within the i-Locate project. For the implementation phase, the museum has chosen an area of about 300 square meters. This area covers the entry to the museum, ticket office, and a number of rooms that contain paintings, rare coins and furniture displayed. The use case for this pilot project is user guidance and information. This means visitors can find their way inside the museum using an available smartphone application.

The museum has installed Wi-Fi technology from ZigPos[12] provider that allows indoor positioning using smartphones with Wi-Fi receivers. Antennas have been installed in a

number of key locations on each floor, covering the whole area included in the pilot project. After downloading the specific mobile phone application, a user can see the indoor map of the museum, splinted for each floor, with labels naming each room. The user can see his own location on the map and request directions to a certain room, either by pointing it on the map, or selecting it from a list of available destinations. Once a destination is selected, the user is shown a route, overlaid on the indoor map, updated in real-time, and provided with step-by-step guidance, such as "go down the hallway", "take the door on the left", "go up the stairs". An example of anchor position used during initial analysis which have been identified for the pilot site at the Brukenthal museum, Sibiu, Romania can be seen in Fig. 4

Fig. 4 Example of existing Wi-Fi points at the Brukenthal museum

3.2 Alba-Iulia County Hospital

The Alba-Iulia County Hospital [12] is another pilot deployment. For i-Locate project, the hospital has chosen to implement asset management in the oncology section, which is hosted in a newly constructed building with three floors. The use case is tracking certain medical devices which are mobile and are often being moved around the building. Hospital personnel can benefit from a unified system tracking and displaying the location of all these devices in real time.

The hospital has installed Energy Efficient Real Time Location System (eeRTLS) technology from ZigPos. The system has several components. First, anchors (antenna devices) are placed around the building so that the whole area is covered. Tags are then mounted on the devices to be tracked, identified with a serial number. A gateway device is installed, which collects data from all the anchors, computes positions, and provides

this information. Finally, a web application is available, showing the position of the tags in real time, and therefore the tracked devices, by reading the information from the gateway through i-Locate proxy. Although the gateway is installed in the building, near both the anchors and the users of the system, the web application reads position information through i-Locate proxy. This allows greater flexibility, the option to change some of the system components or technology without rebuilding the project, and integration with other i-Locate modules. Using any web browser, the hospital's employees can access the map of any floor of the building, including the position of the tracked devices drawn on top. Therefore, this feature helps employees locate certain medical devices faster and easier.

3.3 Brasov City Hall

Brasov City Hall is another pilot location for i-Locate project. Due to particular location constraints, the chosen positioning system is QR-codes for QR-code-based localization as described in Fig 5 This also demonstrates the flexibility of i-Locate toolkit, which allows applications to be built on very different positioning technologies. The use case for this pilot project consists in citizen guidance, offering assistance to citizens coming to the city hall to pay taxes, obtain permits or other similar procedures.
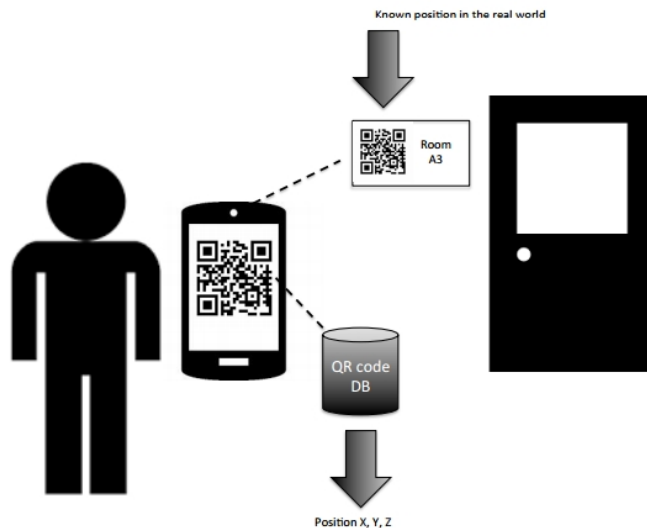

Fig. 5 QR Code position in the real world and correlation with value store in database

A citizen should download i-Locate smartphone application. Once inside the building, the current location of the user can be determined by scanning a QR-code poster with the phone camera. Using the information from the code and by communicating with the i-Locate proxy, the application determines and displays the user's current location overlaid on the map of the City Hall building. The map also displays labels for all the rooms, helping citizens orientate. If necessary, a user can request the app to create a route towards a particular location, either by pointing the destination on the map or choosing it from a list of rooms in the building. When navigating, the user can update the current

location by scanning another QR-code poster located further on his way. QR-code posters are displayed in a number of places in the area of the building accessible to the general public.

4. Conclusions

The i-Locate project has developed and demonstrated a set of innovative tools for indoor positioning as well as a series of services based on this tools such as seamless indoor and outdoor navigation, and real-time asset management. A number of software components have been developed for this purpose and are available open-source, enabling further development of similar or complicated systems in different scenarios. The concept has been piloted in real life conditions, with regular users and clients such as institutions located in public buildings. All the maps for the pilots are available on i-Locate portal, and can be accessed and used by anyone, as open data. We hope this leads to more applications and innovation in the indoor location based services area. The viability of the ideas, hardware and software is now proven. We hope that the experience gained will lead to future expansion of this solution with new components for a smarter city ecosystem.

Acknowledgment

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