Development and Evaluation of Mobile Tour Guide Using Wearable and Hand-Held Devices

Doyeon Kim[1,2], Daeil Seo[2(✉)], Byounghyun Yoo[1,2], and Heedong Ko[1,2]

[1] Department of HCI and Robotics, University of Science and Technology, Daejeon, South Korea
ehdus0219@imrc.kist.re.kr, yoo@byoo.net, ko@kist.re.kr
[2] Center for Imaging Media Research, Korea Institute of Science and Technology, Seoul, South Korea
{xdesktop,ko}@kist.re.kr

Abstract. With the popularization of wearable devices, people who are using multiple mobile devices are increasing; a tourist uses a hand-held device, a wearable device, or both to obtain tour information. However, most mobile tour guides provide tour information with little consideration of their hand-held and wearable characteristics. In addition, tour guides that run on multiple mobile devices do not share their touring context. Therefore, tourists have to input their intention separately on each device. To alleviate these problems, we propose a mobile tour guide system that shares the touring context between hand-held and wearable devices, and presents tour information based on the capabilities and usage pattern of the devices. The system guides tourists by compensating the weaknesses of the devices, and also minimizes user interaction between the system and tourists.

Keywords: Point of interest · Touring context · Mobile tour guide · Mobile user interface

1 Introduction

Mobile tour guides help tourists to search and visit their surrounding points of interests (POIs) with their locations and guide information. Recently, mobile tour guides have become popular because the market share for mobile devices, such as wearable glasses and smartphones, has growing rapidly and individual tourists have been steadily increasing. Accordingly, a large amount of mobile tour guides are developed and some of them, such as Google Field Trip [1] and Trip It [2], support both hand-held and wearable devices.

However, these tour guides for multiple devices do not consider the characteristics of the devices, despite it being important to provide information based on the user's device capabilities and usage patterns. The tour guides have similar approaches without utilizing the user interface and interaction for each device. For example, hand-held devices have a large size screen size to provide enough information and a familiar user interface (UI), such as a touch interface and keyboard. However, tourists have

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difficulties paying attention to their surroundings when they search for or read information on the screen [3]. On the other hand, wearable devices are appropriate for providing information immediately without disturbing their attention because they display information in front of the eye of users (e.g. Google Glass). However, wearable devices have an unfamiliar user interface and wearable tour guides do not provide detailed information due to small screen size on the device [4]. It is also difficult to use both wearable and hand-held devices simultaneously because they do not share their touring context. Tourists have to input their intention separately on each device while entering keywords to search for POIs or pushing buttons to obtain more information. It is supposed that this difficulty is able to be resolved by the sharing tour context between devices.

To alleviate these difficulties, we propose a tour guide system that provides tour information based on the user's device capabilities and shares the touring context between wearable and hand-held devices. The system shares the touring context such as the status of the system, location, orientation, and input of tourists to provide synchronized tour information. Furthermore, we design a screen layout for the devices based on the touring context, and the system provides information according to the characteristics of each device. We also discuss results from a user study to compare them with the proposed approach and others to examine the effectiveness and usefulness of our approach.

2 Related Work

In recent years, many tour guide systems have been researched for mobile device users [5] since Cyberguide [6] was introduced, which designed concept of mobile tour guide. With the prevalence of the smartphone, many studies for mobile tour guides have adopted hand-held devices, which are equipped with built-in sensors for perceiving the location and orientation of users. The previous studies provide tour information with augmented reality (AR) for a first-person view and map for a bird's-eye view. Lee *et al.* [7] introduced a mobile outdoor AR application to visualize buildings that had disappeared due to the effects of devastating earthquakes. Balduini *el al.* [8] presented an AR application named BOTTARI for personalized and localized restaurant recommendations. Dünser *et al.* [9] proved the usefulness of the combination of AR and map interface. Nevertheless, tourists are difficult to obtain surrounding information while they are obtaining tour information from hand-held devices [3]. To avoid the difficulty, we combine multiple mobile devices which are a wearable device for a first-person view and a hand-held device for bird's-eye view.

Wearable tour guides have also researched for a long time. Baldauf *et al.* [10], Langlotz *et al.* [11], and Szymczak *et al.* [12] proposed audio guide systems and they allow tourists to keep their attention on the environment, even when they obtaining information while walking or looking around. Reitmayr and Schmalstieg [13] presented a wearable tour guide with AR technology, and Kerr *et al.* [14] proposed a wearable navigation system. However, most wearable tour guides do not provide information about remote sites because they only provide visualization with a first person view. In addition, the guides interact with tourists in unfamiliar ways, such as

gestural interfaces [14, 15], gaze tracking [10, 16]. These interaction methods help tourists communicate with the tour guides, but tourists do not input their purpose quickly because the interaction is complicated unlike with hand-held devices. To solve this problem, we develop a method for easy and quick interaction with familiar interfaces using the hand-held devices.

Finer *et al.* [17] introduced a touring machine, which is the first mobile outdoor tour guide system. The system was designed as a guide for a university campus with a wearable and a hand-held devices, and they showed the possibilities of combining multiple mobile devices. Vlahakis *et al.* [18] proposed a personalized AR tour guide using multiple mobile devices to virtually reconstruct cultural heritage areas in archeological sites. As mobile technologies have advanced rapidly, a state-of-the-art-approach is needed for combining multiple devices. It is also important to evaluate the usefulness and efficiency of the system.

3 Methodology

In this section, we discuss what kinds of requirements are considered for giving tour information. The section focuses on three topics: type of tour information, characteristics of devices, and conceptual design. The topics will give us insight into what kinds of tour information are needed on tour and how the information should be provided by mobile tour guides.

3.1 Methodology

We divided the status of the tour guide into POI search, navigation, and POI guide as a result of an online survey. The survey was conducted to examine what kind of information is mainly used when they are touring (see Fig. 1 left).

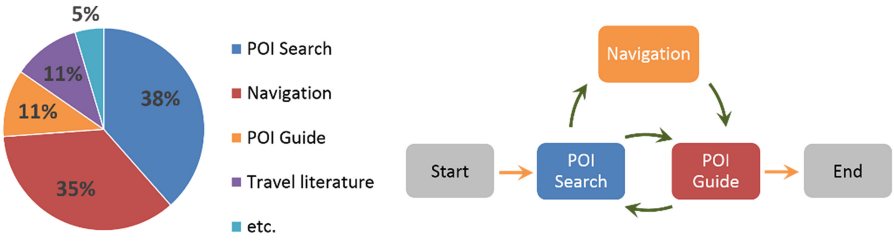

Fig. 1. Online survey result (left) and the status of touring (right)

The participants were composed of 40 people (23 females, 13 males) between 24 and 37 years old (M: 30.58, SD: 3.29). They had experience of searching for tour information with mobile devices through tour guide applications or on the web while traveling. The POI search enables tourists to find POIs such as cultural heritage sites, restaurants, and hotels. The navigation provides route information to go to POIs.

The POI guide helps tourists understand objects or places by providing detailed information of POIs. The status of the touring context is changed as shown in Fig. 1 (right). When a tourist arrives at a travelling area, they search for attractions around them with the POI search and move to the attraction by checking route information. At the attraction, tourists obtain detailed information about the attraction from the POI guide and then search for attractions again with the POI search to decide on their next destination.

3.2 Characteristics of Mobile Devices

The proposed mobile tour guide uses both a wearable device and a hand-held device to compensate for the disadvantages of each device. Table 1 the shows advantages and disadvantages of the devices. A wearable device user immediately receives information because it is displayed in front of the eyes of the user. In addition, wearable devices easily perceive the orientation of the user using their built-in sensors, such as a gyro or compass sensor. However, they do not provide detailed information due to their small screen size. Wearable devices are suitable for providing information in real time without disturbing the touring context. On the other hand, hand-held devices generally have a bigger screen size than wearable devices, which it enables tour guides to provide a lot of information at once. Furthermore, the familiar interfaces of the hand-held devices help tourists quickly search information. With hand-held devices, tourists is able to quickly search for POIs and acquire detailed information without much effort.

Table 1. Characteristics of devices

	Wearable device	Hand-held device
Advantages	• Hands-free • Easily determines what user is seeing	• Familiar user interface • Big enough screen size to show detailed information • Various built-in sensors
Disadvantages	• Unfamiliar user interface • Small screen size • Few built-in sensors	• Hand-held • Blocks view of user

3.3 Conceptual Design and Touring Context

Figure 2 shows the conceptual design of our mobile tour guide system, and we assume that a tourist makes sense of his surroundings with the system. The wearable device gives information using a first-person view aligned with the tourist's sight to provide tour information immediately in front of his eyes. With the wearable tour guide, the tourist is able to easily obtain information on the POIs the tourist is currently seeing. The audio guide for the wearable device provides detailed information such as the name and distance of the POI from the tourist. The hand-held tour guide provides tour information with a map interface that helps tourists obtain tour information by moving

and zooming on the map or inputting keywords. The tourist is able to easily interact with the hand-held tour guide to search for and obtain information, and then the system shares touring context between the devices. Touring context is dynamically changed based on the location, orientation of a tourist, state of the system, and interaction with the tourist. By sharing the touring context, the tourist is possible to simultaneously obtain the tour information from multiple devices without inputting their intention separately on each device.

Fig. 2. A tourist obtaining tour information using the proposed mobile tour guide system

4 System Design

4.1 System Architecture

The proposed system consists of four-parts as shown in Fig. 3: a tour contents management system (CMS), a wearable tour guide, a hand-held tour guide, and a route planner server.

The tour CMS stores and manages tour content, and the route planner server helps the tourist to arrive their destination by providing route information. The system interacts with a tourist through the input handler in the hand-held tour guide. The location and the orientation handler perceive the location and orientation from built-in sensors. The tour context analyzer collects data from the handlers, estimates the touring context based on the collected data, and sends the estimated results to the view manager. The view manager displays the tour information using bird's-eye view. The hand-held tour guide communicates with the wearable tour guide through the network module to share the touring context. The wearable device provides tour information using a first person view and audio guide.

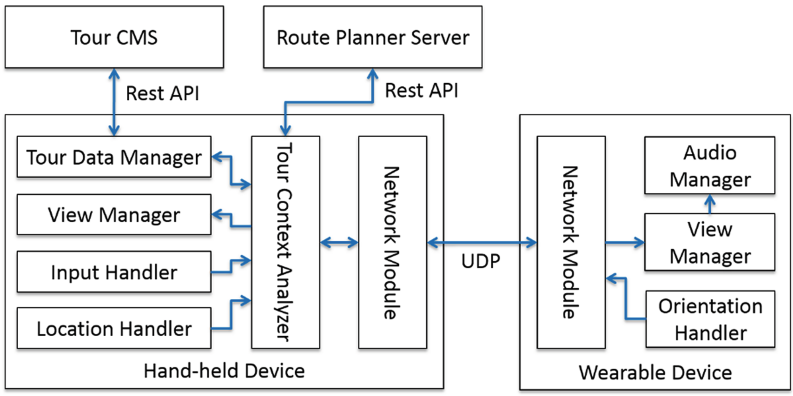

Fig. 3. System architecture

4.2 Prototype Implementation

The mobile tour guide applications are developed with Google Glass and ASUS Nexus7. Figure 4 shows a process overview of the proposed mobile tour guide to explain the usage scenario on tour, and we assume that a tourist is in his traveling area.

Fig. 4. Process overview of the mobile tour guide

The tourist is able to choose an appropriate view that consists of a first-person view on the wearable tour guide and bird's-eye view on the hand-held tour guide. The tourist identifies his current position and orientation through the arrow icon on the POI search view. The tourist searches for POIs he wants to visit using keyword search and location search, and then the searched tour information is shown as a green POI icon. The navigation view enables tourists to get to the destination POI by providing route information. Route information is composed of route, instructions, and remaining distance. When tourists arrive at the destination POI, the hand-held tour guide provides detailed information with text and related photos, and the hand-held tour guide offers animations and an audio guide. After the tourist has finished sight-seeing, the tourist searches for other POIs by repeating the steps.

5 Evaluation

In this section, we evaluate and discuss the strengths and limitations of the mobile tour guide system. To evaluate the system, we designed a user study to examine its general usability and acceptability while touring.

5.1 Experimental Design

The goal of the user study was to compare usability between the proposed approach and others. The study was composed of three groups that use only a wearable tour guide, a hand-held tour guide, or both, and it was conducted over three days from around lunchtime to approximately 6 pm each day. We selected participants who are used to using mobile devices and have a high interest in them and recruited 15 participants (8 females, 7 males) between 23 and 35 years old (M: 28.86, SD: 3.66) who had little or no knowledge about the test site.

The study was conducted to verify that our approach is possible to quickly provide tour information. To experiment with and observe the usability of our approach, we developed the following null hypotheses.

- POI search: There is no difference for the searching time among a group with a hand-held tour guide, a group with a wearable tour guide, and a group with the proposed tour guide
- Navigation: There is no difference in moving time to their destination among a group with a hand-held tour guide, a group with a wearable tour guide, and a group with the proposed tour guide.
- POI guide: There is no difference in the acquisition time taken to gratify their curiosity among a group with a hand-held tour guide, a group with a wearable tour guide, and a group with the proposed tour guide.

To give the same experience to the participants, we provided ASUS Nexus 7 and Google Glass to the participants for the mobile tour guide and requested they only use these devices when they search for and obtain tour information. Before the study, it was

ensured that the participants understood the purpose of the study by giving them an introduction to the study and training for the usage of the tour guide.

The study followed a between-subject design to avoid prior knowledge affecting the study results. During the study, the participants received questions in Table 2 from the manager and then answered the questions using the mobile tour guide. The questions were combined with keywords, locations, and objects related to the types of questions. For the questions, we referred to a study of Kim [19] to compose the questions and modified the tasks which were classified as POI search, navigation, and POI guide. Questions 1 and 8 are classified as POI search because the participants search for the POIs and set as their destination to solve the tasks. While the participants conducted the tasks, the manager measured task completion time. The navigation time was measured while the participants were moving to the next place for another task. To ignore the time taken for the participants to understand the question, the task completion time was measured after the participants understood the question.

Table 2. Questions and combinations for the tasks

Order	Combinations	Question
1	Keyword	How do you get to Injeongjeon?
2	Location	What is the gate in front of you?
3	Location, Keyword	The yard between Jinseonmun and Sukjangmun looks different from the others. What does the yard look like? Who made the gates?
4	Keyword	Passing through Injeongmun, you can see rank stones on each side of the front yard called Pumgyeseok. You are just beginning to wonder why they were divided into two sides
5	Object	While looking around the yard, you find an unknown object. What is the object used for?
6	Object, Location	You find an object on the way to Injeongjeon. While searching for information about the object, it can also be seen on the Daejojeon. How do you get to Daejojeon?
7	Object, Keyword	While seeing the inside of the Injeongjeon, you find a picture behind the throne. What is the name and meaning of the picture?
8	Location	What is the building on the right of Injeongjeon?

After the study, we handed out a post-review questionnaire and the participants wrote down answers to the questions. For a more detailed evaluation, we divided the study results into quantitative and qualitative evaluations to determine how much time was needed to acquire tour information and what user interfaces wered useful. In the quantitative evaluation, participants carried out tasks to obtain information and the manager measured the time taken. For the qualitative evaluation, the manager handed out a post-review questionnaire to check a mainly used device and preferred user interface on each device.

5.2 Evaluation Results

After completing all of the tasks, we asked the participants to answer a number of questions, as shown in Fig. 5. Figure 5(a) is a question for ensuring the relevance of the tasks. The participants recorded the answers on a five-point scale from 1 (completely disagree) to 5 (completely agree) and the results show that all the answers are positive. Figure 5(b) is a question to determine whether participants were influenced by prior knowledge. The participants recorded the answers on a five-point scale from 1 (very much) to 5 (not at all) and the results show that all of the answers are below the average.

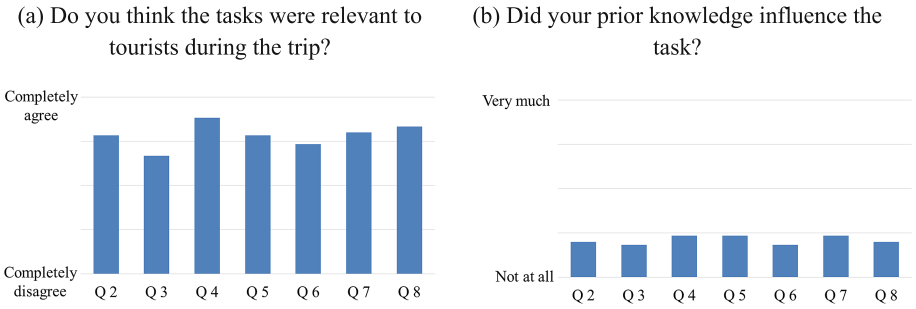

Fig. 5. Post-study questionnaire results

Figure 6 shows the average task completion time of each task group. The group with a hand-held tour guide took about 391 s (Max: 422, Min: 350, SD: 35) to fulfill all the tasks, and the group with a wearable tour guide took about 448 s (Max: 529, Min: 399, SD: 52). On the other hand, the group with the proposed tour guide took about 329 s (Max: 352, Min: 304, SD: 17), and completed the tasks faster than the other groups; 16 % faster than the group with a hand-held tour guide and 27 % faster than the group with a wearable tour guide.

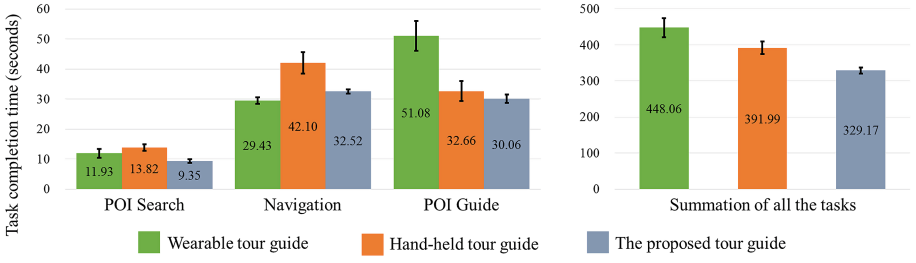

Fig. 6. Tasks completion time

In the case of POI search, the group with the proposed tour guide searched for POIs the fastest. While the participants moved during the tasks, there was a greatly different task completion time between the group with a hand-held tour guide and others. In contrast, the

results in the POI guide show a greatly different task completion time between the group with a wearable tour guide and the group with the proposed tour guide.

The task completion time of the participants were analyzed with a one-way Analysis of variance (ANOVA) to determine whether there were any significant differences among the three groups. We set the criterion to 0.05 for the significance level, and the null hypothesis shown in Sect. 5.1 was rejected when the p-level was below 0.05. Table 3 shows the results of the one-way ANOVA.

Table 3. One-way ANOVA results for the task completion time

Task	Source of variation	Sum of squares	DF	Mean square	F-value	P-level	F-critical
POI search	Between	50.323	2	25.162	5.122	0.025	3.885
	Within	58.945	12	4.912	–	–	–
	Total	109.268	14	–	–	–	–
Navigation	Between	436.232	2	218.116	11.250	0.002	3.885
	Within	232.659	12	19.388	–	–	–
	Total	668.892	14	–	–	–	–
POI guide	Between	1312.66	2	656.331	13.217	0.001	3.885
	Within	595.879	12	49.657	–	–	–
	Total	1908.54	14	–	–	–	–
Total	Between	35371.4	2	17685.7	12.339	0.001	3.885
	Within	17200.4	12	1433.37	–	–	–
	Total	52571.8	14	–	–	–	–

Figure 7 shows the questionnaire result for identifying the mainly used devices during the tasks. When the participants searched for their destination POI or obtained detailed information for the tasks, all of the participants mainly used the hand-held device. In contrast, only one person mainly used the hand-held device and the other participants mainly used the wearable device for getting route information for navigation.

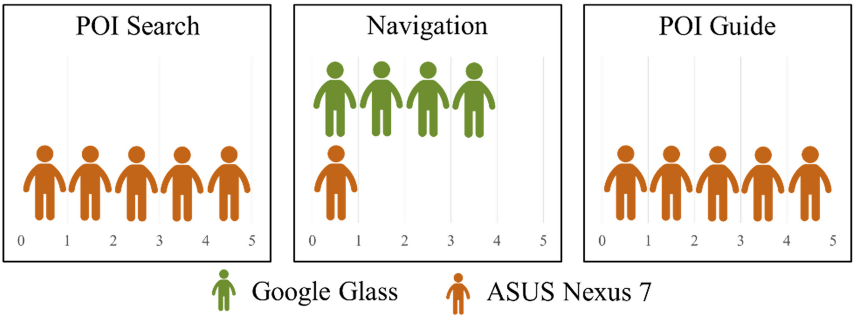

Fig. 7. Questionnaire results for identifying the mainly used devices during the tasks

5.3 Discussion

In the user study, we evaluated mobile tour guides to verify their usability and effectiveness. There were important observations for the behavior patterns of the participants during the study. In this section, we discuss the behavior patterns of the participant group who used the proposed mobile tour guide system.

The participant group recorded the fastest time when they were searching for POIs. In the post-study questionnaire, all of them answered that they mainly used the hand-held tour guide during searching for POIs. They provided reasons such as "The device has a big screen size and convenient user interface" and "It is easy to search for information using the keyboard interface". On the other hand, they searched for POIs with the first-person view by using the wearable tour guide when they did not know the name of the POI but did know the direction, such as in question 8 in Table 2.

In comparison with the POI search, the participants mainly used the wearable tour guide to find the routes to the destinations. They mentioned that "It is useful to get route without disturbing my attention" and "It is easy to find the route because the map rotates to follow the direction of my head". Meanwhile, we observed the group with the hand-held tour guide often stopped at crossroads to obtain their next direction and did not see oncoming people when they looked at the screen of the device.

There is a small difference in the POI guide between the proposed tour guide and the hand-held tour guide. The participants mainly used the hand-held tour guide when they obtained detailed information for the tasks. They also commented that "Listening to the guide is interesting, but it is quite easy to read the guide", "I am used to reading the text for getting information" and "It is faster to read than to listen". The results show that text is more effective than audio when the tour guide offers detailed information.

6 Conclusion and Future Work

Mobile tour guides help tourists quickly obtain tour information. In this paper, we proposed a tour guide system that guides tourists with wearable and hand-held devices by sharing touring context. We also designed a user interface that considered the type of tour information and characteristics of mobile devices. The prototype was implemented and evaluated through a user study. In the user study, we verified the usefulness and effectiveness of the tour guide system.

Even though our approach reduces searching and acquisition time for tour information, some work remain to improve the usability of our mobile tour guide. The user study results show that most people mainly use a mobile device in each task group. In the future, we will conduct a study that automatically selects a mobile device depending on the touring context to provide tour information in a single view. The study may reduce the time spent to select a mobile device to provide tour information.

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