Abstract – We have developed a historical tour learning support system to study pre-tour and post-tour using a personal computer, and tour support using a mobile phone. Pre-tour, users can prepare using 3D graphics, a voice guide and Web resources accessed by personal computer. On tour, support is provided by GPS and voice guide via a smart phone and users can take notes and draw sketches using a touch pen. Post-tour, the system can use GPS data collected during the tour and 3D graphics to display the route taken by the tourist. In addition, users can check their understanding and recall by taking quizzes. About ten students tried this system and filled out an evaluation questionnaire. Most of them rated this system as useful and necessary for maximizing learning benefits.

Keywords: Smart phone, 3D graphics, Study cycle, GPS, Web

1 INTRODUCTION

Many historic sites provide autonomous sight seeing support systems. Almost all of these systems introduce sightseeing spots using the Internet and guidebooks. However there is benefit to the sightseer if the Internet information can be browsed by PC in the user’s home before making a tour. Also there are few services to support tourist in real time at historic sites. Therefore the tourist should probably use only printed guidebooks or pamphlets. However, these printed materials can be slow to incorporate new information because the content cannot be updated frequently. First time visitors often cannot locate their current position or the part of the site they want to visit. Generally they take photos of historic sites, but they do not think of sketching it by hand.

“Shared Virtual Worlds for Mobile Phones” is one system using mobile phones and GPS [1]. This system displays 3D virtual city space and guides using a mobile phone with GPS. This system requires only a cellular phone without any new add-on devices. However, there is no function to enable users to record information themselves. An alternative approach was the “Kyoto e! Project”. This provided tourist navigation support using PDA (Personal Digital Assistant) [2]. This system had the function to provide information on the neighborhood using GPS data, and a function to share users’ information via the Internet. This approach was limited by the fact that this information was only accessible at specific locations. The “Learning Support System using Cellular Phone with GPS for Field Studies” could service proper contents for each user to get current position and his/her past action history [3]. This system was designed as a support to teaching materials, but had no personal record making function to share with another user.

“P-Tour: A Personal Navigation System with Travel Schedule Planning and Route Guidance Based on Schedule” could navigate a pre-set tour route using a mobile phone GPS function [4]. However, this system had no functions to guide by voice or Web page, or to record the tourist’s route. There are few systems that combine a study cycle, ability to get site-specific historic information in real time and personal tour record functions. These systems could not be supported ubiquitously, independent of the user’s status. The paper “Experience Learning Support System in Integrated Study with use of Cellular Phone” adopted the study cycle that was constructed with pre study, study through experience and post study[5]. But this system did not use 3D graphics that was effective to understand leaning objects.

Therefore we are developing a historical tour learning support system modeled on Matsue Castle Park, which is our local historic site. Our system has the functions for pre tour using 3D graphics, tour using mobile phone and post tour using quiz [6][7][8].

The functions of pre tour are to learn about the historic site instinctively using 3D images. Having viewed the site in 3D pre-tour, a tourist can appreciate the perspectives and important characteristics of the site when actually there. The role of pre tour study is to provide the root knowledge about what to look out for at tour time. Smart phone is used to make the file of tour track. The file is produced from GPS latitude and longitude records every ten seconds, and sent to the server when the termination button is selected. The file will be downloaded in the terminal for post tour learning.

We developed the 3D virtual tour function for post-tour study. We wrestled with a method to re-create the user’s walking trace in 3D space to enable review of his/her tour.
2 SYSTEM STRUCTURE

Figure 1 shows the structure of historical tour learning support system. This system supports three steps; pre tour, tour and post tour. Users can operate this system using a personal computer and smart phone. They can prepare before the tour using the 3D space virtual tour and WWW. While touring, the system provides guidance via a smart phone and also allows for photographs and note taking. Post tour, the user can re-trace his/her route in 3-D space and check memory and understanding via the quiz function. In this way, this system can increase learning effectiveness by supporting the study cycle; pre tour, on tour and post tour learning. It will be most effective to learn about historic site when user uses all of these modes according to the study cycle. But if user cannot use pre tour or post tour by PC, he/she can use only tour mode by smart phone.

3 FUNCTIONS OF HISTORICAL TOUR LEARNING SUPPORT SYSTEM

3.1 Functions for pre tour

Pre tour, the user can study using the virtual tour in 3D space. Figure 2 shows the first screen the user would see after selecting this area in Matsue Castle Park. The user can learn about the historic site by moving the avatar using a mouse or keyboard.

The system has content for teaching the history, characteristics and layout of Matsue Castle, Matsue Local House, Gokoku Shrine and Jozan-Inari Shrine.

The user can move freely in virtual 3D space by clicking and dragging a mouse. Extended click action moves the avatar backward and forward and the view direction is changed up or down by dragging the mouse. Additional functions facilitate changes in walking speed and direction of viewpoint. More detailed information is provided by the system voice guidance or can be got from Web pages, which are accessed by clicking on the historic site symbol in virtual space. The same voice data will be downloaded from the server using the smart phone GPS function when user actually visits the historic site.

3.2 Functions for tour

3.2.1 Guide function

Currently, it is difficult for a newcomer to find the exact historic site information for their location from a pamphlet. Our system guides the user around the site according to the user’s position by using GPS. Figure 3 shows the image of guide function.

When the start button on the initial screen of the user’s terminal is selected, a user name input form will be displayed. If the user name is input, the system will connect to the server and download the newest historic site map.
information to the user’s terminal. At the same time, the system will get position data using GPS.

When the user activates the system and approaches the historic spot, the system will display information on lower portion of the initial screen. At the same time, the system will download guidance voice to the terminal and play it automatically. The “Replay guidance voice” button allows the user to listen again.

3.2.2 Historical material browse function

The browse function (Figure 4) accesses historical material, information viewed pre-tour and sketch data.

Figure 4 Historical material brows function

Historical material can be browsed by clicking on the “Information serviced by guide function” button. At present, the user can find many kinds of information independent of position. This information should be automatically updated so that the user has access to the newest information. Information available via the pre-tour function can be reviewed by clicking on the “Information used pre tour” button. By selecting the “Browse learning record” button, a user can browse the learning records he or she produced or those generated by another user. This function also allows records to be edited or removed. The “Sketch browsing” function allows users’ sketches to be viewed. Clicking on the thumbnail image of the sketch expands the image. Tourists can study a historic site with reference to another user’s learning record and sketches by communicating with the server.

3.2.3 Sketch function

Photography is forbidden in many castles and museums. Therefore, we developed a hand writing and sketch function to record images of historical material where photography is banned. Figure 5 shows a sample screen. Alternatively, where photography is allowed, the user can use this function to annotate any photographs.

The pen for hand writing has six line thickness options and 48 colors. Since the screen of a smart phone is narrow, it is difficult to display all the color choices. Therefore only major colors are indicated on the main screen. All colors can be accessed by choosing the “another color” option allowing any of the 48 colors to be selected from another window. The “Erase” button removes unwanted parts of the sketch and “Clear screen” button erases the whole screen. Sketched images can be stored on the smart phone and server as JPEG files. The images stored in the server can be browsed via “Sketch browsing” in the historical material browse function menu.

Figure 5 Sketch function

3.2.4 Creating a tour trace

One of the characteristics of this system was to be improved learning effectiveness by incorporating the data produced during the tour into the post tour learning function. To do this, we planned to produce tour route data, and send it to the post tour learning database. The tour route data file is produced from GPS latitude and longitude records every ten seconds. This file is sent to the server when the termination button is selected, and the file will be downloaded in the terminal for post tour learning. A user can review his/her tour track in 3D virtual space. Figure 6 is a sample of a trace on map derived from a set of tour track data. The traced curve is the route the tourist took.
4 FUNCTIONS FOR POST TOUR

4.1 Reproduction of tour trace

It is necessary to make good use of reproduction in 3D space to use the trace data produced during the user’s tour. The tour trace data is the latitudinal and longitudinal position information produced by GPS. This data is transferred to position data presented by plane coordinates to project it in 3D space. The next step is to smooth the transferred tour trace data to make the trace curve. Then the avatar can walk through on the trace curve, seeing everything from a camera position at the avatar’s eye level.

Figure 7 shows a scene from the tour route review. The avatar walks through from Matsue Castle to Matsue hometown mansion in 3D space at real speed. Such a 3D space can be built using LightWave3D, a tool of 3D contents developing tool. In addition to this tool, 3D space is developed with Virtools, which builds with BB (Building blocks) [9].

The tour trace data is latitude and longitude from GPS, recorded every ten seconds during the tour. This data is downloaded to the personal computer from the server. The format of the trace data reflects that of latitude and longitude, do is shown as ddd.mm.ss.

The latitude and longitude have to be changed to plane coordinates of unit meters to reproduce the tour trace, because 3D space is expressed by the coordinates x, y and z. Change in position as meters per second, must also be calculated because the tour trace data changes are smaller than the second unit.

Figure 8 Difference in movement interval depends on latitude and longitude

The earth can be approximated by a sphere as in Figure 8. Latitude means lines drawn on earth parallel to the equator. Movement distance of latitude is solved from circumference of the earth. Circumference of the earth calculated by: $2\pi R \approx 40075020$[m] (radius of the earth $R = 6378137$[m]).
If latitude changes 1 degree, distance is derived as in the formula.

\[ 2\pi R / 360 = 111319.5 \text{[m]} \]

Therefore if latitude changes 1 second, distance follows:

\[ 2\pi R / (360 \times 60 \times 60) \approx 30.92208 \text{[m]} \]

Longitude is the line from the North Pole to the South Pole. When longitude is changed, the movement distance must be calculated differently. The movement distance is equal to latitude on equator, but radius cutting the earth along latitude changes less as latitude becomes greater, and becomes 0 on North Pole. Label “b” in Figure 9 that is the plane cutting latitude 35 degree N (the location of Matsue City). The radius \( r \) of the cut plane is calculated by the next formula if angle \( \theta \) (see Figure 9).

\[ r = R \cos \theta \]

When longitude changes 1 degree, distance becomes:

\[ 2\pi r / 360 = 2\pi R \cos \left( \pi \times 35 / 180 \right) \approx 111313.2 \text{[m]} \]

Therefore if longitude changes 1 second, distance is \([10]:\)

\[ 2\pi r / (360 \times 60 \times 60) \approx 30.92032 \text{[m]} \]

By using this method to project in 3D space, the changes in position information can be expressed using planar coordinates. The transformed trace data is then used to make the tour trace curve. The avatar can walk through on the trace curve by programming BB of Virtools. The system can project the viewer’s position during the tour by using a camera that has the avatar’s eyes.

4.2 Understanding check

The understanding check quiz verifies how much the user understood about the historic site at pre-tour and tour. The quizzes are constructed with elements that are elective questions and practical that asks filler questions. Each quiz is constructed with fifteen questions, therefore number of total question is thirty. Figure 10 shows a scene for quiz of filler question. If the user thinks about the answer, fills in blanks and selects “Answer” button, the system will respond correct/incorrect of each blank. Then the user can recognize about his/her understanding about the historic site.

5 IMPLEMENTATION

3D graphics are developed by building BB using Virtools4.0, and C++ scripts are created automatically. Figure 11 is a sample screen of development using Virtools.

We used the 3D modeling software MetasequoiaLE R2.4 to produce the historic site objects. Metasequoia has an easy interface and plentiful polygon editor. We used LightWave Modeler 8.0 to post textures of historic site objects. If the Virtools plug-in is added, 3D objects usable in Virtools can be created.

The OS of smart phone is Windows Mobile6.1 Professional. Programs of smart phone are implemented with C# language using .NET FRAMEWORK.
6 EVALUATION

Twelve students tried the pre-tour learning functions and gave their evaluation by questionnaire. The questionnaire asked:

Q1. Could you operate the mouse smoothly?
Q2. Did you feel there were enough function buttons?
Q3. Could you move between different areas smoothly?
Q4. Was the quality of 3D objects, such as structures, good?
Q5. Didn’t you feel somewhat out of place with the background of graphics?
Q6. Was the Web page useful for tour learning?
Q7. Was the voice guide useful for tour learning?
Q8. Did you feel the content of the quiz was good?
Q9. Do you think pre tour learning functions using 3D space are effective for preparing for your tour?

Figure 12 Evaluation of pre tour learning functions

Figure 12 shows the evaluation results. Q1 indicates that three users felt the operation with clicking the mouse was difficult and the operation manual was not easy to read. However, there was an opinion that operation by keyboard was comfortable. Results for Q4, Q6 and Q7 were hopeful for us. Some evaluators felt that Web pages were necessary for a tour, and that an on/off function was needed for the voice guidance. Evaluators felt that ground display was unnatural (Q5) and there were not enough quiz answers (Q8). Most users considered that the pre tour learning functions were effective.

Ten students tried the tour learning functions. They were subsequently asked:

Q1. Could you operate the system easily?
Q2. Did you feel comfortable carrying the mobile terminal?
Q3. Did you feel at ease operating the touch pen?
Q4. Could you use the guide functions smoothly?
Q5. Could you make your records smoothly?
Q6. Were the historic information pages useful?
Q7. Was the position display function useful?
Q8. Was the handwriting sketch screen easy to operate?
Q9. Would you want to use this system for your sightseeing?
Q10. Do you think any functions need improvement or development?
Q11. Please comment if you have another opinion.

Figure 13 shows the evaluation of tour learning functions. In response to Q9, all evaluators answered that they hoped to use this system on their tour. All thought that the mobile terminal was easy (Q2) and useful for getting historic site information (Q6). The responses to Q3 and Q4 were positive regarding ease of use of the sketch and guide functions.

The very positive evaluation for mobility is a result of using a smart phone rather than a PDA. The historic site information browse function elicited positive evaluation because its pages were constructed with images in addition to text. The convenience and learning effect responses had improved over evaluations of earlier systems due to the new additions of the voice guide and handwriting sketch functions.

Conversely, the relatively negative responses to Q1 and Q5, ease of operation and creation of learning records, show that these areas must be improved. We also need to think about adjustments in response to the opinions and remarks of the evaluators given in Q11.

Finally, ten students tried out the post-tour learning functions and evaluated them by this questionnaire.

Q1. Did you feel the 3D virtual space looked like real space?
Q2. Was keyboard and mouse operation comfortable during the virtual tour?
Q3. Were you comfortable seeing the map and changing the viewpoint?
Q4. What are functions need to be improved or added for post tour learning?
Q5. Were the quiz contents suitable for review?
Q6. Were the quiz number and level measurable?
Q7. How about responding to the quizzes by keyboard?
Q8. What was your opinion of the avatar display by trace review function?
Q9. What are functions need improvement or what functions should be added for the route review?
Q10. Would you want to use this system for your historic site tour?
Q11. Please give your opinion or comment on your impressions.

Figure 14 Evaluation of post tour learning functions

Figure 14 shows the evaluation of post-tour learning functions. Ninety percent of users answered that the 3D space looked like reality (Q1) and that the tour assistant functions were good (Q3). The contents of the quizzes were considered suitable for review by eighty percent of users (Q5) and all users answered that they hoped to use this system for their sightseeing (Q10). Five of the ten evaluators commented in their responses to question 11 that this system was interesting, delightful like TV game and impressive for structure’s reality. This was a better result than we had hoped for.

However, only sixty percent of users were satisfied with the animation of the route reproduction (Q8). This was because there was an error of about five meters in the position data from GPS, and the trace curve could not be made correctly. The Japanese government has decided to launch stationary satellites in 2014 to construct Japanese GPS. If Japanese GPS were combined with American GPS, the error would decrease to less than one meter in the animated avatar display [11].

7 DISCUSSION

We considered the questionnaire results and identified the next set of challenges for the tour phase.

(1) Improvement of operation

It will be effective to review the design of smart phone screen, and add a “Return” button in each function to return the start page. It also needs a help function to guide beginners in the basic operation of smart phones.

(2) Improvement of function for making a learning record

Some evaluators found the create learning record function difficult to use effectively. So the screen design needs improvement and the “Free note” window should be reviewed. For example, this window should be divided into impressions of the historic site and advice for visiting there. Users should also be able to write information on these more materially.

(3) Replacement of the mobile terminal

We used a smart phone with a 4.1 inch screen as the mobile terminal. This screen size is too small so the characters and images on-screen are also too small. Also it is not easy to operate buttons on the screen. Therefore we are planning to upgrade to a tablet PC like GALAXY Tab of NTT docomo which has 7.0 inch wide screen. On the other hand, a tablet PC is bigger and heavier to carry than a smart phone. We need to find a balance between the priorities of ease of operation and ease of carrying.

The future challenges for post tour learning, as identified from the evaluations are listed below.

(1) Addition of 3D object

Evaluation of 3D was good, but it is necessary to further improve the reality factor. For instance we are planning to place objects such as trees. In addition, the passable route needs to be limited by putting in a transparent wall.

(2) Addition of a route selection function during re-trace review

This trial trace review used only one file created from GPS data. However the ability to select and display a file from re-trace route files is desirable. To improve this defect, menu screen should indicate the list of trace data available for selection by the user.

(3) Append voice guidance for trace review

Appending automatic voice replay as the user approaches the historic sire during post-tour review would create consistency with pre tour learning and tour learning. This historical tour learning system can support three phases; pre tour, tour and post tour learning. We evaluated each phase individually. As a next step, we must evaluate the system in combination, and identify the effects of the whole study cycle, which is the primary characteristic of the system.

8 CONCLUSIONS

We used 3D graphics and smart phone to create the Historical Tour Learning Support System to support tourists. We developed voice guide and handwriting/sketch functions to resolve problems identified in earlier support systems.
Ten users tried the system on tour and evaluated it by responding to a questionnaire. All of them hoped to use this system for sightseeing and evaluated each function as good. We developed tour trace function to record the tour route, and to incorporate tour learning with post tour learning. We believe that user can study more effectively by combining preparation and review.

For post tour learning, we considered a method to review the tour route and as a result, it is now possible for a tourist to follow the route they took in 3D space. Moreover we developed a quiz function to deepen and check understanding.

The ten students who tried and evaluated the system responded that the system was useful for historical tour learning, and most of them hoped to use this system at their historical tour.

We are planning to evaluate the system in combination. That is, to have evaluators undertake all three phases, pre-tour, tour and post-tour, to confirm its effectiveness. Finally we need to seek evaluation from the general tourist.

In future this system should be progressed to cover not only historical tour learning but also outdoors learning such as sightseeing, social visitation and school excursions.

REFERENCES


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