Customized Panorama System for Wayfinding and Walkthrough

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Abstract

Wayfinding in an unfamiliar place, such as a large city, can be difficult. It is an important behavior in daily life; however, the complexity of the environment and difficulty associated with positioning can increase confusion relative to navigation. This study attempts to design and implement a system comprising a mobile application and a set of web services to provide an efficient wayfinding method. The system is evaluated through a user questionnaire based on the technology acceptance model. The evaluation results indicate a high degree of satisfaction and positive support of users' attitude.

Keywords: Wayfinding, Walkthrough system, Panorama

1 Introduction

Over time, real-world environments have become increasingly complex, and the wayfinding process has become more difficult. For example, finding a small store in an unfamiliar city, a cafe in an alley, or a specific shop in a shopping mall can be difficult. The increasing amount of environmental information, particularly three-dimensional (3D) information, makes spatial information seem more complex. According to Lynch [1], people feel anxious and insecure when they get lost in an unfamiliar environment. To improve quality of life and promote physical and mental development, it is important to enhance people's wayfinding ability.

Over the past 30 years, wayfinding tools have progressed from paper maps to satellite navigation systems and mobile applications. Typically, navigation systems, most of which are based on maps, are updated frequently. However, such systems do not provide local environmental information. Most tourist destinations, such as Disneyland [2], provide guide maps. A guide-book system with a map view or a real-view guide can support marketing and advertising initiatives. To support development, Google Street View provides a virtual environment comprised of images processed to deliver a panoramic view. It also provides users with information that allows them to construct a comprehensive spatial understanding of the environment [3-4]. Google has also released Business View, which helps shop owners promote and market their services. Business View is built on the Google API (application programming interface, API) and is open to all developers.

This study proposes a route guidance system as a mobile application. The proposed system embodies the concept of panorama and how users might be influenced by the spatial knowledge at wayfinding and provides a wayfinding solution.

The remainder of this paper is organized as follows. Related work is discussed in Section 2. The research methodology and system architecture are described in Sections 3 and 4, respectively. Conclusions are presented in Section 5.

2 Literature Review

Wayfinding can be defined as a spatial problem solving. The process of wayfinding involves the relationship between people and environment, such as how a user recognize and construct the surrounding spatial environment. The involved theories include spatial knowledge, cognitive mapping, and wayfinding strategies [5-7]. This section reviews wayfinding studies related to spatial knowledge, wayfinding methodologies, and the technology acceptance model (TAM).

2.1 Spatial Knowledge and Cognitive Map

Spatial knowledge, which forms part of an individual's cognitive map, comprises the basic information people rely on in spatial activities. We live in 3D space; thus, most activities involve spatial tasks [8]. A cognitive map is a mental representation of spatial relationships and includes people's perception and memory of spatial relationships [1, 9]. In wayfinding, people can use external auxiliaries, such as maps and landmarks, to construct a mental map that

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reflects a given space. Building a cognitive map involves the processes of constructing and using spatial information. Thus, it is necessary to acquire, store, and use information based on specific tasks and problems to be solved prior to recalling and decoding information fragments via reasoning and creativity [10-11].

2.2 Types of Spatial Knowledge

Spatial knowledge is divided into three categories, i.e., landmark, route, and survey knowledge.

Landmark knowledge is a type of visual reproduction of remarkable and outstanding elements of an environment [12]. A landmark can be both artificial architecture and naturally formed elements [13-14]. When people first enter a new environment, they generally encode all the objects and places they perceive and select specific information about landmarks, such as shape, size, color, location, context or significance [15]. Accurate landmark knowledge can help people recognize orientation and where they are. Thus, landmark knowledge is the basic element of a cognitive map and the foundation of route knowledge.

Route knowledge is spatial knowledge built on route information. It comprises a series of landmark knowledge, wayfinder decisions, and actions. Route knowledge is sequential and linear [16], and constructing route knowledge typically involves sequential connection of landmark knowledge based on experience and perception of the given environment. Using route knowledge, wayfinders can estimate the distance between two points along a given route and appropriate turning directions [17]. Route knowledge is the most frequently-used spatial knowledge; thus, it is referred to as the primary spatial knowledge [17-18]. In addition, route knowledge is related to user experience; therefore, landmark and path knowledge are constructed from user's egocentric perspective.

Survey knowledge is also referred to as configuration knowledge. The landmark knowledge can be viewed as points. By connecting two points, we can get a line, which is the route knowledge. Lines can intersect to form planes, and planes form an integrated spatial structure. Using survey knowledge, users can determine how to move to new places [15-16]. Therefore, survey knowledge cannot be constructed until the user transforms, integrates, and speculates enough spatial information.

2.3 Wayfinding

Wayfinding refers to the ability to evaluate environment knowledge, look for a route, and move in space [16]. Wayfinding is used to describe how humans find a destination according to the five basic elements of a city, i.e., paths, edges, districts, nodes and landmarks [1]. Zeng [19] discussed various definitions of wayfinding and concluded that wayfinding is an internal or external human representation of space. In wayfinding, people observe things in the environment to understand the overall relationships present in the given space.

The theoretical wayfinding model proposed by Chen and Stanney clearly demonstrates the process and influential factors of cognitive correspondence [17]. The cognitive correspondence process can be divided into three stages. The first stage is information processing. Wayfinders process environmental information by direct contact with the environment or a cognitive map. Then, wayfinders construct special knowledge based on the collected information. The second stage is decision making, where wayfinders make decisions using their cognitive map. The third stage is execution, i.e., taking action.

Wayfinding strategies. Wayfinding strategies are unique to each individual; however, they generally fall into two categories [20-21], i.e., route and survey strategies. Based on a questionnaire related to wayfinding strategies, these strategies can be further divided into landmark-centric, route-centric, and survey-centric strategies. The landmark-centric strategy focuses on the location and orientation of each landmark, i.e., specific marked visual identifiers along the route. These can be used to recognize directions; however, users do not memorize the route between landmarks [22].

The route-centric strategy is a sequential guidance method, where wayfinders typically take landmarks as reference points and then walk toward their destination along a route comprising all landmarks [20, 23].

The survey strategy is also referred to as an orientation strategy. In the survey strategy, people are required to understand the entire spatial relationship based on the overall situation. In wayfinding, wayfinders combine their cognitive map with spatial knowledge of the environment, which is beneficial to know their current location [20].

Wayfinding mechanism. From the related research, we identify that wayfinders must acquire sufficient spatial knowledge prior to constructing a cognitive map and determining the walking direction. In matching wayfinding strategies, the kinds of knowledge provided about the environment may influence wayfinders to adopt various strategies. However, wayfinding is not only affected by spatial knowledge. For example, a guidance system can help wayfinders acquire spatial knowledge of the local environment via pictures, characters, images, and panoramic views. Such systems can also enable users to develop a general understanding of the directions and routes of the entire area [2]. However, panoramic views alone are insufficient for users to construct complete knowledge about the environment. The interaction between a panoramic view and users, which is significant to a virtual environment, can be used to recognize spatial position information. For example, the purpose of designing a small map and orientation key is to make users feel that they walk into a real space when they are in a virtual space and enhance their cognition of spatial knowledge. Such a system is referred to as an image-based remote walkthrough system [24].

2.4 Technology Acceptance Model

The TAM proposed by Fred D. Davis in 1986 advocates that people's use of information technology is influenced by their behavioral intent [25-28]. Davis believed that the intention of use for new information technology is influenced by the perceived usefulness and ease-of-use of the given technology (Figure 1 and Figure 2) [26, 28].

In 1996, Venkatesh and Davis measured the impact of cognitive usefulness and cognitive ease-of-use on the intent to use. As both usefulness and ease-of-use have direct or indirect impact on the intent to use, they decided to provide a revision, as shown in Figure 3 [27].

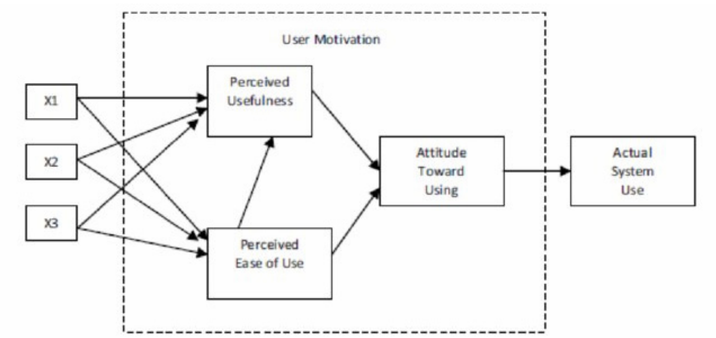

Figure 1. Original TAM

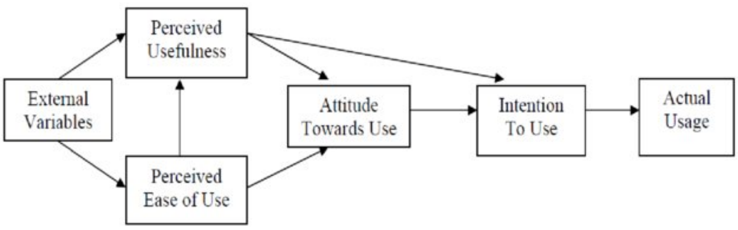

Figure 2. First modified version of TAM

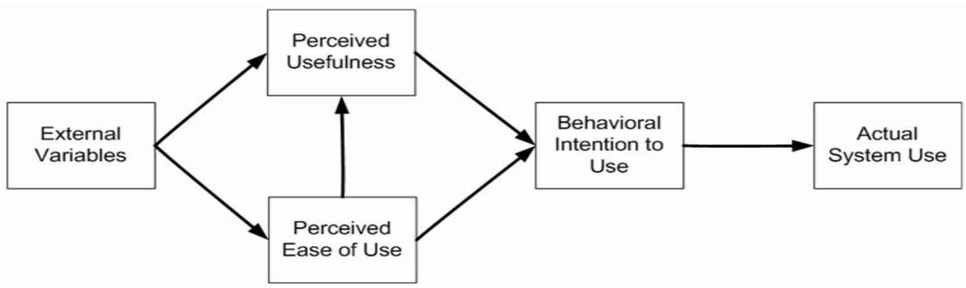

Figure 3. Revised TAM [28]

External variables are related to cognitive ease-of-use and cognitive usefulness and have an impact on a user's willingness to use a technology.

The perceived ease-of-use is defined by Davis as "the subjective expectation that users believe that using this technology can improve work performance." Here, higher cognitive usefulness yields a more positive user attitude about using the given information system.

Davis defined cognitive ease-of-use as "the ease with which users can operate the learning technology" [25-26]. Greater perceived ease-of-use yields increased user confidence in the given system.

The intent represents the degree to which the user is willing to use the technology continuously.

Technology acceptance has become a significant model in developing information technology, and many theories and models have been proposed to explain individual technology usage behavior [29-30].

3 Research Methodology

This study involved three phases.

Phase 1 was system analysis. To design a new wayfinding mechanism, related studies were reviewed to gather system requirements.

Phase 2 was system design and implementation. In this phase, a prototype was built, and the system architecture was designed. Unit testing and pilot test have been conducted, and some revisions had occurred as a result. Software prototyping is creating an application prototype, which may be an incomplete version or a minimum viable product. In this study, the prototype was used to evaluate and revise the system requirements.

Phase 3 was evaluation. Here the TAM was used to design a questionnaire survey to evaluate whether the system satisfied the requirements established in Phase 1.

3.1 System Architecture

The proposed system comprises a frontend application and a set of backend services. The frontend is a smartphone application with the most important functionalities, such as creating a new route, wayfinding mechanism and storing information. The backend is a set of API services and databases of routes and landmarks to provide services to the application. The system architecture is shown in Figure 4.

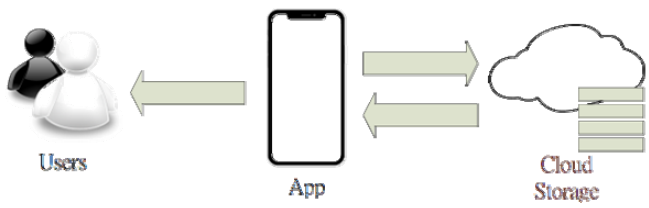

Figure 4. System Architecture

New route. Users who cannot find an existing route using the application can create and publicly share a new route. The new route function provides high customization. Users can freely add a new landmark or a specific place based on their local knowledge.

Storing a route in the database. The application transfers the route along with all information, such as landmarks and description for storage in the database. A relational database is employed because every route has its unique feature and components.

Wayfinding. Users can search for a specific route by a route id or a specific destination. All relevant information is retrieved from the database so the wayfinding mechanism can be applied.

3.2 System Implementation

The system comprises route creation and wayfinding functionalities.

Route creation. This function allows users to set up a preview project using their smartphones. Each project must be set up in three steps, i.e., the basic route information, landmark configuration, and direction marking.

The basic information includes the name and location of the path, which can be directly pointed on Google Map or searched by address (Figure 5).

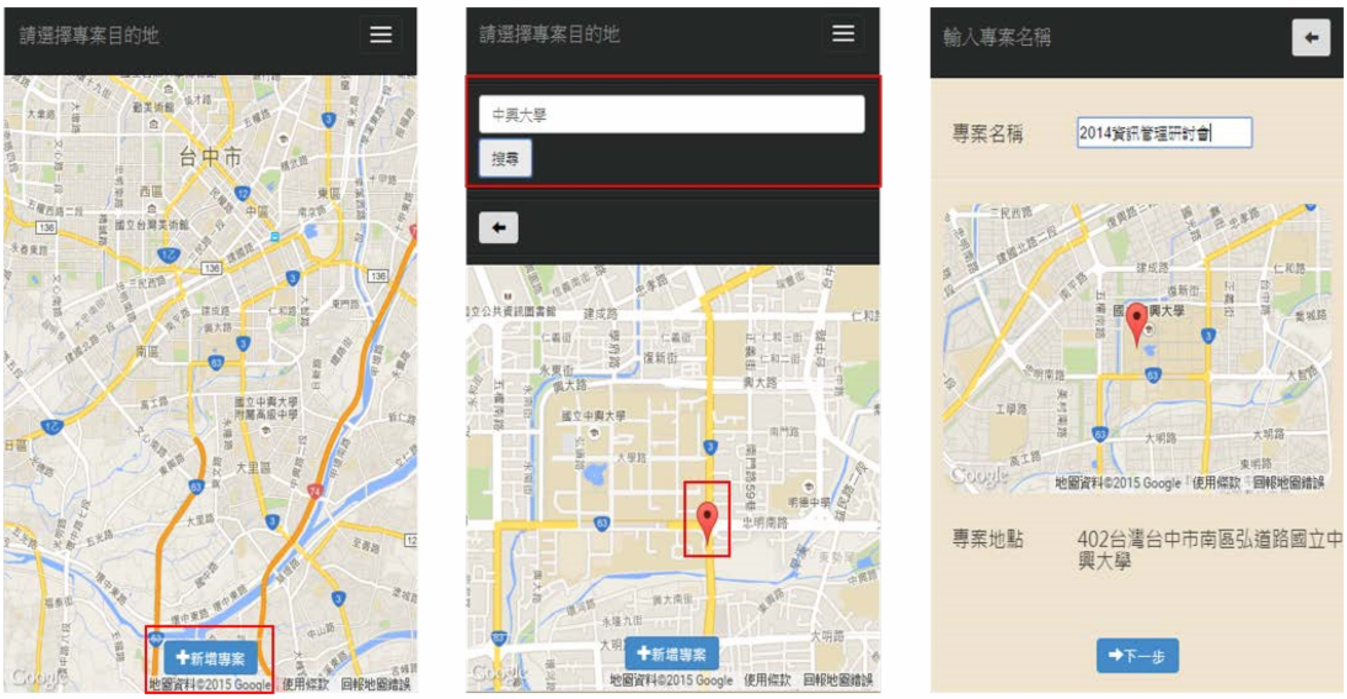

Figure 5. Basic information

Landmark configuration is an important step because the path is shown by linking landmarks, shown in Figure 6. The user must determine the location of each landmark on the path. The landmark live view can be a street view based on the Google API or a panoramic image uploaded by users. Using various kinds of image-based information, a path can become more explicit and readable.

Direction marking involves adding direction arrows to the live-view. The main purpose of adding direction arrows is to allow the user to identify the direction from one landmark to the next. Here, an arrow description is required, and the next landmark must be specified. An example is shown in Figure 7.

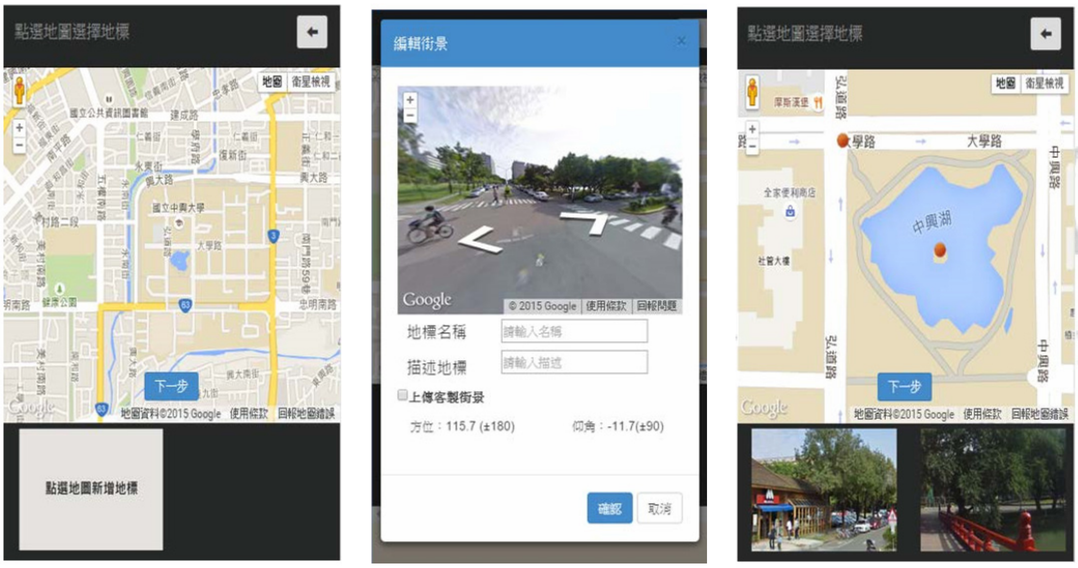

Figure 6. Landmark configuration

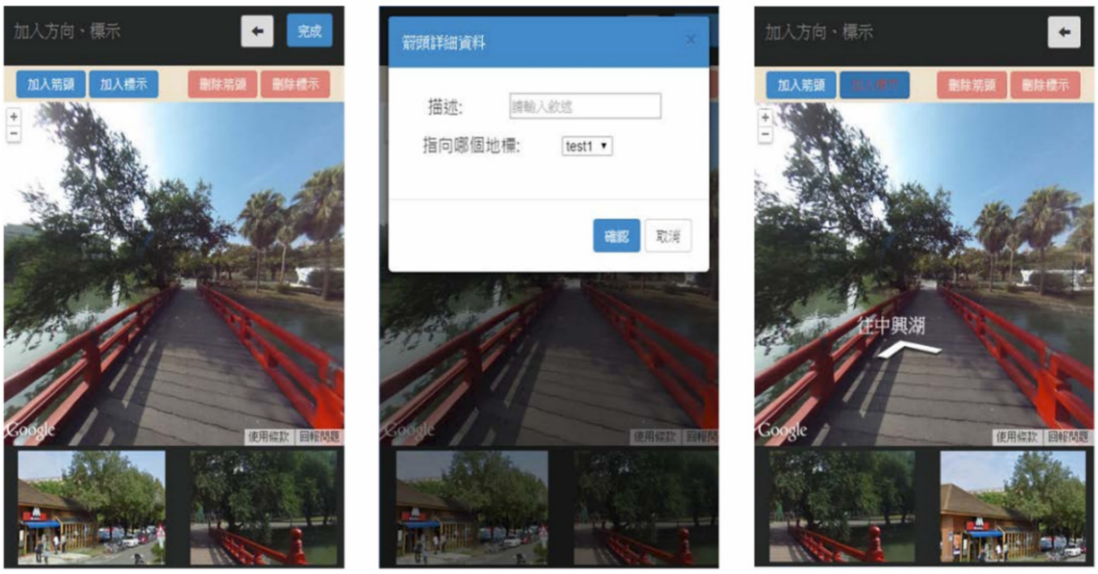

Figure 7. Direction marking and arrows

Navigation system with preview. A preview-enabled navigation system provides both map and live-view modes for wayfinding.

The map mode provides complete routes and marks all landmarks along a route, shown in Figure 8. Users can construct a cognitive map by observing roads, buildings, and landmarks.

A live-view of each itemized landmark can be viewed. On the menu bar, the page contains the name of the path, the total number of landmarks along this path, and the estimated walking time from the current location.

The live-view mode is a modified presentation proposed in this study. Guidance presentation is very important because it allows the user to reach a destination step by step. In the live-view mode, the initial point can be either a user-selected entry point or the first landmark in a project. With proper arrows, the next landmark is presented explicitly. The detailed description provided by a creator, the walking distance, and the estimated time of arrival is also shown. The illustration can be found in Figure 9.

Figure 8. The map mode

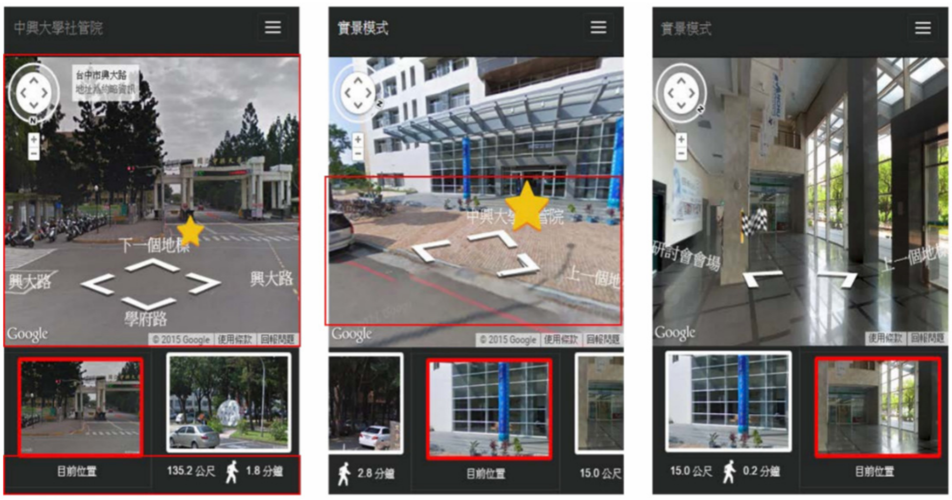

Figure 9. The live-view mode

4 System Evaluation

The questionnaire survey was based on the TAM and divided into three parts, i.e., demographics and personal information, scenario simulation, and perceived attitude and willingness to use the technology.

A total of 70 valid questionnaires were collected at the main campus of the National Chung Hsing University, Taiwan. The respondents included 25 females and 45 males. Most respondents were students, faculty, and staff. In addition, most respondents have used smartphones (93%) and have smartphone navigation experience (93%). The statistics result is shown in Table 1.

Question 1-6 show the usefulness of extra supportive system (external variables). The use of landmarks, live-views, map-view, direction, and distance are all very helpful in wayfinding. Question 7-9 are designed to understand the perceived usefulness from TAM. More than 90 percent of respondents agree the system is useful. Question 10 and 11 shows 85% of respondents feels the system is ease of use. Finally, around 80% of respondents would like to use the system while wayfinding.

5 Conclusion

The main purpose of this study is to help people identify appropriate directions to reach a destination. The map is a common wayfinding utility in the daily life, particularly due to the popularity of smartphones. Most users have used map-related applications because such applications provide a high degree of information about the given area on the map. However, a map application may not be able to provide sufficient spatial information to build a cognitive map; thus, wayfinding may fail and users may get lost.

Table 1. Questionnaire based on TAM (%)

Question	Strongly Agree	Agree	Average	Disagree	Strongly Disagree
1. When you ask someone for directions, it helps if they tell you the way through the landmark.	58.57	38.57	2.86	0	0
2. It is helpful to you to have a live view of key points and turns.	41.43	52.86	5.71	0	0
3. The map view in the system is helpful.	44.29	48.57	7.14	0	0
4. Information, such as the distance and direction between landmarks, is helpful.	31.43	55.71	12.86	0	0
5. In the street view mode, knowing that the sequence of all landmarks is useful for wayfinding.	21.43	45.71	28.57	4.29	0
6. In the street mode, using arrow and line to direct the location of next landmark is useful.	28.57	57.14	4.29	0	0
7. Landmark-centric wayfinding is useful.	42.86	50.00	7.14	0	0
8. Panoramic images are useful at building virtual environment	41.43	42.86	14.29	1.43	0
9. Generally, the system is useful.	38.57	55.71	5.71	0	0
10. I can handle this system with ease.	25.71	50.00	22.86	1.43	0
11. I think wayfinding in the system is convenient.	28.57	61.43	8.57	1.43	0
12. I would like to use this system for wayfinding in the future	28.57	51.43	20.00	0	0
13. I would love to use this system.	25.71	51.43	21.43	1.43	0

To design a new wayfinding principle and develop a prototype wayfinding application, this research considered spatial knowledge, the wayfinding process and analyzed the wayfinding mechanism. A questionnaire survey about user attitudes about the prototype system was also conducted, and the respondents indicated that the system is useful and convenient and would like to use it for wayfinding.

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