Developing a Location-Aware Mobile Guide System for GLAMs Based on TAPIR Sound Tag: A Case Study of the Lee Ungno Museum

Jimin Jeon, Gunho Chae, and Woon Seung Yeo

Audio & Interactive Media Lab, GSCT, KAIST – Daejeon, South Korea
{jimin.jeon,chaegunho}@kaist.ac.kr, woony@kaist.edu

Abstract. With the emergence of new mobile media, Galleries, Libraries, Archives, and Museums (GLAMs) have paid attention to interactive context-aware mobile guide systems that can provide visitors with a customized experience based on their location and movement. However, existing location-aware guide systems using GPS, Wi-Fi, QR Code, NFC, RFID, etc. tend to overlook the special conditions of GLAM environments, often require additional hardware, and have shortcomings like inaccurate identification, high cost, and low usability. This project aims to develop a novel location-aware mobile guide system for GLAMs that can overcome such limitations and offer visitors a tailored experience. To this end, we utilize "Theoretically Audible but Practically Inaudible Range (TAPIR)" sound tag-based data communication and location detection using audio signals within the human hearing range (typically between 18 to 22 kHz). This paper describes the TAPIR sound tag-based mobile guide system, and it discusses the first user evaluation result of the guide we developed for Lee Ungno Museum.

Keywords: TAPIR, Sound Tag, Indoor Positioning, Museum, Mobile guide, Lee Ungno Museum.

1 Introduction

With the emergence of new mobile media (e.g., smartphones and tablets), Galleries, Libraries, Archives, and Museums (GLAMs) have paid attention to interactive context-aware mobile guide systems that can provide visitors with a customized experience based on their location and movement[1]. However, existing location-aware guide systems using GPS, Wi-Fi, QR Code, NFC, RFID, etc. tend to overlook the special conditions of GLAM environments, such as lighting systems, architectural structure, and exhibits. They also have shortcomings, such as inaccurate identification, high cost, and low usability, and they often require additional hardware.

This project aims to develop a novel location-aware mobile guide system for GLAMs that can overcome these limitations and offer visitors a tailored experience. To this end, we utilized "Theoretically Audible but Practically Inaudible Range (TAPIR)" sound[2] tag-based data communication and location detection using audio signals within the human hearing range (typically between 18 to 22 kHz). This paper describes the TAPIR sound tag-based mobile guide system, and it discusses the first user evaluation result of the guide we developed for Lee Ungno Museum.

M. Kurosu (Ed.): Human-Computer Interaction, Part III, HCII 2014, LNCS 8512, pp. 425–433, 2014.

2 Related Works

2.1 Mobile Guide Systems for Museums

Since the Stedlijk museum in Amsterdam developed its first audio guide–Philips radio tour (Fig. 1)–in 1952, museums have been developing their own mobile guide to provide their audience with more accessible and useful interpretations and information about their collections[3].

Early mobile guide systems for museums evolved in various ways until smart devices-smartphones and tablets-appeared on the market. One of the first mobile guides was a portable cassette player, which played a recorded audio guide. At that time, visitors passively listened to the audio guide. However, when keypad-based audio guides were developed, visitors could choose the artwork they want to know more about by choosing a number and listening to the recorded clip. This keypad-based audio guide (Fig. 1). was widely used in the 1980s and 1990s because of its interactivity[3].

After the introduction of smart devices, such as smartphones and tablets, museum mobile guide systems dynamically evolved. With new smart devices that have a camera, touch screen, and sensing and networking features, various types of new interaction were introduced in museum guides. At that time, a multitude of technologies (e.g., Wi-Fi positioning) for indoor location-aware systems (Fig. 1) were developed and applied to museums mobile guides[4]. Since the location-aware guides can provide visitors with information and content based on their position and context in museums, the indoor positioning system has attracted attention.

Fig. 1. Philips radio tour; keypad based; Wi-Fi positioning mobile guide app of AMNH

2.2 Indoor Positioning Systems in Museums

The head of mobile strategy initiatives at the Smithsonian Institute, Nancy Proctor, categorized indoor positioning systems for museums based on nine categories at the 2013 Museums and the Web Asia in Hong Kong[5].

- Manual Interface
- GPS
- Wi-Fi: Base station ID, Triangulation

- Bluetooth and iBeacons
- LED and IR
- RFID and NFC
- QR codes
- Visual Recognition (computer vision)
- Ultrasonic

Some of these technologies-Manual Interface, LED, IR, RFID, NFC, QR codes, GPS, and Wi-Fi-are currently available in a small number of museums and the others are in the experimental stage. The reason why these existing location-aware guide systems are not widely used in museums is because they tend to require additional hardware, and have shortcomings like inaccurate identification, high cost, and low usability. These limitations act as barriers for museum staff to actively use location aware mobile guides in museums.

2.3 Sound-Based Data Transmission

There have been many attempts to develop new techniques to utilize sound as a medium of data communication, and some of these have been commercialized in a limited way.

Normally, these techniques tend to deliberately hide the communication process using various techniques to build a seamless user experience. Although the transmission speed and stability of these systems varies depending on the techniques and algorithms they adopt, most are capable of sending a few bytes of digital data per second across a few meters.

"Shopkick[6]" is an example of a successful commercialized works. One or more speakers are arranged in specific regions in the affiliated shop. Every speaker has a unique sound ID and repeatedly emits a triggering sound, which does not disturb visitors, since it is encoded in a specific frequency band (20kHz) that is barely audible to the human auditory system (HAS). Once the app on the mobile devices is triggered by these sound signals, it downloads and provides location-specific information by detecting the ID included in the sound. This system has limitations in terms of advanced use due to its constraint of the sort of data that can be sent in its effort to maintain a simple structure. However, this limitation is also one of the main reasons why the system is stable. A similar service called Dingdong is provided in Korea.

Another example is "Yamaha Infosound[7]." This system uses an audio band above 18 kHz and has a transmission rate of 80 bps within 10 meters. Its purpose was to send additional information of TV content to audiences' devices by including the signal into the background sound. Although its usefulness is doubtful due to the emergence of IPTV technologies, Fuji TV used this system for promotional information in 2012. Its growth in TV content market and exploration of commercial uses are expected.

NTT Docomo is another organization researching data transmission using audio in a system called "Sound Barcode[8]." Its research is focused on data hiding by replacing specific bands of sound with audio signals that have a similar waveform shape as the original source[9]. This technique shows fast transmission speed and robustness against noise because it uses advanced algorithms, such as Orthogonal Frequency Division Multiplexing (OFDM), which is usually used for modern network systems, digital

TV, or cellular networks. However, commercial products and application projects using this technology have not launched yet.

3 System Design: TAPIR Sound Tag and Mobile Guide System

As mentioned above, several methods for using sound as a medium for data transmission have been suggested in recent years. These studies showed that sound can be used to transmit information to multimedia devices including Sound Barcode, Infosound, and Shopkick, which are primarily for commercial uses.

In our previous research, we focused on inaudible-high frequency sound's potential and noticed that it can be used for various purposes. Therefore, we suggested its possible application in prototypes utilizing TAPIR sound.

The most of microphones in today's mobile devices are designed to cover a wider range of sound (0 to 22-24kHz) than that of human hearing (0 to 18-20kHz). Thus, we can utilize this marginal sound band as a medium for communication between devices without human awareness[2]. This method offers a way to instantly form a kind of platform-independent local area network with a microphone but not additional hardware.

Therefore, we developed a TAPIR sound tag-based system, which is a novel acoustic data transmission system that is especially suitable for providing personalized and concrete information. We noticed that our new system is suitable for location-aware mobile guide systems for GLAMs. Transmitting information with inaudible sound is not affected by special conditions, such as lighting, and it works for every mobile device with speakers but without requiring any additional expensive hardware.

3.1 TAPIR Sound Tag

By applying advanced techniques from modern data communication system, our TAPIR sound tag system is a novel acoustic data transmission system, which shows enhanced performances and stability not found in other systems. Moreover, since we designed the system as a software framework, it is easily applicable to diverse purposes with a variety of personal mobile devices.

The new system can transmit 200 bits a second within five meters using a general small portable speaker (3W output power) in most situations. This means it can transmit one of 65,535 kinds of distinguished codes (enough for most GLAM situations) in about 0.1 sec. Thus, with our system and their own mobile devices, users can have a similar experience that of using modern tagging systems such as RFID and NFC.

3.2 TAPIR Sound Tag-Based Mobile Guide App

We designed a mobile guide app using our TAPIR sound tag system. Visitors to GLAMs can set up the app on their own devices without paying an additional fee to rent an audio guide. In GLAMs, each exhibit is assigned a sound tag, which emits its predefined unique ID information as a short-length audio stream (i.e., the TAPIR sound signal) periodically. The mobile guide app on each visitor's mobile device detects the signal

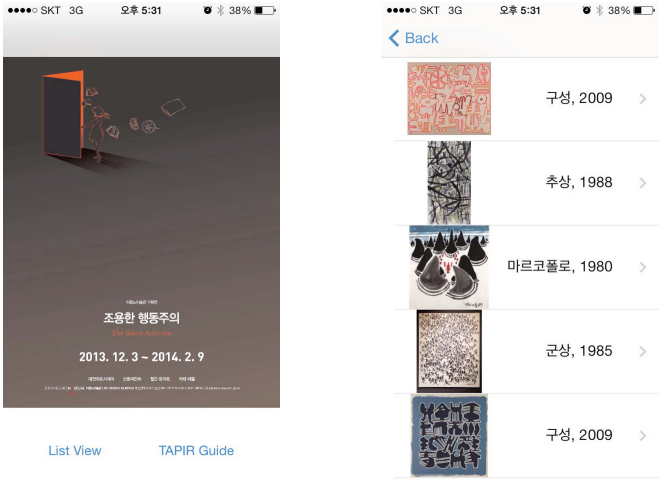
from the nearest sound tag automatically (without any active response from the user) and presents the appropriate content, such as video clips or audio docent information, making it a natural, context-aware user experience.

These sequences allow users to access information on the artwork in a way similar to existing tag-based sensing technologies, such as RFID and NFC. However, the system with the sound tags does not require any special handheld device with additional wireless communication feature(s), and it can work on most smartphone platforms. This allows us to provide an interactive, location-aware mobile guide system with reliable performance and platform-independency at a lower cost.

4 Case Study: Lee Ungno Museum Mobile Guide

To test the performance of our system, we developed an exhibition application (Fig. 2a) for the Lee Ungno Museum, an art museum in Daejeon, South Korea.

This application offers an audio guide for a special exhibition named *The Silent Activists*. Visitors can use it while they are appreciating artwork in galleries. The experiment presented two methods for audio guide: (1) a list view with thumbnails of artwork, which is familiar to existing smartphone users (Fig. 2b) and (2) a TAPIR guide that we developed for this paper.



(a) The main screen view (b) The list view

Fig. 2. The developed application

On the thumbnail list view, visitors choose the artwork from their own smartphone and then listen to the recorded audio clip. However, if visitors choose the TAPIR guide, the device will catch the TAPIR sound from the speaker next to artwork (Fig. 3) and play the relevant audio clip.

Fig. 3. A participant using TAPIR sound-tag

5 Evaluation

5.1 Experiment Method

We conducted a between-group experiment to evaluate whether the TAPIR sound tag is useful as a museum mobile guide. The experiment was designed to investigate the impact of the Tapir sound tag-based guide compared to the traditional list view with thumbnails.

For the visitor (user) test, we used the Museum Experience Scale (MES) and Multimedia Guide Scale (MMGS) developed by University of York [10]. With MES, we can evaluate visitors' general museum experience based on four components-engagement, knowledge/learning, meaningful experiences, and emotional connection. With MMGS we can evaluate satisfaction with the mobile guide based on three components-general usability, learnability and control, and quality of interaction.

5.2 Procedure

A total of 20 participants were recruited for this experiment. The mean age was 29.7 with a range of 22-45; eight were male and twelve were female.

The experiment consisted of two stages. First, we put participants into two groups–A and B–randomly. We asked Group A to use the Lee Ungno Museum's mobile guide

app with a list-view guide only, and we asked Group B to use only with TAPIR guide. After that, they went into the gallery to appreciate the artwork with the mobile guide for 20 minutes. After completing the tasks, participants were asked to answer survey questions about MES and MMGS based on the guide system they used. Also one open-ended question was given to know general opinion or idea of participants on each guide systems.

5.3 Result

After the participants answered questions on a scale of 1 to 5, we analyzed the results. Through MES, we knew the general satisfaction of the museum experience based on four components: engagement, knowledge/learning, meaningful experiences, and emotional connection.

The result (Fig. 4) shows that visitors, who used the TAPIR guide felt more engaged with the exhibition, knew and learned more about the museum, had a meaningful experience, and felt emotionally more connected with the museum and its exhibition compared to visitors who used the list-view guide.

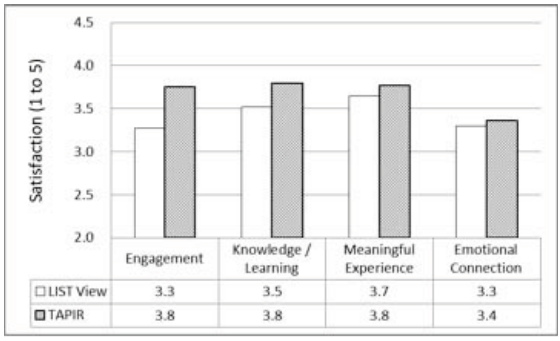


Fig. 4. Result of MES

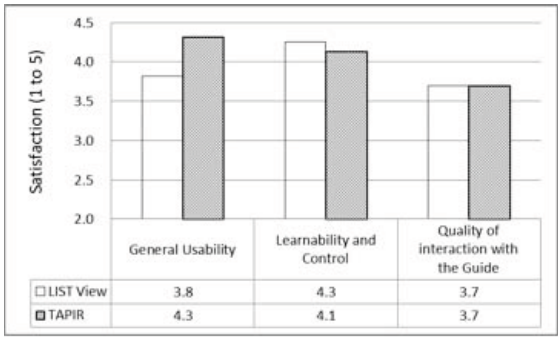


Fig. 5. Result of MMGS

However, using MMGS, the results (Fig 6.) showed visitors' general satisfaction on user experiences, such as general usability, learnability and control, and quality of interaction, and we discovered some experience-related issues with the TAPIR guide that should be improved.

When it came to general usability, the TAPIR guide received a higher score than the list-view guide. However, for learnability and control, the TAPIR guide has a lower score than the list-view guide. For quality of interaction, the TAPIR guide and list-view guide had the same score.

5.4 Discussion

After analyzing the result, we reach two conclusions.

With the TAPIR guide, visitors tend to have a better and more satisfactory museum experience. Since the TAPIR guide offers a location-based service, which does not ask visitors to play the audio guide, visitors can focus on the exhibition, and this leads to a better museum experience. After analyzing the open-ended answers on the TAPIR guide, we learned why the TAPIR guide showed a lower score on learnability and control. Even though users liked the TAPIR guide and regarded it as usable, they felt it was initially difficult to use, and they needed time to learn how to use it. Thus, we need to think about how to make this system more accessible to users, and help them learn how to use it easily.

6 Conclusion

When combined with the TAPIR sound tag, a location-aware mobile guide can provide an enhanced museum experience for visitors. We hope our research serves to convince people of the new role of sound as a tool for a location-aware guide in GLAMs that can overcome the limitations of existing technologies. In future studies, we plan to explore how to increase the user experience with the TAPIR sound tag-based mobile guide, particularly focusing on learnability and control.

Acknowledgement. We thank the members of the Lee Ungno Museum and YZ interactive for assisting our research; we are especially grateful to Geunhyoung Luke Kim and Seunghun Kim from KAIST.

References

1. Proctor, N., Burton, J.: Mobile Apps for Museums: The AAM Guide to Planning and Strategy. AAM Press, American Association of Museums (2011)
2. Yeo, W.S., Kim, K., Kim, S., Lee, J.: TAPIR Sound as a New Medium for Music. Leonardo Music Journal 22 (2012)
3. Tallon, L., Walker, K.: Digital Technologies and the Museum Experience: Handheld Guides and Other Media. Rowman Altamira (2008)
4. Roes, I., Stash, N., Wang, Y., Aroyo, L.: A personalized walk through the museum: The chip interactive tour guide. In: CHI 2009 Extended Abstracts on Human Factors in Computing Systems, pp. 3317–3322. ACM (2009)

5. Proctor, N.: Finding our way with both hands: Interior location-based systems in museums. In: Forum: Mobile Wayfinding and Location-based Solutions in Museums and the Web ASIA 2013 (2013), http://mwa2013.museumsandtheweb.com/proposals/finding-our-way-with-both-hands-interior-location-based-systems-in-museums/
6. shopkick, Inc.: shopkick (February 2014), http://www.shopkick.com
7. Yamaha Corporation: INFOSOUND (February 2014), http://jp.yamaha.com/products/soundsignage/infosound/
8. NTT DOCOMO, INC.: NTT DoCoMo Sound Barcodes (February 2014), http://www.diginfo.tv/v/09-0171-r-en.php
9. Matsuoka, H., Nakashima, Y., Yoshimura, T.: Acoustic OFDM system and its extension. The Visual Computer 25(1), 3–12 (2009)
10. Othman, M.K., Petrie, H., Power, C.: Engaging visitors in museums with technology: Scales for the measurement of visitor and multimedia guide experience. In: Campos, P., Graham, N., Jorge, J., Nunes, N., Palanque, P., Winckler, M. (eds.) INTERACT 2011, Part IV. LNCS, vol. 6949, pp. 92–99. Springer, Heidelberg (2011)