QR-Maps: an Efficient Tool for Indoor User Location Based on QR-Codes and Google Maps

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Abstract- **An increasing number of new geolocation services are exploiting the new capabilities of smartphones, most of which incorporate GPS location. There are fewer applications for providing indoor location, partly due to the cost of the required infrastructure. In this paper, we present QR-Maps, a simple and efficient tool that can be used in smartphones to obtain accurate indoor user locations. This tool employs QR-Codes containing a short text which indicates locations shown within a custom Google map. The proposed solution is cheaper than other approaches based on wireless technologies.**

I. Introduction

With the advent of phones with advanced features such as smartphones, a wide range of mobile services have become available to users. Some of these services employ geolocation, which is the identification of the real-world geographic location of an object by means of different technologies. Location estimation is accurate outdoors thanks to GPS, and not so accurate when triangulation of radio stations is used.

Since GPS is not available indoors, many approaches have been proposed to facilitate indoor location based on wireless technologies such as RFID (radio frequency identification), Bluetooth or IEEE 802.11. All these solutions require the deployment of a wireless infrastructure and, in some cases, specific technologies seldom found in smartphones.

In contrast with those approaches, in this paper we present QR-Maps, a simple and inexpensive solution to obtain indoor user locations using QR-Codes (Quick Response Codes) [1] and the Google Maps API [2]. Since a smartphone is available, a QR-Code with a short text can be decoded. This text is sent to a location server, which returns an URL showing the map centered in the specified location. Thus, no special hardware is needed, just a smartphone with enough resolution to depict QR-Codes and with an Internet connection.

II. Background

As mentioned above, most previous approaches in the literature provide indoor location based on the use of some sort of wireless technology such as RFID, Bluetooth or IEEE 802.11.

The RFID system LANDMARC is presented in [3]. It consists of a sensing system for locating objects inside buildings that improves overall accuracy by means of *reference tags*, and demonstrates that this technology is viable for indoor location sensing. Other interesting work is described in [4], where the authors describe an environment that combines both active and passive RFID technology, which supports automatic positioning of mobile devices in closed spaces. This is useful for providing location-aware information automatically. It has been successfully tested in the location and positioning of PDAs.

In the area of Bluetooth applications, we highlight the work in [5], where the authors proposed a Bluetooth Location Network (BLN) for location-aware or context-driven mobile networks and evaluated its performance.

There is abundant research making use of the IEEE 802.11 standard. In [6], the authors presented an indoor location system using a pre-existing IEEE 802.11 wireless network, where location was determined from radio signal strength information collected from multiple base stations at different physical locations. Their experiments indicated high accuracy. In [7], the authors demonstrated that a system based on probabilistic techniques allowed remarkably accurate localization across an entire office building by simply using the built-in signal intensity meter of standard 802.11 cards.

As stated above, the main weakness of all these solutions is that they require the deployment of a wireless infrastructure and, in some cases, specific technology that is seldom found in smartphones. We, in contrast, propose the use of visual QR-Codes and the Google Maps API. No special hardware is required, simply a smartphone with a camera to capture QR-Codes and an Internet connection to access the map.

Barcodes have been adopted universally. For example, in [8], the authors considered diverse labeling technologies, especially 2D barcodes, as well as popular applications, to compare prices on mobile phones. QR-Codes are a type of visual tag, like a 2D barcode, yet they are more efficient than traditional tags and have a much higher information capacity.

Specifically, QR-Codes, as their name indicates, have been designed for fast data retrieval. They also provide error control mechanisms that ensure correct data decoding. They can be depicted on screen or printed on paper. In our case, the basic hardware requirement to work with these visual codes is simply a camera capable of reading them. Although not all

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mobile phones, especially those in the low-end range, include a camera, the number of smartphones is growing. Due to the open QR-code specification [9], these codes can be employed without restriction and for all applications. Many mobile services rely on them [10] [11]; indeed it has been proposed that they should be embedded in images [12], such as those used on printed paper tickets.

In this context, Google recently presented Favorite Places [13]: by attaching a QR-code sticker on the window of a business, potential customers passing by can instantly learn more about it by visiting a mobile version of the business' website on any supported phone. Another application of QR-codes is access control [14][15]. Finally, the research in [16] proposes a new robust color 2D barcode specifically designed for mobile applications to enhance user experience.

Finally, the Google Maps API is a free service that allows developers to integrate maps and geocoding from the Google Maps service (as well as other content from Google) into their websites or applications, with their own data points. It also allows the use of custom maps. Creating a customized map interface requires adding the Google JavaScript code to a page, and then using Javascript functions to add points to the map. Google Maps actively promotes the commercial use of its API. Real estate mashup sites were the first large-scale adopters, but since then, this API has been used to create mashups in a range of areas: traffic conditions, gas prices, earthquakes, places of murders, etc.

To conclude, we can say that, to the best of our knowledge, there is no other research on a solution for indoor user location using QR-Codes.

III. SYSTEM DESCRIPTION

Our model is composed of four basic elements:

1. **QR-Code**: A small label usually placed on a wall containing the name of a map and a number indicating the location inside that map.
2. **Smartphone**: an advanced mobile phone capable of decoding QR-Codes, with a connection to the Internet.
3. **Location server**: a Java server containing all the map locations in XML. The smartphone requests information from this server, such as the URL associated with a specific map and location, or all the different possible locations in a map.
4. **Map server**: a web server containing all the custom maps using the Google Maps API. The smartphone requests all the maps with their corresponding tiles from this server.

Figure 1 shows our model. A user that arrives at an indoor location and wishes to know where he/she is just needs to locate a QR-Code and decode it with the QR-Maps application in the smartphone. This QR-Code contains a short text indicating, first, the specific map associated with the current

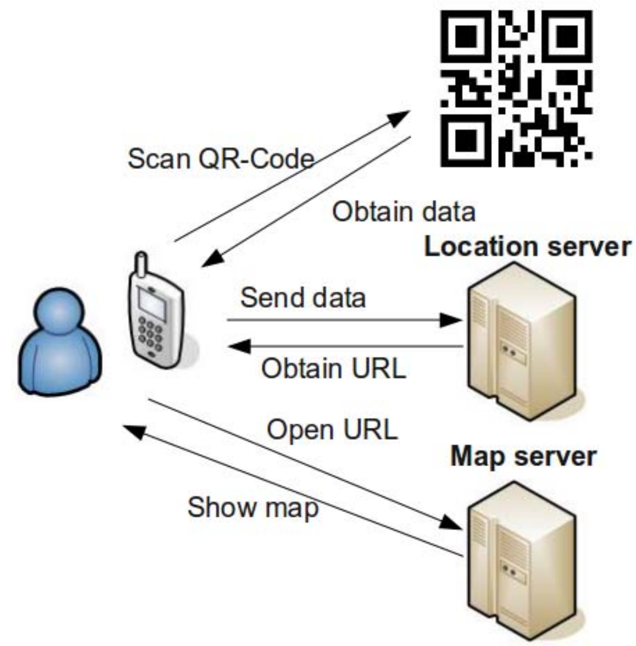

Figure 1. QR-Maps system model

indoor location, and, second, a reference to the position inside that location. As an example, the QR-Code in Fig. 1 contains the text "teleco#7", where "teleco" indicates the map corresponding to the Telecommunications Engineering School, and "7" is the specific location in this map.

With this information, the QR-Maps application in the smartphone can issue a request to the location server. This server is written in Java, and it parses information about the map and its locations in an XML file. This file contains one entry for each of the different maps. Each entry is described by:

- Full name of the map.
- Abbreviated name of the map.
- Number of floors in the map.
- Number of different locations in the map.

Each map entry contains all the locations in that map. These locations are described by:

- Type: whether they are (1) a location, (2) elevator or stairs to go up, or (3) elevator or stairs to go down.
- Floor: the floor the location is on.
- Longitude of the location.
- Latitude of the location.
- Name of the location.

The location server receives UDP packets from the smartphones indicating the type of request and its parameters. With the request and the information obtained from the XML file, the location server responds with an UDP packet with the specific URL for the request. The QR-Maps application opens that URL in a browser. The URL belongs to the map server, and it shows the map of the indoor location, centering the map in the current position indicated by a marker.

Once the user has accurate information on his/her current location, he/she can use the QR-Maps application to locate other points of interest in the map. To know these points, the application issues a request to the location server for the list of all the points in the map. Once a point of interest is selected, the application issues another request to the location server indicating the current location and the selected point of interest, and obtains the specific URL that shows a centered map with the current position and the selected point of interest.

If the selected point of interest is located on a different floor, the location server calculates the closest available stairs or elevator, and returns a URL with a map displaying the shortest way to change floors.

The QR-Maps application also allows the user to navigate across a map and select points of interest without staying in the indoor location, in order to, for example, know the location of shops in a mall before visiting it.

IV. Design Considerations

QR-codes have been specifically designed for fast information transfer. They provide efficient error correction when the code is damaged in any way. QR-code data retrieval depends on factors such as camera quality, picture angle or luminosity, as well as on the area of the code [17]. Thus area depends on the size of the data. In our case data size is minimal, just a short text identifying the map and the location, which corresponds to a small QR-Code that can be placed on any wall or displayed on any screen with negligible aesthetic impact.

The design choice of a location server allows us to change or add/eliminate locations in the map, to change the resulting URL without needing to generate a new QR-Code or to reuse the QR-Code for a different location. The location server also eliminates the need to store all locations in different maps in every user smartphone. When a location is needed, the smartphone just issues a request to the location server indicating the desired map.

Using the Google Maps API to display custom maps simplifies the design of the maps server, as all it requires are the custom maps, with the different tile sizes, to permit typical interaction modes: zoom, moving across the map, placement of markers in interesting locations, etc.

V. Implementation

We have developed a prototype of QR-Maps for Android [18]. For this purpose, we used the ZXing open-source 2D barcode development library [19] for QR-Code decoding. As smartphone hardware, we selected an Android Dev Phone 1 terminal with SDK version 1.6. As the server, we used a computer with Ubuntu 9.10 and an Apache web server. To obtain the custom map, we employed MapTiler [20], a graphical application for online map publishing. It allows the creation and publication of maps as overlays of standard maps such as Google Maps. The user simply uploads the automatically generated directory with tiles to the webserver. We used six different levels of zoom for the maps.

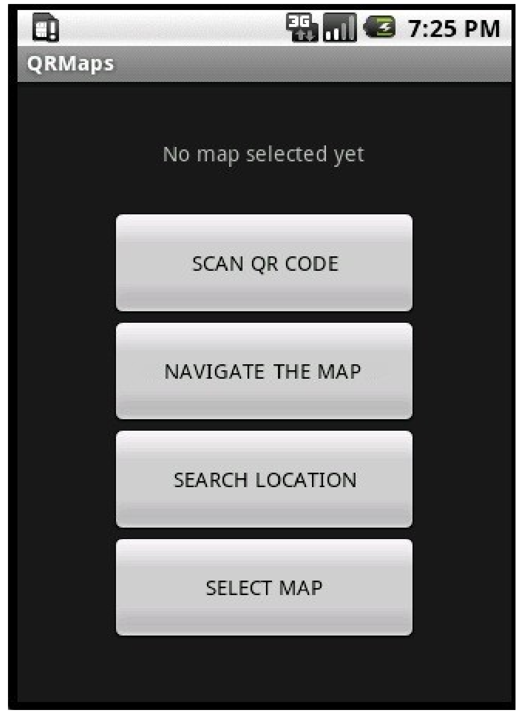

Figure 2. QR-Maps application menu

The QR-Maps application menu is shown in Fig. 2. The user has the option to scan a QR-Code in the indoor location, navigate the currently selected map, search for a location in the map or select another map. In this snapshot, we can see that no map has been selected yet.

Once the user has scanned a QR-Code in the indoor location, a map is shown (see Fig. 3) with the current position of the user, shown as an android marker. We can see that the interface is Google Maps, meaning that the user is able to zoom, navigate, etc. In the top right corner, there is a drop-down list that allows the user to select the different floors of the indoor location (see Fig. 4).

Once the user position is available, he/she can see a list of points of interest in the current map and select one. A map showing the current position of the user is then shown (see Fig. 5). The destination is displayed as a checked flag marker. If the destination is on another floor, the map shows the closest stairs or elevators, identified by a checked flag marker (Fig. 6), and the android marker shows how many floors the user has to go up or down in a balloon.

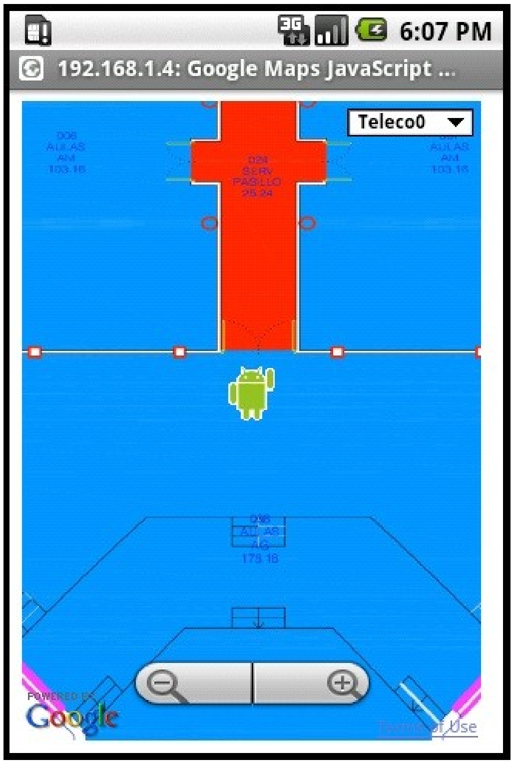

Figure 3. Current location in the map

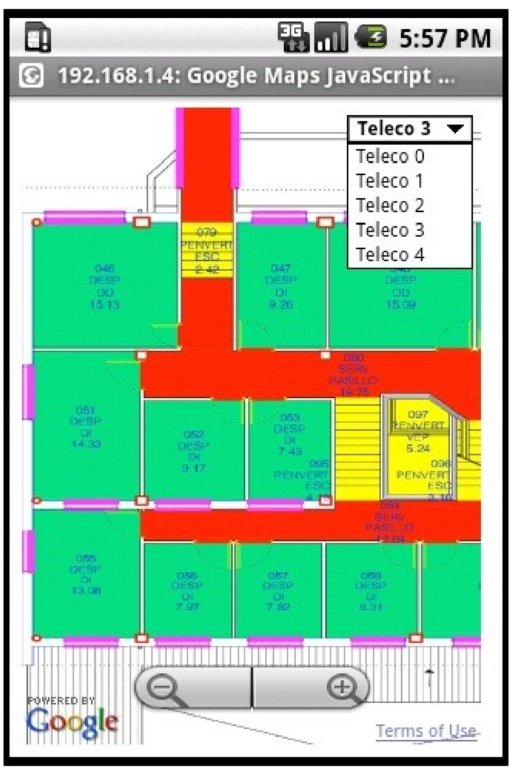

Figure 4. Floor selection

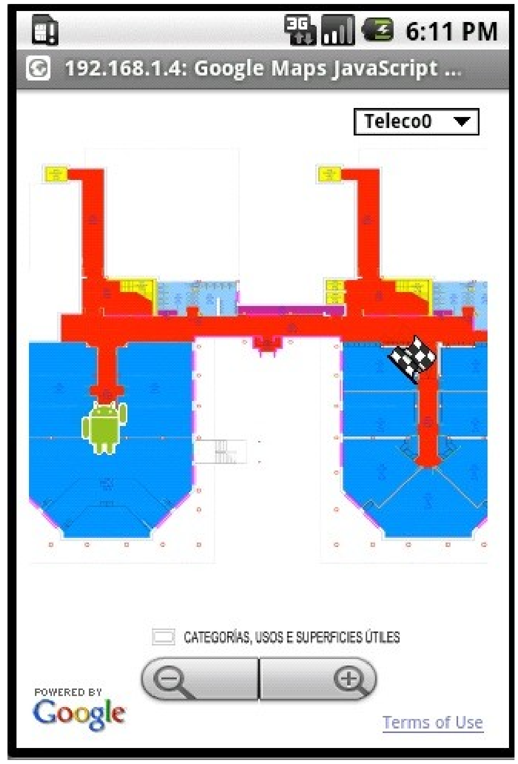

Figure 5. Current location and destination

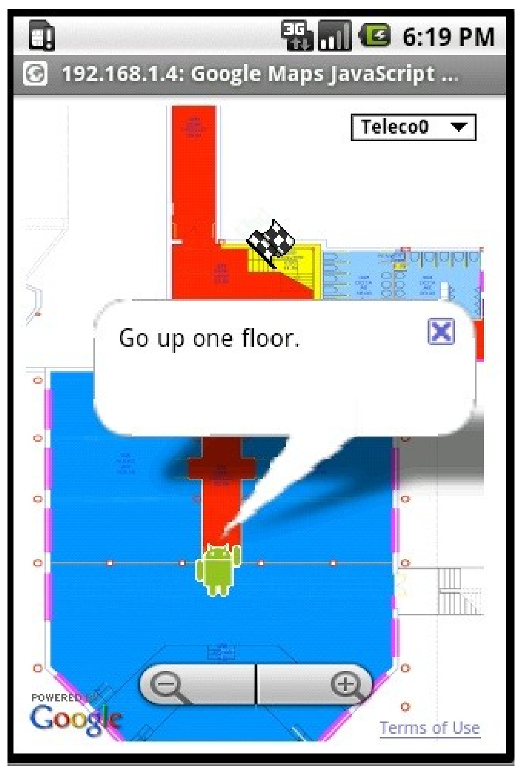

Figure 6. Destination on another floor

VI. CONCLUSIONS

We have developed the QR-Maps tool for indoor user location without the need for supporting wireless technology. This simple tool employs QR-Codes to obtain the current position of the user. Once that position is available, with the help of location and map servers, the tool displays a custom map for the position using the Google Maps API. It also helps to find points of interest, and shows users how to reach them within the map.

As future work, we intend to use smartphone compasses to direct the user to the destination. With the help of accelerometers, it will also be possible to estimate walking distances as auxiliary information.

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