

Nara Palace Site Navigator: Device-Independent Human Navigation Using a Networked Shared Database

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Abstract. Many human navigation systems which present location-based information to mobile device users are developed in recent years. We have already developed a wearable tour guide system which presents location-based tour guide information using augmented reality techniques. In this research, we try to improve the previous system into a new device-independent human navigation system "Nara Palace Site Navigator" which can present tour guide information according to the specifications of the user's devices: wearable computer, personal digital assistant (PDA), and cellular phone. Additionally, this paper describes the experiments using the proposed system in the Nara palace site to show the feasibility of the proposed system.

1. Introduction

The explosive spread of a small computer and a PDA has made it possible to realize human navigation systems which can present location-based information to mobile device users according to the user's location. These systems present navigation information or tour guide information based on the user's location data to cellular phone, PDA, or wearable computer[1, 2] users.

A number of navigation systems using a PDA are proposed until now. For example, CYBERGUIDE system presents context-aware tour guide to a PDA user[3]. CYBERGUIDE system can presents the user's circumference map with an arrow which points out the destination. GUIDE system is a tour guide system for Lancaster City[4]. It can present location aware tour guide information according to the user's preferences using multimedia contents. The mobile museum guide system in HIPS project presents to the user location-based guide information in the museum[5]. REAL pedestrian navigation system can navigate the user using the user's circumference map and virtual reality contents in both indoor and outdoor environments[6]. REAL system can be used with not only a PDA but also a wearable computer using polygon reduction techniques for CG contents. Moreover, using powerful notebook computers, it can be realized that the mobile navigation systems present more attractive contents. DEEP MAP system is a wearable personal guide system using a notebook computer[7]. DEEP MAP system realizes useful tour guide for foreign tourists combining a language translation tool. MARS system is a wearable navigation system which can be used in the Columbia University campus[8, 9]. MARS system overlays annotations on buildings using augmented reality techniques[10, 11, 12]. ARCHEOGUIDE system is a mobile guide system for guiding tourists[13, 14]. This system is intended to present archaeological information to the user at cultural-heritage sites. The archaeological information in this system includes virtually reconstructed buildings which are overlaid on



Figure 1. The aerial photograph of the Nara palace site

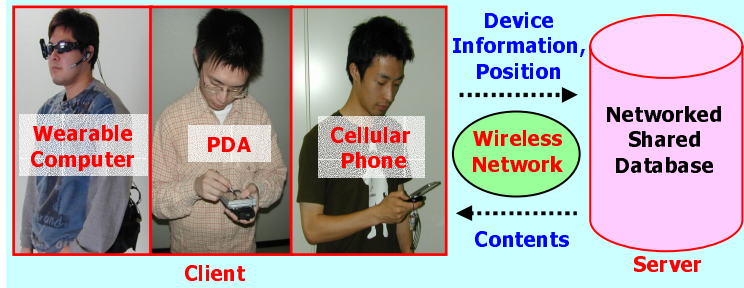


Figure 2. Nara Palace Site Navigator

ruins of buildings using augmented reality techniques. This system demonstrates that augmented reality provides an effective method for guiding tourists. We have also developed a wearable annotation overlay system which can be used indoors and outdoors[15]. Our previous system presents to the user location-based information using augmented reality.

However, these mobile navigation systems provide services which restrict the user's mobile device suitable for contents to be presented. In other words, the specification of the user's mobile device is determined by contents to be assumed. It is not a really useful service model in these days when many kinds of mobile devices are put on the market. Therefore, in this research, we try to improve our previous wearable augmented reality system[15] into a new device-independent human navigation system "Nara Palace Site Navigator". "Nara Palace Site Navigator" can present tour guide information according to the specifications of the user's devices using the networked shared database[16].

This paper is structured as follows. Section 2 describes the outline of "Nara Palace Site Navigator". Section 3 and Section 4 describe the detailed information of the client system using a wearable computer and a PDA/cellular phone, respectively. In Section 5, experiments with a prototype system in the Nara palace site are described. Finally, Section 6 summarizes the present work and also describes future work.

2. Device-Independent Human Navigation: Nara Palace Site Navigator

2.1 Assumed environments

Nara palace site is the Japanese ancient capital palace which existed approximately 1300 years ago. Nara palace site which has an area of 2 square kilometers is shown in Figure 1. The proposed system is supposed to be used in outdoor sightseeing sites which include some scattered sightseeing spots in wide areas just like the Nara palace site. Many of sightseeing sites (ruins or temples) in the world are classified into such sites. Namely, the proposed system has much possibility to be applied for many other sightseeing sites. Additionally, the proposed system runs on the premise that a wireless network can be used in such environments. To guide the user in such environments, the system is required to navigate the user from spot to spot along the tour route and guide the user at scattered sightseeing spots.

2.2 Outline of Nara Palace Site Navigator

Figure 2 shows the outline of the Nara palace site navigator. Nara Palace Site Navigator is a server and client system. The server stores a networked shared database of location-based contents, and clients are mobile devices which are equipped by tourists in the Nara palace site. The proposed system realizes to guide the user by navigating him/her between sightseeing spots and presenting guide information at every sightseeing spot. The system



(a) Example of web map



(b) Example of html content

Figure 3. Example of web map and html content

Table 1. Kinds of contents presented to each device

DEVICE TYPE	CONTENTS				
	AUGMENTED REALITY	MOVIE	SOUND	TEXT AND IMAGE (html)	AUTOGENERATED Web MAP (resolution)
Wearable Computer (WC) type	O	O	O	O	O (640*320)
PDA type	X	O	O	O	O (320*320)
Mobile Phone type	X	X	X	O	O (230*230)

(O: possible to present, X: impossible to present)

navigates the user between sightseeing spots using autogenerated web maps. Figure 3 (a) shows an example of autogenerated web maps which are headup-displayed user's circumference maps with some information. Our system guides the user at every sightseeing spot using multimedia contents: movies, sounds, texts and images (html files), and augmented reality contents. Figure 3 (b) shows an example of text and image contents.

Our system assumes that all client devices can measure the user's position and absolute direction and send them to the server. Moreover, client devices must be able to brows web pages. In the present system, such mobile devices are classified according to the performance into three device types as follows: wearable computer type devices, PDA type devices, and mobile phone type devices. Table 1 summarizes the kinds of contents which are presented by three device types.

We describe our planning service model of this system. We plan to construct the tour guide system guiding every device users in every sightseeing spots. Namely, only downloading the client application, the system guides the user in every sightseeing spots.

2.3 Networked shared contents database

The server stores a networked shared database of location-based contents. The database includes the following three tables.

- Contents table
- Device information table
- User's state table

Table 2. Example of the contents table

FILE NAME	CONTNTS TYPE	LATITUDE	LONGITUDE	DEVICE TYPE
1.mpg	Movie	Latitude 1	Longitude 1	All
2.mp3	Sound	Latitude 2	Longitude 2	All
3.html	Web	Latitude 3	Longitude 3	PDA type, Cellular phone type
4.vrml	Virtual object	Latitude 4	Longitude 4	Wearable computer type
4.txt	Position of virtual object	Latitude 4	Longitude 4	Wearable computer type
5.jpg	Annotation	Latitude 5	Longitude 5	Wearable computer type
5.txt	Position of annotation	Latitude 5	Longitude 5	Wearable computer type

Table 3. Example of the device information table

USER ID	DEVICE TYPE
ID 1	Wearable computer type
ID 2	PDA type
ID 3	Cellular phone type

Table 4. Example of the user's state table

USER ID	LATTITUDE	LONGITUDE	DIRECTION
ID 1	Latitude 1.1	Longitude 1.1	Direction 1
ID 2	Latitude 2.1	Longitude 2.1	Direction2
ID 3	Latitude 3.1	Longitude 3.1	Direction 3

Table 2, 3, and 4 show examples of these tables. The contents table stores contents file names which are associated with contents-embedded positions and the kind of device which can present each file. The device information table manages specifications of all users' devices. The user's state table manage every user's present position and direction. The contents table is prepared beforehand and the other two tables are created or updated when the data are transmitted from clients. These tables are used for deciding the contents which should be sent to the client.

2.4 Flowchart of Nara Palace Site Navigator

In this section, the flowchart of the system is described. The Nara Palace Site Navigator realizes device-independent human navigation with the processes described below.

1. When a client device starts the client program, the client device sends the device information including specifications of the device to the server. In the present system, the user input the device information manually.
2. When the server receives the device information, the server issues the user ID for the accessing client. At the same time, the server adds the new client data into the device information table.
3. The client sends the user ID, the user's current position data (in latitude and longitude), and absolute direction to the server constantly. The data transmission rate is determined by the band width of the wireless network.
4. The server updates the user's state table based on the transmitted information. The server generates the headup-displayed web map around the user's current position based on data of the user's state table.
5. The server sends contents file which is determined by three tables. Concretely, a certain user's device type is found from the device information table and the user's current position is found from the user's state table. Using these data, the server can find file names whose contents can be presented by the user's device and are embedded near the user's current position. Finally, the server sends these files to the client.
6. The client displays web maps and contents to guide the user.



Figure 4. User's appearance of the wearable system

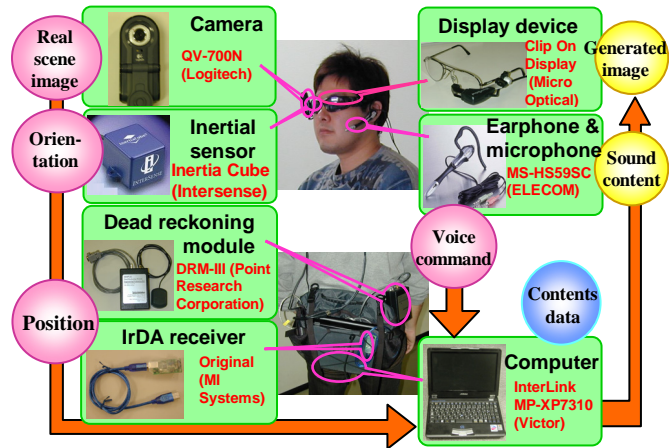


Figure 5. Hardware configuration of the wearable system

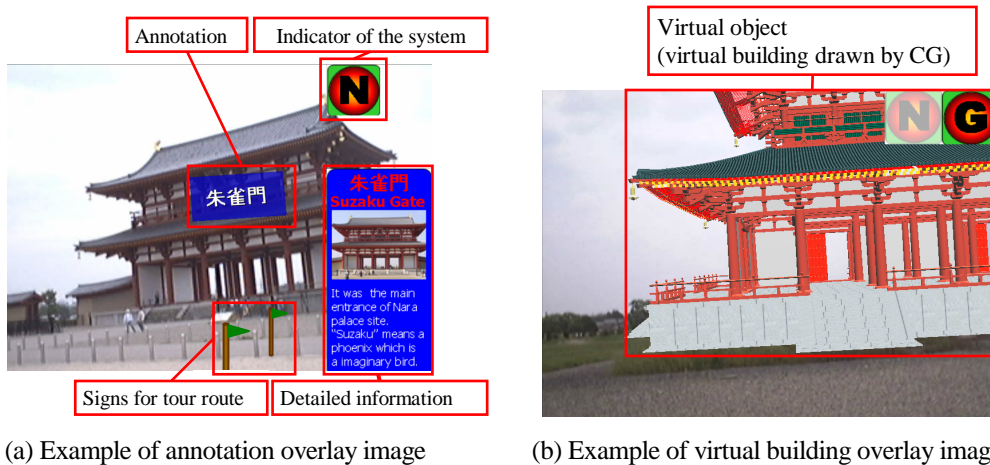


Figure 6. Examples of generated images of the wearable system

3. Client System Using Wearable Computer Type Device

3.1 Overview of wearable computer type

The client system using a wearable computer type device can present all prepared contents (movies, sounds, and augmented reality contents[15]) to the user. The user's appearance and the hardware configuration of the client system using a wearable computer is shown in Figures 4 and 5, respectively. Since the system uses video see-through augmented reality, the user equips a view camera. The client device composes augmented reality contents (virtual objects and annotations) on real scene images from the user's view camera based on the user's position and orientation measured by sensors. Then, positions of virtual objects used for augmented reality contents have been obtained from the server. Generated images are presented to the user through a display device which is attached to the user's glasses. Examples of generated images are shown in Figure 6. Figure 6 (a) is an example of the generated image when the system composes an annotation and signs for tour route on a real scene image. In Figure 6 (b), note that a virtual building is overlaid on the real scene of the ruins of the building.

3.2 Measurement of user's position and orientation

To overlay virtual objects in the correct position in the real scene image of user's view, the user's position and orientation should be measured in real time. The user's orientation, the

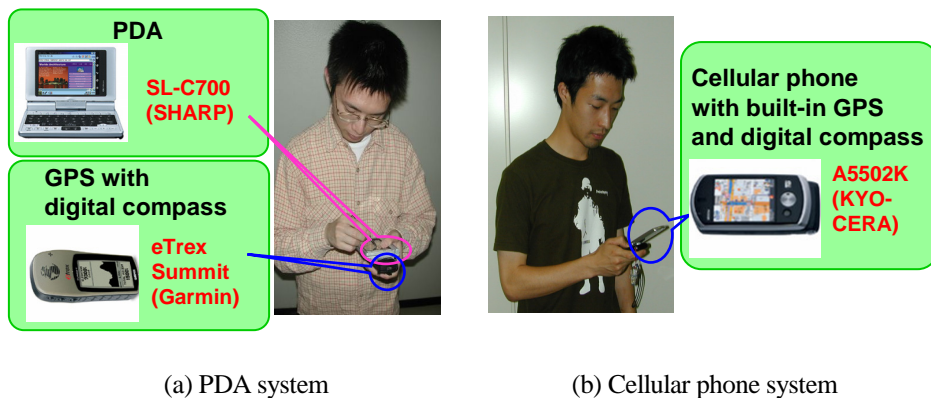


Figure 7. Hardware configuration of the PDA and cellular phone systems

direction of the user's viewpoint is measured with the inertial sensor attached to the user's glasses. The inertial sensor used in the proposed system can correct the inertial data measured by a gyroscope with an electronic compass and a gravity sensor. Accordingly, the system can measure the user's orientation without drift errors and accumulative errors that are principal problems when a gyroscope is used solely. There still remains a problem in the inertial sensor: that is, the data acquired from the inertial sensor are not synchronized with input images from the camera. In this system, the asynchronism of two data is reduced by delaying the data of the inertial sensor.

The system measures the user's position by combining the user's absolute position measured by the GPS or IrDA devices and the user's relative movement measured by the pedometer. When the GPS is used solely for measuring the position, the error fluctuates between 5 meters and 50 meters which is caused by various reasons: the number of captured GPS satellites, the weather, and so on. In the supposed environments which have no high-rise buildings, the error of the standard GPS is within 20 meters. This accuracy is sufficient enough for overlaying annotations on far and large real objects, but not sufficient enough for overlaying virtual buildings on ruins of buildings close to the user. Therefore, IrDA markers are set up at certain appointed points near the ruins on which virtual buildings are prepared to be overlaid. The user equips the IrDA receiver to identify the infrared ray including position IDs from the IrDA markers. Using IrDA sensors, the system can specify the user's absolute position with the error of less than 1 meter[15]. When the user goes away from one of IrDA markers, the system estimates the user's position by the pedometer. In outdoor environments without high buildings, the positioning error of the pedometer used in the proposed system is within 5% of the distance traveled.

3.3 Interaction with system using speech recognition engine

In our wearable system, the user needs to input some information just like the selection of the tour route and the selection of sightseeing contents to be presented. To realize the interaction with the system, the use of a hand-held mouse or a wearable keyboard is considered. In this system, the user can make a hands-free interaction using voice recognition. Our system uses the speech recognition engine "Julius"[17] for inputting information using the user's voice commands.

4. Client System Using PDA / Cellular Phone Type Device

Table 5. States of data transmission and renewal times of web map

Device type	Data transmission format	Maximum data transmission rate	Renewal time of web map
WC	Wireless LAN IEEE802.11b	11Mbps	1sec.
PDA	Wireless LAN IEEE802.11b	11Mbps	3sec.
Mobile phone	Data transmission format of mobile phones	144Kbps	7sec.



Figure 8. Examples of user-presented images in Nara palace site

The user's appearance and hardware configuration of the PDA system and the cellular phone system are shown in Figures 7 (a) and (b), respectively. In both systems, it is necessary to measure the user's position and absolute orientation. In the PDA system, the GPS receiver with digital compass is attached to the PDA to measure the user's position and absolute direction. In the cellular phone system, we use the cellular phone with built-in GPS receiver and a digital compass.

5. Experiment in Nara Palace Site

We have carried out an experiment in Nara palace site using the prototype system. In this experiment, we used all of three client devices (a wearable computer type device, a PDA type

device, and a cellular phone type device) described in Sections 3 and 4. The data transmission format and maximum data transmission rate of these devices are shown in Table 5. Experimental results including generated images are described below.

Figure 8 shows some examples of user-presented images. In Figure 8, (a), (b) and (c), and from (d) to (h) are presented to the user of the wearable computer, PDA, and mobile phone, respectively. We found that all contents files were presented to the user correctly as established in Table 1 using the proposed system. Table 5 also shows the renewal time of autogenerated web maps shown in Figure 8 (a), (b), (d), and (e). The renewal time means the time after the client transmits the demand of updating to the server until the web map is updated. The network delay in addition to these renewal times has an influence on the comfortableness of tour guide. Since walking users cannot move so fast, the present network delay and the poor update rate of the user's position is a trivial problem. However, for the user's orientation, it is a significant problem. This is the problem which has occurred also in conventional human navigation systems using a wireless network. In the present system, the server generates a web page of the headup-displayed user's circumference map using the user's position and orientation data that are sent to the server. Figure 8 (f), (g), and (h) include augmented reality contents. Especially, in Figure 8 (g) and (h), a virtual building that existed in 1,300 years ago is overlaid on the real scene of the ruin of the building. In the experiments, generated images including augmented reality contents are presented to the wearable computer user at more than 8 fps. We found that these virtual objects are overlaid on correct positions of real scene images to present tour guide information to the user.

6. Summary and Future Work

This paper has described a device-independent human navigation system "Nara Palace Site Navigator". The proposed system presents location-based tour guide information according to the user's mobile device (wearable computer, PDA, and cellular phone) by sending device information to the networked shared database server and receiving device-suitable contents from the server. This paper has also described experiments with the prototype system in the Nara palace site actually to show the feasibility of the system.

For future work, we plan to improve the present system into a more useful device-independent system. Even though the present system classifies the user's mobile devices into only three types (wearable computer type, PDA type, and cellular phone type), the future system should classify the user's devices more strictly based on the various capacity (network power, rendering power, resolution of the display, and so on). Thereby, for example, the system can provide detailed virtual objects for a powerful wearable computer and rough virtual objects for a less powerful wearable computer.

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