A Geocoding Framework for Indoor Navigation based on the QR Code

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Abstract—*Currently, indoor navigation has become a hotspot in the field of Location Based Service. However, there is no universal model to geocode and locate interior facilities. In this paper, the indoor space is constructed of three layers, including venue, room, and POI. Then a geocoding framework is proposed to encode each POI as a code including three parts, namely partition number, functional number and connectivity number. In contrast to most indoor navigation methods which use WIFI or RFID would necessitate extra cost of money, manpower, and maintenance, we take advantages of QR code, which is money saving and convenient, to restore the location information. Taking the library of Wuhan University as a sample area, a prototype implementing our method for indoor navigation is generated. On this basis, a mobile navigation electronic map is developed and implemented, which can provide services of indoor positioning and optimal path push in the library.*

Keywords—indoor geocoding; QR code; indoor navigation; optimal path; library

I. Introduction

With the advanced locational technologies and the power of the mobile devices, numerous location-aware services are available in our ordinary daily life [1]. Global Positioning System (GPS) has been widely used in most outdoor navigation since it can provide the location information with a high precision in real-time. Nevertheless, GPS has its own weakness and faces challenges in indoor positioning. Due to the fact that GPS signal is restricted by buildings [2], some research-based and commercial indoor navigation systems were implemented utilizing wireless and electronic sensors to find out the solutions [3], [4]. For instances, RF (radio frequency) ultrasound, infrared, vision-based systems and magnetic fields technologies can be applied in both indoor and outdoor navigation [2], [5], [6]. Though these technologies can provide high precision in some aspects in indoor positioning, they necessitate extra cost of money, people, and maintenance.

Noticed that QR code is well known around the world for its convenience, safety, and ease of use, we developed QR code with geo-location information in our research [5]. There are two different ways to restore geo-location information using the QR code. One is to encode the information into QR codes as a unique URL. Then, by scanning the QR codes, users can easily obtain the encoded information from the Internet. While the other is to provide decoders on the client so that QR code could be decoded and information can be extracted offline [6]. In our research, both are implemented.

Different from the outdoor space which always uses geography coordinate system to define the location, indoor space is formed by various rooms and corridors, which is hard to locate just according to coordinates. There are three viewpoints to build an indoor spatial data model, including geometry space, symbolic space and network connectivity space [7]. The first approach mainly focuses on the geometric representation of indoor features, such as the boundary representation models [7]–[9] or tessellation models [10], [11]. such method allows us to understand the shape inside the venue intuitively, but it is not conducive to positioning and navigation for its lack of route representation. The second one symbolizes the location units with tags, like “room1”, “room2”. In this way, the semantic information is stored in the text, and the natural language is transformed into text information, which can be stored in other media. The third approach uses a topology map to display the connectivity between objects, by which the spatial relationship between different indoor objects can be demonstrated, and route guidance and navigation can be carried out.

From a perspective of symbolic space, each area and object could be demonstrated as a symbolic code with location information and attribute information. QR code could be used for encoding the POI with attribution restored. In the meanwhile, to navigate from one point to another, a network space should also be generated. Currently, the main framework combining both symbolic and network space is Indoor GML [12]. IndoorGML is an OGC standard for an open data model and XML schema for indoor spatial information, which aims to provide a common framework of representation and exchange of indoor spatial information. IndoorGML is based on the requirements from indoor navigation due to strong and urgent standardization demands, such as indoor LBS, routing services, and emergency control in indoor space. The version 1 of IndoorGML uses a node to symbolize a cell (an indoor space surrounded by architectural components) and uses edges to symbolize walls and doors, which lack the information of indoor facilities[13]. Thus, it’s not suitable for QR code positioning because it cannot locate a POI position in a cell precisely. A new framework of indoor geocoding is still needed.

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In this paper, we propose a geocoding framework to organize the spatial data for indoor navigation. Special focus is laid on the encoding ruler that present the indoor information in the manner of QR code. A prototype system based on this geocoding framework has been developed taking the Wuhan University Library as an example. The primary experiment shows that the proposed geocoding framework has a bright prospect in indoor navigation application.

II. METHODOLOGY

A. *Geocoding Framework based on QR Code*

The indoor space can be decomposed into series of objects hierarchically, namely venue, room, and internal POI. Each venue contains a set of rooms. A room can refer to either a storey, corridor, or a reading room in the library. Namely, the room is a basic functional division in an indoor space. Internal POI is the smallest functional units in a room, like an information desk, a restroom, a door and a stair that can link the room to another room or corridors. Figure 1 shows an example of the three layers of objects in our geocoding system.

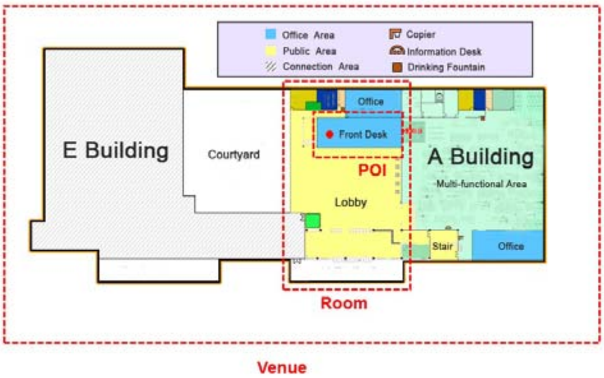

Figure 1 The hierarchical structure of indoor space

When people enter into an indoor environment, they always need to navigate to some specific functional areas, which corresponds to specific internal POI. A movement in indoor space could be demonstrated as a directional connection between two POI. By connecting all different POI in the whole venue based on the connectivity, a route map could be generated for navigation. Therefore, that is why POI is used as the key research object in our study., and location information at each POI are recorded in form of the QR code. In our geocoding framework, a code contains three sections: (1) partition number, which demonstrates the venue partition, (2) functional number, which illustrates the function of the POI provided to the users, (3) connectivity number, which indicates doors and stairs that link to different areas.

(1) partition number: one capital letter (A-Z) and a number. Large venues always have an official partition to distinguish different areas, so this number can identify the official partition number, which is in accordance with our human's cognition. For example, the library of Wuhan University has five partitions(A-E), and each room is named by its belonging areas and an identification number, like A1, A2, B1.

(2) functional number: A unique number recording the function types of the area. This field aims at helping people to find a specific functional area efficiently in a large venue with various kinds of POI. For a specific venue, we can create a specific function list by enumeration.

Each number in this list can correspond to the same kind of POI positions distributed in different rooms. When users are retrieving a functional area, all satisfactory POI will first be found and then the nearest one will be displayed on the screen.

(3) connectivity number: A capital number "D", "S", or "N" to demonstrate the POI is a door, a stair, or neither of them. And then followed a number to identify the same kind of POI in the same room if needed. This field is created to demonstrate the connectivity between different areas. A door can connect two rooms on the same storey and a stair can connect two storeys in the same building. Thus, these points are key points to construct a topology map in a whole building. If a room has several doors, we can number them sequentially from the northeast corner in a clockwise direction.

B. *System Design*

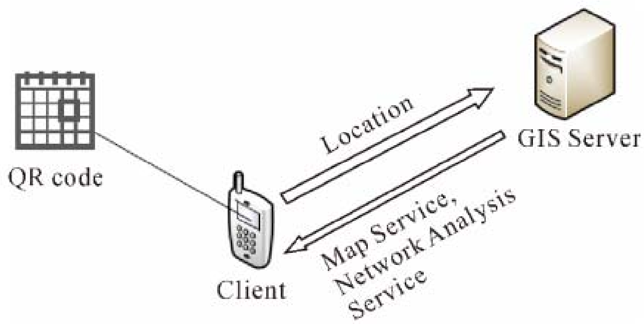

Figure 2 System structure

Figure 2 shows an overview of the system design of our QR code-based indoor navigation system. The system has three components: GIS server, which stores the indoor map and network information; client, so that user can send their location to the server and get navigation; and QR code of at an inner space. Each building could be geocoded based on each room's type, floor, and attribute. Users could scan QR code in any position, and the code will be decoded so that user can get his location.

III. CASE STUDY

Taking Wuhan University Library as an example, we created a prototype of indoor navigation system using the proposed geocoding framework and system design. For each POI in the library, the corresponding QR code was generated. These POI were then used as connecting nodes to establish a network map for the whole venue. When a user scans the QR code at the

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starting point and designates an ending point through a fuzzy query or precise query, an optimal path can be calculated automatically and returned on the screen.

A. Geocoding Framework of Wuhan University Library

Wuhan University Library is one of the largest libraries in China with more than 6,870,000 books reserved. It has a total of six floors, each of which consists of five areas named A - E. For the first step, each place available is abstracted and represented by a POI and its location and attributes are recorded. In the next phase, we classified the type of POI based on its attribute. Table 1 shows the result of the category of POI in Wuhan University Library. It can be shown that there are 29 function areas in the library.

Table 1 Category of POIs in Wuhan University Library

Function Area	Code	Function Area	Code	Function Area	Code
Book Lending Area	01	Self-study Area	11	Ancient Books Stack	21
Official Area	02	New Book Exhibition Area	12	Wuhan University Stack	22
Front Desk	03	Group Study Room	13	Liberal Arts Chinese Stack	23
Gate	04	Second Training Room	14	The Republic of China Document	24
Service Desk	05	Individual Study Room	15	Liberal Arts Chinese Reading Area	25
First Training Room	06	Media Reading Area	16	Toilet	26
Physical Area	07	VIP Room	17	Main Hall	27
Electronic Reading Area	08	Librarian Studio	18	Liberal Arts Reading Area	28
Multifunction Area	09	Office	19	Academic Report Hall	29
North Entrance	10	Liberal Arts Center Stack; Preserved Liberal Arts Stack	20		

Based on our geocoding rules, each POI could be encoded well. For example, for the front desk in the first floor located in the A area, the partition number is A1. Then retrieving from

Table 1, the functional number is 03. And since there is no connectivity door or stairs for this POI, the connectivity number is N. Therefore, its overall geocode is A1-03-N. Another example, for the east door in the book lending room on the second floor of B building, the partition number is B2, and the corresponding functional number is 01. This door is the second door counting from the northeast corner in a clockwise direction, so the connectivity number is D2. Therefore, this POI could be encoded as B2-01-D2.

B. Indoor Navigation Application Development

According to the system design introduced in section 2, an indoor navigation application is developed. The data of the map of Wuhan University Library, including POI, rooms, venues, linking routes and base map, are stored in the cloud service using ArcGIS Server. Users could access map through map tile service. In order to find an optimal path between two POIs, either on the same floor or on two different floors, network analysis service is published and could be called by the client.

After scanning QR code at the POI, the system will match the POI restored and then get the attributes of the POI. Users can select the starting point and the ending point for navigation. There are two conditions and could solve in different ways. If the starting point and the ending point located on the same floor, then utilizing network analysis with ArcGIS SDK for Android, which could compute the optimal path shown in Figure 3. If the starting point and the ending point are not on the same floor, the system will search for the nearest stairs of the starting point using DFS algorithm. After that, the system will find the corresponding stairs on the floor of the ending point. Finally, calculate the shortest path for generating the optimal path.

Figure 3 Optimal path computing

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IV. CONCLUSION

In this paper, we proposed a geocoding framework for indoor navigation and generated a QR code-based indoor navigation system. In our framework, internal POI is the basic functional unit and could be encoded as a geocode containing three sections: partition number, functional number, and connectivity number. Based on this geocoding framework, each internal POI could be encoded and restored in a QR code, which could provide both location and attribute information (functional information) of the inner environment to meet people's needs for navigation. The case study shows that our QR-code navigation system could be implemented successfully in managing information of indoor facilities and indoor navigation.

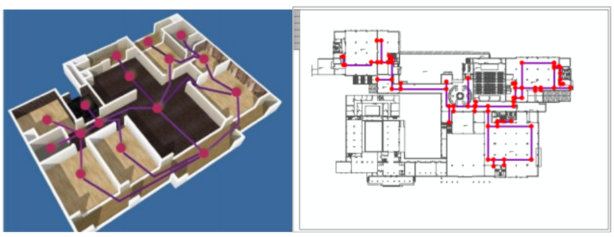
V. DISCUSSION

As indoor navigation is increasingly popular today, QR-code positioning distinguished as an excellent indoor navigation method with its advantage of saving money and manpower. QR code can be updated at any time and displayed on electronic screen. Users only need to scan the QR code at the starting point and would obtain the path to the destination easily.

However, there is still lacking of a framework that can describe and record information on the location, properties, and connectivity of indoor facilities. IndoorGML, as a currently most general framework, is also not suitable for positioning due to its lack of indoor facilities' information and the inability to locate POI.

As shown in Figure 4, the framework proposed in this paper expands the IndoorGML model, using each point to represent a POI (indoor facility) rather than a room, and the connecting lines between points represent connectivity. At the same time, for each POI point, a simple three-section code is used to encode the information. The encoding includes information such as location area, functional attributes, and connectivity between POI. This method can well support indoor positioning and navigation.

In the future, we will explore the substance of IndoorGML and try to expand the part of Multi-Layered Space Model in IndoorGML, thus developing our QR-based framework as a supplement and extension of the current IndoorGML model.



(a) (b)

Figure 5 Comparation of IndoorGML (a) [13] and our framework (b)

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