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enRoute: An Indoor Navigation Application Using Digital Signage

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Navigation tools such as paper maps, vehicle navigators, and map applications have long been essential in our daily lives. For the outdoors, a GPS is used to navigate between two points. However, GPS technology does not work well indoors, and we have a weaker sense of direction when inside buildings. In particular, with the increase in the number of large-scale buildings, people more often have to navigate complex indoor spaces. To achieve indoor navigation, we need to know our current location, the intended destination, and the correct route. We can determine indoor reference points by using Bluetooth Low Energy (BLE) beacons as well as digital signage, which is widely used indoors for promotional and informational purposes. An indoor navigation system consists of digital signage, pre-installed BLE beacons, and a mobile application. When the mobile application computes the shortest path from the current location to the destination, a step-by-step navigational instruction graph is shown both on users' phones and on nearby digital signage until the user reaches the destination. We conducted an experiment and survey to understand users' attitudes toward the application. The result shows that most subjects find the system useful and easy to use and hold a positive or neutral attitude toward continuing to use it.

1. Introduction

GPS technologies, smart devices, and navigation applications address difficulties in finding our way around. After entering a destination on a map application, the traveler receives directions for the shortest route to the destination. However, such systems are based on satellite positioning technology, which does not work well inside buildings. With the increasing number of large-scale buildings, indoor navigation has become even more essential than before. Taipei Main Station is a good example here. Even though the government has been trying to improve its system of directions, Taipei Main Station is still a place where people get lost easily.

In this paper, we propose an indoor navigation system comprising a mobile application (enRoute), digital signage, and Bluetooth Low Energy (BLE) beacons. A BLE beacon broadcasting signal is installed behind every digital sign. When a user walks by a digital sign, enRoute senses the beacon's broadcast and also finds the nearest beacon to determine the user's

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position. We use digital signage because it can be installed throughout the building, is able to display crucial information, and is easy for users to read. When a user chooses the destination, enRoute finds the shortest route in reference to the user's current location and guides the user to the next sign along the route. The navigation instructions are shown not only on the enRoute app but also on the nearest digital sign, so users do not need to continually check their phone. Furthermore, the information shown on the digital signage can be customized depending on the set preferences of the user walking by, making the communication of information more effective.

2. Related Research

The user's position can be calculated by referencing a signal and the base station from which the signal is transmitted. In contrast to indoor positioning, outdoor navigation uses positioning satellites. This is because indoor positioning can be affected by indoor structures and signal attenuation, especially in multi-story and larger buildings.(1,2) To improve the accuracy of indoor positioning while considering factors such as time and money spent, researchers have proposed various hardware and software solutions.(3) Possible hardware solutions mostly involve different sensors or wireless technologies, including BLE beacons, Wi-Fi, radio frequency identification (RFID), IR, ZigBee, ultrawide band (UWB), LEDs, and geomagnetism.(2,4–6) Other researchers used software and algorithms to compute or improve the accuracy of indoor positioning and navigation.(4,6–8) In 2001, Butz *et al.* proposed a hybrid indoor navigation system using information booths, smart devices, and mounted IR transmitters.(6) This system provides a framework from which to generate accurate graphics for different output devices by referencing conveyed information and working within the device's specific display capabilities. It also draws on incoming orientation and positioning information to improve readability while the user is moving.

Gozick *et al.* proposed that magnetic field fluctuations can be used to identify the user's position inside a building if magnetic readings are collected and maintained.(7) Moreover, landmarks and guideposts can be marked on magnetic maps using these readings, which can complement existing visual maps. Since magnetic maps are purely digital and independent of the sensitivity of the sensor being used, they are suitable for an autonomous robot.

Gunagwera and Kiani proposed a low-cost indoor positioning system for both visually and physically disabled people.(8) The system is based on Wi-Fi fingerprinting and sensor fusion and can also be used for emergency evacuations. Dong *et al.* proposed a system called ViNav, which is based on visual and inertial sensor data collected from smartphones.(9) ViNav is scalable and cost-efficient for indoor mapping, localization, and navigation, and it uses crowdsourcing to reconstruct 3D models indoors. In addition, ViNav implements image-based localization that identifies users' positions and facing directions.

BLE technology is also frequently used in indoor positioning and navigation systems.(10–12) A BLE beacon is used for transmitting data over short distances with the benefits of low power consumption, low cost, ease of installation, convenience, and bandwidth. Sukreep *et al.* developed an indoor position detection system using pre-installed beacons for positioning in a smart home environment. This application can also be used on a smartwatch as a personal emergency response system for elderly people.[12] In addition to indoor positioning, this system is also designed to monitor users' behaviors and track their time spent in a specific area. Therefore, the system is suitable for hospitals or health centers.

3. System Analysis and Design

The BLE beacon system has definite advantages, such as being low-cost and easy to install. With careful planning and proper installation, it can be used throughout an entire indoor environment. Smart phones are the most popular navigation device; however, reading a phone while walking is not safe and should not be encouraged. For this reason, we provide an alternative display by using digital signage.

3.1 System architecture

In this section, the requirements and functions of the system for indoor navigation are introduced. For navigation in a large, complex building, floor plans and arrow signs are the usual aids. However, neither floor plans nor arrow signs provide sufficient information to navigate from one place to another. For the navigation process, we need to know the current location, destination, and route. To know the location, we need a position reference point. Since digital signage is used throughout the building, we install a beacon behind each digital sign. Therefore, a beacon and signage can work together, with the beacon sending signals and the signage displaying information.

A mobile application called enRoute has been designed through this research. When enRoute senses the nearest beacon, the application determines its current location. Throughout the navigation process, the application computes the shortest path between the current position and the destination. Navigation instructions are shown on the user's mobile phone and on nearby digital signage. This system architecture is illustrated in Fig. 1.

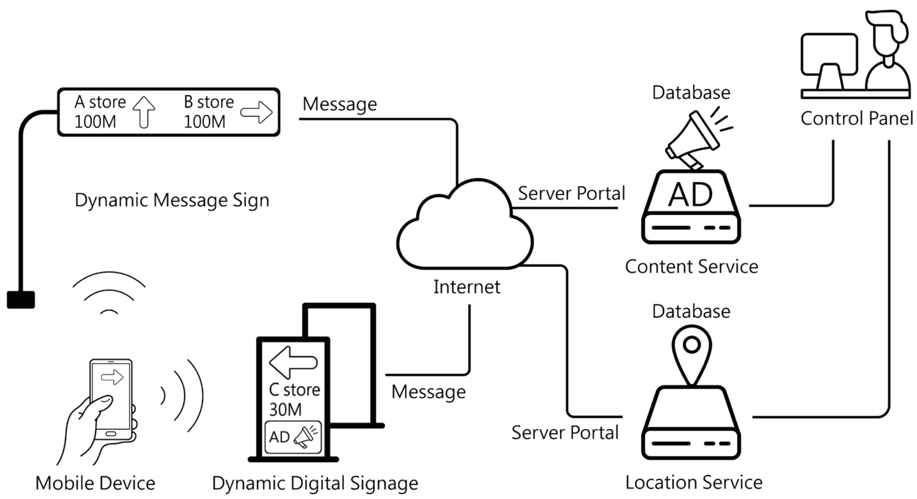


Fig. 1. System architecture.

3.2 System analysis and functionalities

This system comprises a client application, a digital signage application, and a content provider.

(1) EnRoute as a client app

EnRoute is an Android-based application and is the client's app in this system. The app detects BLE beacon signals hidden behind nearby digital signage to determine the user's current location.

Dijkstra's algorithm is employed by the application to calculate the shortest route. Shortest path planning is the primary function of this navigation system. Once the application knows the user's intended destination and the location of a nearby digital sign, it will use this algorithm to calculate the shortest path and obtain the location of the next closest digital sign along the route. The result is then uploaded onto the server. After receiving the results, the nearest sign shows an arrow that leads the user to the next sign. As the cycle continues, the user finally arrives at the destination. Dijkstra's algorithm divides the area into several nodes, i.e., beacons in this study. After obtaining the starting point and ending point, the program compiles a list covering all the beacons on the route. An index value in the list represents a node, which stores information about the shortest path to the starting point. After accessing different node paths, the program computes the shortest route and updates the list when a shorter path is found. The cycle repeats until all nodes are calculated. The shortest path is now within the generated list.

(2) Digital signage, beacons, and proximity

Digital signage and beacons are used for determining position and proximity. A beacon is designed for low energy consumption and short-range transmission. It constantly broadcasts a signal containing at least three fields: universally unique identifier (UUID), Major, and Minor fields. These three fields can be customized to identify unique locations within the building. For instance, the UUID might be the building name or number, Major might be the floor, and Minor might be the room number. When enRoute senses the closest beacon signal, the tuple (UUID, Major, and Minor) reveals a unique location within the proximity algorithm.

Digital signage, which is primarily used for advertising, is an efficient communication medium in place of bulletin boards for showing directional information in each step of the navigation process. Digital signs functioning as nodes in an indoor space serve as agents for interior navigation, and together with the appropriate beacons behind these signs, they form an indoor navigation network. When users stand close to the digital signage, they can obtain their current location, next move, and which direction to go by following the arrows on the signs until they arrive at their destination. A schematic of the system is shown in Fig. 2.

(3) Firebase as a cloud service

Firebase is the content provider usually used in this system to store user information, signage data, beacon data, and advertisement content. After the user enables Bluetooth and internet connection on their mobile device, the digital signage receives data from the server and shows directional arrows. enRoute sends a query including the beacon tuple (UUID, Major, and Minor) and user information, and receives results. Firebase also updates the content system so that the corresponding digital signage shows the correct messages and directions for the user.

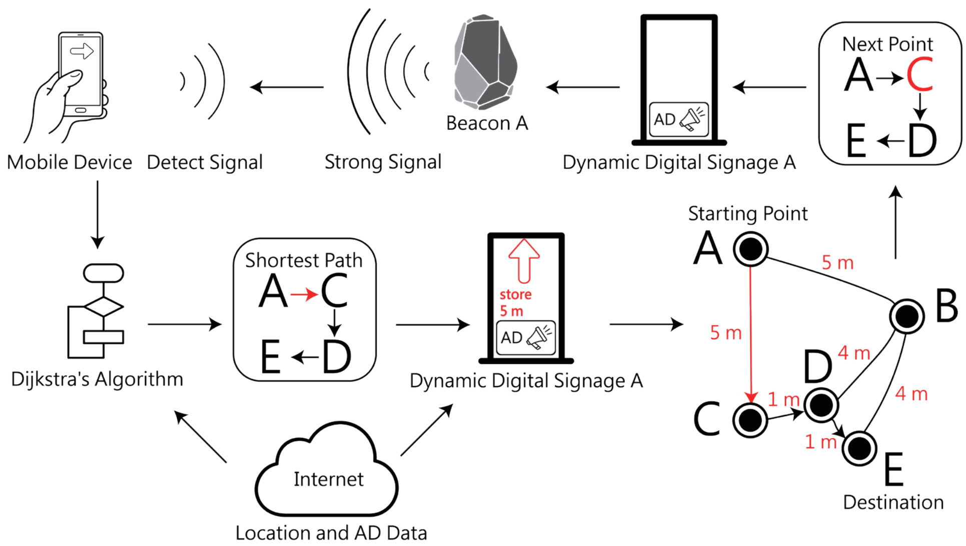


Fig. 2. (Color online) Schematic of system.

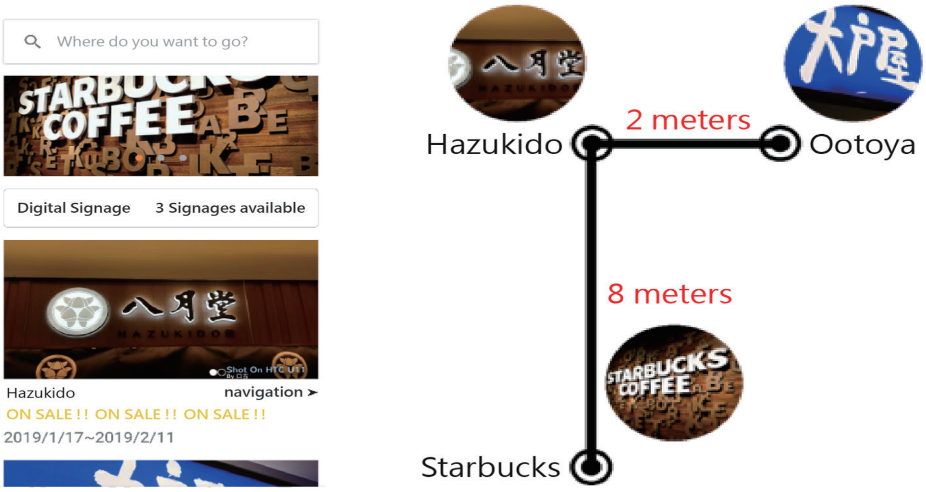
3.3 System implementation

To use the navigation app, the user must first register or log in to allow the recommendation system to learn the user's preferences, which are all stored on the cloud. To enable all features of the app, the user must grant permission for access to location services and Bluetooth on their Android phone. Thereafter, the phone detects the nearest beacon and matches the UUID, Major, and Minor of the beacon with the data stored in Firebase, thus determining the beacon's location and showing the results on nearby digital signage as well as on the application interface.

Upon opening the app, the system displays a list of suggested locations and information for the first-time user. Every time the user selects a new location after that, the user's favorite locations are marked and a list of preferences is compiled. The list is then used for later recommendations. Keywords regarding the descriptions, features, and categories of the user's selections are considered as this list is compiled.

Content that best meets the user's interests is displayed on the main page of the application [Fig. 3(a)]. Content and images from the locations are retrieved from Firebase in real time in the form of streaming data. For example, when a store launches a promotion, related information in Firebase is updated automatically.

Assume the user is at Starbucks and wants to go to Ootoya [Fig. 3(b)]. After the application detects the beacon at Starbucks, it downloads data from the cloud and calculates the shortest path using Dijkstra's algorithm. Navigation instructions including direction and distance are shown on the application. At the same time, these results are uploaded to the Firebase data store. Corresponding digital signage shows the correct navigational arrows. As shown in Fig. 4, the arrow points to the right, indicating that the user needs to turn right at Hazukido. With this design, the user does not have to keep looking at their phone; they can focus only on the digital signage. When the user arrives at Location 2, the same process is repeated to update the directions and lead the user to Ootoya (Fig. 5).



(a) (b)

Fig. 3. (Color online) (a) Main page with recommended information and (b) finding route from Starbucks to Ootoya.

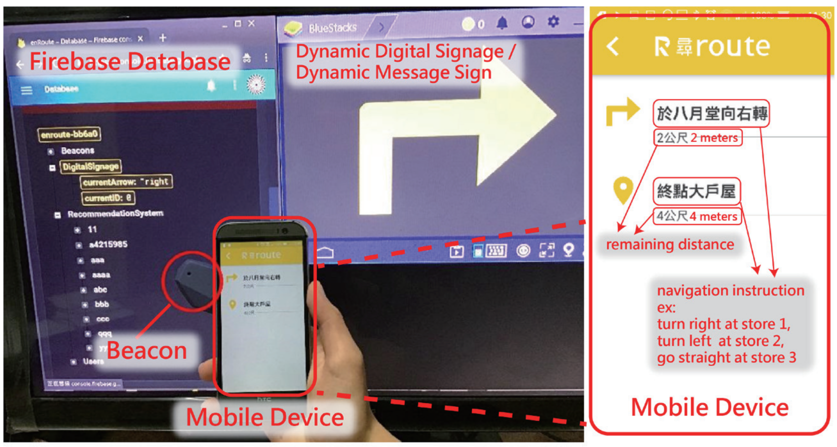


Fig. 4. (Color online) Navigation in progress (left: digital signage; right: app).

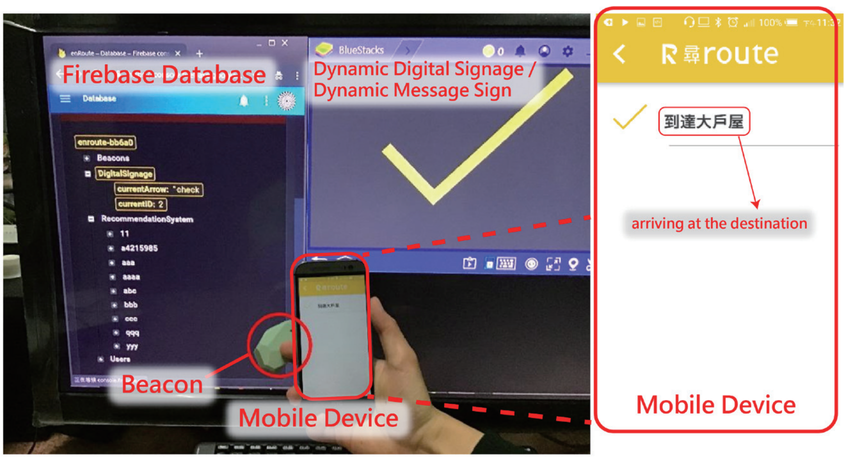


Fig. 5. (Color online) Reaching final destination.

4. Technology Acceptance Model

To learn about users' attitudes toward and perception of this system, the technology acceptance model (TAM) proposed by Davis in 1986 was used in the form of a questionnaire survey. TAM is designed to analyze users' acceptance of emerging information systems and is mostly used in the computer technology sector. By constructing a basic model, TAM learns about users' beliefs, attitudes, and intentions, which affect technology use. Below are the questionnaire items based on the functions of this system (Table 1).

The respondents were required to use the application for navigation before filling out this questionnaire. The experiment was conducted at the Chinese Culture University with respondents aged between 18 and 22 (38.7% male and 61.3% female). Only three respondents (9.7%) had used other indoor navigation applications, which suggests the low popularity of indoor navigation systems in Taiwan. The results of the questionnaire are listed below (Table 2):

1. Perceived Usefulness: Most respondents find the application useful.
2. Perceived Ease of Use: Most respondents find the application easy to use.
3. Attitude Toward Using: Most respondents feel confidence and reliance when using this application to navigate.
4. Behavioral Intention to Use: The respondents do not reject this application but show limited intention of continuing to use or recommending this application. According to some respondents, the arrow signage is useful, but they tend to read the map simultaneously.

Table 1
Questionnaire.

	Item
Perceived Usefulness	This application enhances indoor navigation efficiency
	This application makes indoor navigation more convenient
	This application allows me to determine my current indoor location
	This application shows precise positioning of my indoor location
	Generally speaking, this application is useful
Perceived Ease of Use	The interface of this application operates smoothly
	The colors used on the interface of this application are appropriate
	The interface arrangements of this application are not redundant
	The functions of this application are readily accessible
	Generally speaking, this application is easy to use
Attitude Toward Using	Using this application can increase my sense of security for indoor navigation
	Using this application can increase my confidence in indoor navigation
	Using this application can improve my sense of direction for indoor navigation
	Using this application can reduce my worries about indoor navigation
	Generally speaking, this application is satisfactory
Behavioral Intention to Use	I will continue to use this application
	I will recommend this application to others
	I will use this application in other indoor spaces
	I will give up on paper maps and use this application instead for indoor navigation
	I will choose this application over other indoor navigation systems, if any

Table 2
Questionnaire and results of TAM.

	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)
This application enhances indoor navigation efficiency	9.7	35.5	38.7	9.7	6.5
This application makes indoor navigation more convenient	6.5	51.6	29	9.7	3.2
This application allows me to determine my current indoor location	6.5	35.5	32.3	19.4	6.5
This application shows precise positioning of my indoor location	6.5	29	38.7	12.9	12.9
Generally speaking, this application is useful	6.5	45.2	32.3	9.7	6.5
The interface of this application operates smoothly	6.5	51.6	32.3	6.5	3.2
The colors used on the interface of this application are appropriate	3.2	48.4	38.7	9.7	0
The interface arrangements of this application are not redundant	0	12.9	22.6	41.9	22.6
The functions of this application are readily accessible	12.9	51.6	22.6	6.5	6.5
Generally speaking, this application is easy to use	12.9	54.8	25.8	6.5	0
Using this application can increase my sense of security for indoor navigation	3.2	48.4	32.3	16.1	0
Using this application can increase my confidence in indoor navigation	3.2	54.8	25.8	12.9	3.2
Using this application can improve my sense of direction for indoor navigation	16.1	38.7	38.7	6.5	0
Using this application can reduce my worries about indoor navigation	3.2	58.1	32.3	3.2	3.2
Generally speaking, this application is satisfactory	12.9	38.7	38.7	6.5	3.2
I will continue to use this application	12.9	29	38.7	16.1	3.2
I will recommend this application to others	6.5	19.4	54.8	12.9	6.5
I will use this application in other indoor spaces	9.7	32.3	38.7	16.1	3.2
I will give up on paper maps and use this application instead for indoor navigation	16.1	29	41.9	6.5	6.5
I will choose this application over other indoor navigation systems, if any	3.2	25.8	58.1	6.5	6.5

5. Conclusions

As reported in this paper, we designed and implemented an indoor navigation system composed of a mobile application called enRoute, a set of web services on Firebase, beacons, and digital signage. The enRoute application can determine a user's current location by sensing the nearest beacon. When a user enters a destination, the application provides navigation directions, which are also displayed on nearby digital signage using the cloud content service, so users do not need to continually read the directions on their phones. The signage can also display specific advertisements that might be of interest to users. With digital signage as the agent, users arrive at their destinations by following the arrows on the enRoute interface as well as the digital signage.

The TAM questionnaire results show that most respondents find the application useful and readily accessible. However, they hold a relatively conservative attitude when it comes to their perceptions and intentions of using the app. The reason might be that most people prefer to navigate with a visual map showing their current location. Nevertheless, generally speaking, users hold a positive attitude toward this navigation system, i.e., the enRoute application, and believe it is helpful for indoor navigation.

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