H-Treasure Hunt: A Location and Object-Based Serious Game for Cultural Heritage Learning at a Historic Site

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Abstract. Serious game is commonly used to support cultural heritage such as historical teaching and learning, and enhancing historic site visits. Nowadays most of in situ serious games have been supported by GPS but it is not suitable for a small-scale historic site. In this paper, we propose a location and object-based serious game application H-Treasure Hunt. H-Treasure hunt integrates location-based service with object-based sensors to find more exact location of artifacts at a historic site. In the game, the players wear Head Mounted Display (HMD) and explore a historic site interacting with artifacts to complete missions. In this way, H-Treasure Hunt will act as a tour guide helping users learn about the historic site and artifacts. The use of this application is to support cultural heritage teaching and learning as well as enhancing historical site visits.

Keywords: Collaboration technology and informal learning · Mobile and/or ubiquitous learning · Serious games and 3D virtual worlds for learning · User-generated content

1 Introduction

Serious game is commonly used to support cultural heritage such as historical teaching and learning, and enhancing historic site visits. Its playful characteristic not only increases motivation to learn but also raises interest of children and young adults in cultural heritage. Serious games for particular sites help players to find historical or geographical significance of the site and to learn more information than when they just observe. While playing the game, visitors are able to have immersive experience and construct personal meaning as well.

Nowadays most of serious games at outdoor sites have been supported by GPS based location technologies for in situ experience. However, using GPS at a historic site may result in GPS confusion areas, since artfiacts are located close to each other. Therefore, we improved location-based technologies with object-based sensors to pinpoint the location of artifacts at a historic site.

This paper suggests a location and object-based serious game, Historical Treasure Hunt. H-Treasure Hunt is a treasure hunt like location-based game that allows users to create their own content. Furthermore, H-Treasure hunt integrates location-based

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service with object-based sensors to interact with artifacts at a historic site. The game is composed of two major parts: authoring tool (H-Treasure Hide) and playing tool (H-Treasure Hunt). The overall system will be further described in Sect. 3.

Since the object-based sensor provides pinpoint locational accuracy of the user and the artifact, the user can be provided with information about the artifact at a suitable time and place. In this way, he or she will be able to have a feeling of being connected to the artifact with the sense of interaction. We expect that H-Treasure Hunt can provide a new way to explore a historic site and enhance the visitor's experience.

2 Motivation and Related Work

2.1 Motivation

Unlike the majority of location-based games, we desired to make H-Treasure Hunt not tied to specific gaming contents but playable at any historic site by utilizing authoring tool to satisfy different user groups. How can such a game support exploring a historic site by e.g. students and teachers on a field trip. While students are new to a historic site and naturally interested in sightseeing and learning about the history of a city, teachers might be able to re-evaluate their pre-existing view of the site by exploring it with prior knowledge and research.

According to these traits, H-Treasure Hunt has two roles: hider and hunter (Fig. 1). Teacher's role is the hider who hides sensors around artifacts and creates missions. Students can be the hunter who hunts points through completing the missions to reach their ultimate goal of getting a real treasure as a prize for the winner.

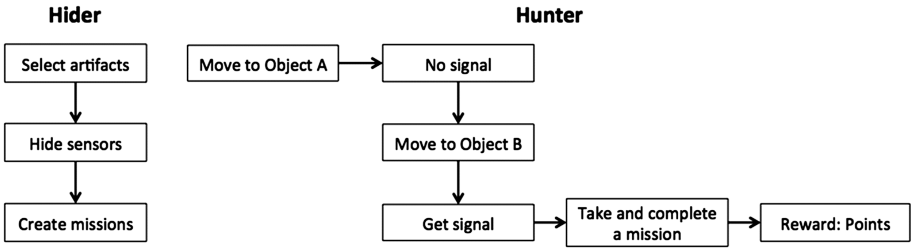

Fig. 1. Overview of the game actions separated by 'Hider' and 'Hunter'

Exploring the site with H-Treasure Hunt, students will be able to discover and learn many interesting facts about history. The game will help them to have an immersive and realistic reconstruction of a real location. As a result, they will be able to appreciate and learn the historical values of the site. It also engages mechanisms to motivate students into a real experience.

2.2 Related Work

Serious games for a historic site are often inflexible because game place is targeted to a certain place and POIs (Point of Interest) are selected in advance. As a result, users have to play the game in one fixed place with the same game content every time they visit the site. One example is mobile tour game that provides location-based service [1]. There are, on the other hand, other location-dependent studies that adopt more flexible approaches towards game place and content [2, 3]. Such studies provide authoring tools allowing user-created content. Instead of relying on already existing content, user creates game content that is relevant to the user's current situation.

H-Treasure Hunt is a close relative to Tidy City [2] and GeoCaching [3]. Tidy City is a scavenger hunt that players need to interpret riddles to find the correct target destination. Geocaching is a hide and seek game where treasures are hidden in the real world focusing more in the real world than in the virtual game world. They are similar to H-Treasure Hunt in that there are two type of user groups including one type of user group who design the gaming content. However, Tidy City and Geocaching focus more on entertaining than learning. On the other hand, H-Treasure Hunt not only has typical entertaining traits of games but also has educational effect.

Typically, these location-based serious games are designed for a wide range of area such as city [2, 3]. Location-based techniques are not oriented to historic site since these techniques are mainly based on GPS, which are robust for outdoor environment. Historic sites are usually smaller than the city scale and artifacts are too close to each other. For example, Bulguksa temple located in South Korea has stone pagodas and stone lanterns as well as buildings. GPS can be used to mark locations of relatively broad area like big objects but is too inexact for small scale positioning. It is not correct for indicating specific artifacts like stone pagodas and lanterns that are only few meters away. Therefore we need to improve location-based technologies to find more exact location of historic site and to interact with artifacts.

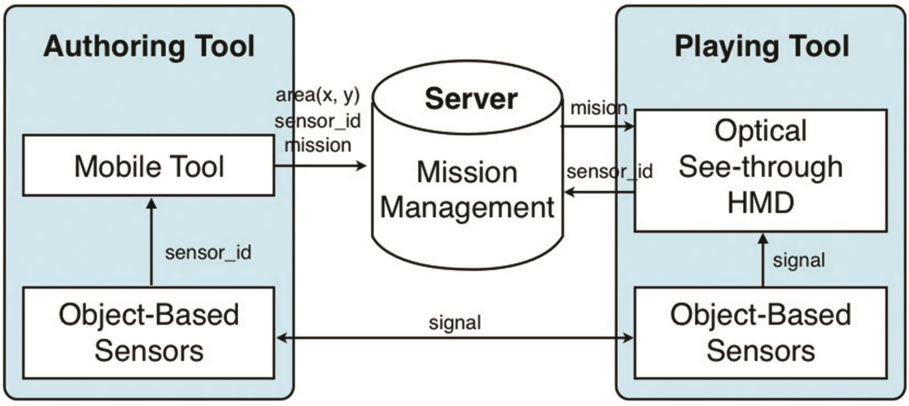

Fig. 2. Overall system diagram

3 System Design

3.1 Basic Architecture

Figure 2 shows a general outline of our system. The game is composed of two major parts: authoring tool (H-Treasure Hide) and playing tool (H-Treasure Hunt).

With authoring tool, designers walk around a historic site carrying object-based sensors. Selecting the artifact, they place the sensor around the artifact and mark a GPS location on mobile authoring tool to give players a rough area. Then designers specify the sensor number and create missions for the artifact. The data is then uploaded to the server and it becomes available for the game.

With playing tool, players hang the user sensor around the neck and wear optical see-through HMD that guide them to the designated area. Then they can freely explore the site to find the object sensors that are scattered around the site as shown on the map on their HMD. As the player gets closer to the hidden object sensor around the artifact, the signal between the object sensor and the user sensor gets stronger. Then, H-Treasure Hunt recognizes the artifact by receiving the unique sensor number from the object sensor and fetch corresponding mission from the server. Finally, HMD displays the mission for the player. After having completed the mission, the player is rewarded with points (Fig. 3).

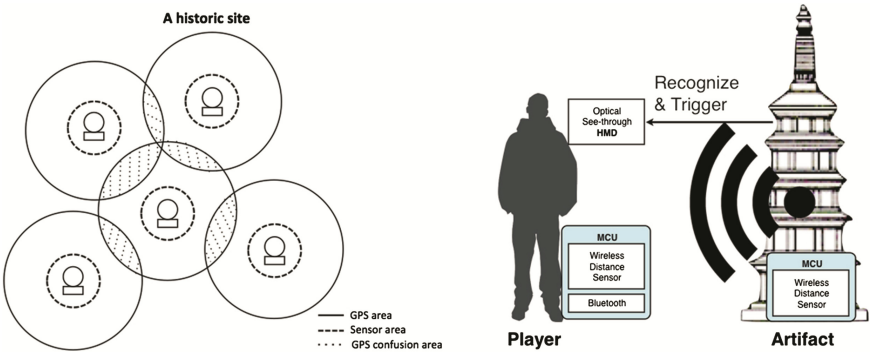

Fig. 3. LBS with object-based sensors (left), and object-based sensor module (right)

3.2 Sensor Design

Object sensor is composed of Arduino and ZigBee (Tx). ZigBee is used to send radio signal to user sensor. User sensor is composed of Arduino, ZigBee (Rx) and Bluetooth. Unfortunately, Google glass can only receive Bluetooth signal. In order to overcome the weakness, the sensor is equipped with Bluetooth and ZigBee. ZigBee calculates the power of radio signal (RISS) then transmits it to user. If the RISS value is high enough, then the Bluetooth sends a signal to Google glass. After that, Google glass creates events.

Beacon is also used to find locations. Bluetooth can connect up to 8 nodes at the same time. ZigBee, however, is suitable when connecting multiple same cell nodes simultaneously (Fig. 4).

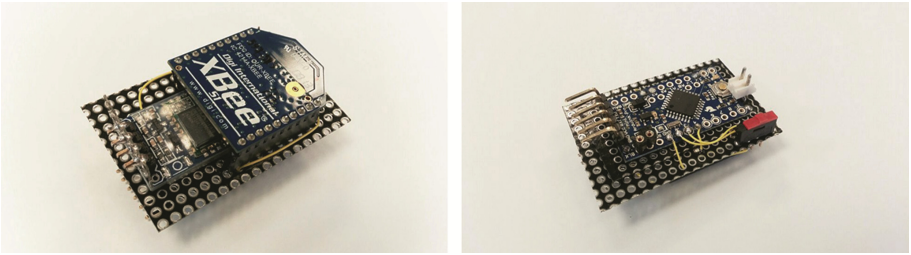

Fig. 4. Hardware design (front and back side)

We can read ZigBee RSSI pin using Arduino pulseIn. Pin 6 is PWM0 /RSSI Output PWM Output 0 /RX Signal Strength Indicator on ZigBee and ZigBee-PRO modules. When AT Commands, P0 on the ZigBee module is set to 1 (default), pin 6 outputs the RSSI value as timed electrical pulses (PWM, pulse width modulation.) We can read those pulses using Arduino's pulseIn function. Those pulses will equate to a number in hex. That hex number can then be translated to decibels (dB) which is the unit of measure for our RSSI value.

We fixed the threshold value which allows user sensor to detect object sensor. To get the exact value, we had to perform several tests because wireless signal is easy to be interrupted. Above all, we covered three sides of the sensor box to have only connection from front side. Table 1 shows the results of distance and angle test of the proposed sensor.

Table 1. Relsults of sensor's distance and angle test

	Test1		Test2		Test3		Test4		Average
Sensor	1	2	1	2	1	2	1	2	
Distance(m)	1.1	1.3	0.9	1.7	1.0	1.2	0.7	1.5	1.175
Angle(°)	-30	0	+20	+45	+30	-10	-20	+10	5.625

We designed this device for users to be around 1 m from the object sensor. Programed RSSI setting value is 30(dBm) that is lower than Benkic's result [4] since we covered the sensor box with aluminum foil except front side. We recorded distance and angle between the user and the object sensor every time the user receives the signal from the sensor and gets the mission from the Google glass. The average distance is 1.175 m that is similar to designed value. When testing the device, it was able to detect the sensor within up to about 50 ~ 60 degree. While the test, all the users were able to find the sensor within 0 ~ 45 degree.

3.3 Application

The game accompanies mobile authoring tool that enables users play the game anywhere and with any artifact as well as playing tool application for HMD. Therefore, H-Treasure Hunt is composed of two major software parts: authoring tool (H-Treasure Hide) and playing tool (H-Treasure Hunt).

We incorporated Naver Maps into an Android app, installing the Naver APIs [5]. For exchanging data between android applications and the server, we created PHP classes to connect to MySQL database [6]. The architecture will activate simply by calling a PHP script from android application in order to perform a data operation. The PHP script then connects to MySQL database to perform the operation [7]. The data flows from the Android app to PHP script then finally is stored in our server, MySQL database.

Authoring tool. The game provides mobile authoring tool to let users create their own content anywhere and with any artifact. Designers create missions for each artifact by recording necessary information. There are mainly two activities in mobile authoring tool, Mainactivity.java and CreateQuiz.java. Mainactivity.java shows a list view of registered sensors and missions available, whereas CreateQuiz.java deals with creating missions. Figure 5 shows a screen of CreateQuiz.java. Designers can specify a title, a sensor number, a picture as a clue, answer, and examples. The data is then uploaded to the server and it becomes available for the game. Created missions can also be played by other players.

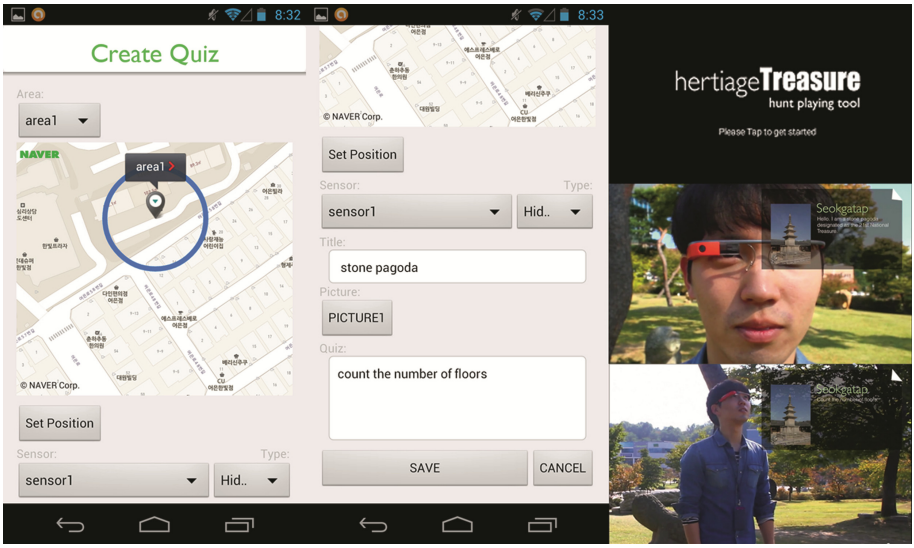

Fig. 5. Authoring tool (H-Treasure Hide) and playing tool (H-Treasure Hunt)

HMD. At the historic site, players wear optical see-through Google glass freely explore the site to find treasures that are scattered around the site shown on the map on their Google glass. As the player gets closer to the object sensor attached to the artifact, the object sensor's signal gets stronger [4]. When the player is close enough to the sensor, the sensor attached to the artifacts sends its unique number to the player's Bluetooth that is paired with the Bluetooth mounted on the HMD. These two Bluetooth devices carry out text chat over Bluetooth [8]. Through transferring data over Bluetooth, the Google glass application recognizes the unique sensor number and displays the corresponding mission.

Google glass application is implemented with the Glass Development Kit (GDK) which is an add-on to the Android SDK [9]. For Google glass application, activities are divided into 6 parts: AboutActivity, AnswerActivity, BluetoothChat, BluetoothChatService, DeviceListActivity and SettingsActivity. DeviceListActivity and SettingsActivity should be preceded prior to game play. SettingsActivity fetches all the necessary information from the server in advance of outdoor activity by extending the range of the game which includes non Wi-Fi zone. The player's Bluetooth can be paired with the Bluetooth mounted on the Google glass through DeviceListActivity. BluetoothChat and BluetoothChatService are activities for carrying out text chat over Bluetooth. When BluetoothChat activity receives the number via Bluetooth chat, this activity passes the received number to AboutActivity that displays corresponding mission with the number [10]. AnswerActivity deals with events when the player inputs answer such as A, B, C or D. The following code shows handler that gets information back from the BluetoothChatService and data exchange between activities.

Google glass offers a voice interface as well as gesture interfaces such as tapping, swiping, and scrolling. We implemented Google glass application to support both voice and gesture interfaces. Users can choose to launch the application and manipulate the menu through either voice or gesture interface. In addition, the players checks if he or she is in the right spot by just saying: "Mission!", if so, the corresponding mission is displayed on their screen.

```
private final Handler mHandler = new Handler() {
        public void handleMessage(Message msg) {
        switch (msg.what) {
     begin
        case MESSAGE_READ:
        byte[] readBuf = (byte[]) msg.obj;
        String readMsg = new String(readBuf, 0,
     msg.arg1);

     ((Mission)this.getApplication()).setBt(readMsg);
        Intent intent = new Intent(BluetoothChat.this,
     AboutActivity.class);
        startActivity(intent);
end.
```

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4 Experimental Results

4.1 Game Design

We conducted a test to evaluate H-Treasure Hunt application with four test participants and four artifacts at stone sculpture park on KAIST campus. There were more than ten artifacts at the park, and we selected four artifacts in advance to hide sensors: a stone bridge, a stone pagoda, a stone lion and a stone elephant. The test participants had two main tasks of finding the right four artifacts and completing the missions. Before this experiment, with the selection of artifacts, we also played the role of hider by creating missions with authoring tool to focus on evaluating the playing tool (H-Treasure Hunt). Missions were created after reading and understanding the contents of each artifact on panel. After setting the environment for game, hunters were guided to the site as shown on the map on their HMD and they were encouraged to play the H-Treasure Hunt at stone sculpture park (Fig. 6).

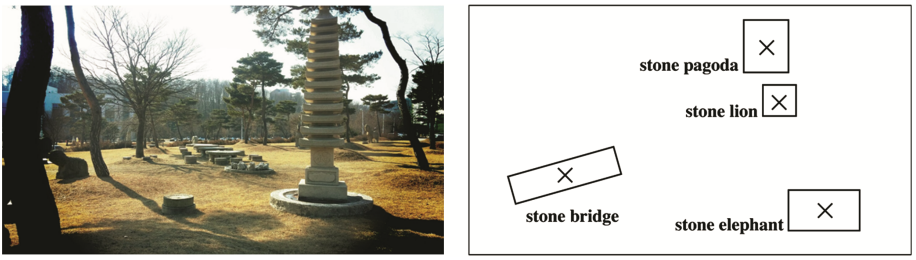

Fig. 6. The Stone sculpture park in KAIST (left), and location of four selected artifacts (right)

4.2 Evaluation Method

We selected four representatives of our target audience to participate in a small-scale, in depth user study for playing tool (H-Treasure Hunt). The group included two male and two female students of KAIST who have never visited the park. All of the participants had no experience using HMD or any AR related devices but they were all familiar with using smartphone.

The evaluation of each participant was approximately a half an hour long and consisted of the following four different stages. First we helped the participants familiarize with gesture and voice interfaces of Google glass by giving them instruction and

some time for practice (5 min). We showed them a brief demo of H-Treasure Hunt (3 min) and gave them some time for getting familiar with its environment (5 min). When they are ready, we asked them to freely explore the site playing H-Treasure Hunt (15-20 min). After completing all the missions, we asked them to complete a comprehensive questionnaire that consists of three different parts. The first part evaluates practical benefits of playing the H-Treasure Hunt game at a historic site. The second part evaluates convenience of the H-Treasure Hunt application interface. The third part evaluates participants' emotional experiences. We used Likert-type scale to measure attitude using the following options: Strongly agree, agree, neither agree nor disagree, disagree, strongly disagree.

The goal of this experience is to improve out study by having evaluations from people to find the pros and cons have better insight. Through the experiments and feedback, we can extend our system by developing better game design and system. Especially we focused on the experiential aspects (emotions, feelings, values, meanings, etc.) related to the system.

The reults from Table 2 show that H-Treasure Hunt application was easy to use and understandable on the whole for most of the participants. They also felt that H-Treasure software was supportive for observing artifacts. They believed that the H-Treasure application offered adequate missions to understand the artifacts.

The participants felt that our application was helpful for understanding the historic site and its artifacts. In convenience of the interfaces, participants thought gestural interface was easy to use. However, they felt that voice interface was not much easy to operate. They answered that the interface of the software helped them engage more in the game.

The H-Treasure Hunt offers a new experience, encouraging participants to explore and investigate the site. The result indicates that a combination of fun and challenging assignments creates an effect that leads to deeper engagement and enjoyment. They said this engaging experience provides a link with the artifacts and gives them a chance to appreciate cultural values of the historic site after using the H-Treasure Hunt application. Additionally, they said the H-Treasure Hunt application offers a new and stimulating way to experience the historic site.

Location-based games have been used for educational goals. As an example, Geocaching [3] used GPS for teaching and learning activities. This indicates that the H-Treasure Hunt application can also be applied to the field of education, motivating students to learn about the site while playing the game. The participants expect that the H-Treasure Hunt application would boost motivation and offer educational contents in game design.

4.3 Observations and Interviews

In observations of test participants using our application, they quickly became adept at navigating the interface and completing missions with gestures and voice command. They also had a lot of fun playing H-Treasure Hunt at the historic site showing different playing patterns. In one case, if there is no mission for the artifact, two people passed by the artifact without even observing it. Their playing times were about 12 min, which is relatively shorter than others. On the other hand, the other two participants had a deep

Table 2. H-Treasure Hunt user test statement

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Practical Benefits:					
H-Treasure Hunt application is easy to use			25%	75%	
Software supports my actions for observing artifacts		25%	25%	50%	
Software offers adequate missions to understand artifacts				25%	75%
Convenience:					
Gestural interface is easy to use		25%		50%	25%
Voice interface is easy to use		25%	50%	25%	
Software interface supports game immersion		25%	25%	50%	
Emotional Experience:					
Software offers me new experience				50%	50%
H-Treasure hunt was challenging and at the same time interesting			25%	75%	
Software offers stimulation to explore the site			25%	50%	25%
Using the software gave me a sense of connection between me and artifacts		25%		75%	
Software makes me learn more about the site			25%	50%	25%
Software could easily be used in education			25%	75%	
Using the software makes me think about cultural value of the site		25%	25%	50%	

observation of artifacts even though these were not selected artifacts. Therefore, their playing times were around 20 min, which is much longer than previous group's playing time.

The interview process helped us to gain a deeper understanding of each user's personal experience with our system. During the interview, participants most frequently used the words "fun" and "new way to learn" in describing the most positive aspects of H-Treasure Hunt. In negative aspects, participants most frequently mentioned discomfort of HMD with the expression "dizzy" and "unfamiliar".

5 Conclusions and Future Work

In this paper, we proposed a serious game application for cultural heritage learning using location and object-based technologies and accompanying authoring tool for creating flexible game content with smartphones. Preliminary evaluation results confirm that H-Treasure Hunt is new, playful and a stimulating tool that encourages exploration and learning, especially suitable for cultural heritage learning. The element of play proved to be a significant factor that appealed to users, and most of them agreed that the gesture and voice interaction made the experience of exploring more immersive. Remaining frustrating aspects derived from unreliable gesture and voice recognition and the uncomfortable head-mounted hardware. Also some users focused on completing missions rather than exploring the site and observing artifacts. Nevertheless, all participants agreed its playful approach would dramatically increase the motive for learning.

We were encouraged by the detailed feedback we received from our participants, and are eager to forge ahead with intuitive interaction design for exploring the historic site and observing artifacts via HMD. We will develop the system that help users exploring and observing more in detail with free-hand. And design more game rules which make users could not just pass by the artifacts. In current version of H-Treasure Hunt, in addition, no social element can be found even though it is actually aimed at group activities. The most important component in game design is social experience and co-experience. The group game can be one of the goals in social competition. Users could be more motivated by competing or co-playing with their friend. Therefore we needs to extend and create new tools in H-Treasure Hunt for social experience.

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