Orientation-Aware Handhelds for Panorama-Based Museum Guiding System

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ABSTRACT
This paper presents an intuitive user interface (UI) for visitors in the museum to quickly locate an exhibit through orientation-aware handhelds, which would aid visitors in experiencing fluid visiting. The physical environment is represented as a set of panoramas. The corresponding view of the environment will be automatically displayed on the handheld device, which is equipped with an orientation sensor to align the panorama with the real world. A user can interact with an object within the environment by selecting the corresponding item on the display. Perceiving the same scene on both the handheld and the real world, a user can quickly and accurately select an item by clicking the corresponding item displayed on the handheld. Furthermore, the panorama is augmented with additional information to provide a better understanding of the environment. The simple yet intuitive selection scheme allows users, in the physical environment, to exchange information with the machines. A prototype system has been implemented to demonstrate the usefulness of this UI for museum guide applications. A user study has been conducted to examine its usability and performance.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces

General Terms
Design, Human Factors.

Keywords
User interface, orientation sensor, interactive environment, human-computer interaction, museum guide.

1. INTRODUCTION
Cultural and natural heritage are commonly collected in Museums, historical houses, or art galleries. These exhibition spaces consist of exhibition rooms populated with hundreds of exhibits. While visiting exhibition rooms, visitors roam from exhibit to exhibit, appreciating them and reading information from labels. To facilitate visiting and learning, institutions may present information through electronic guidebooks. In addition, visitors can query electronic guidebooks about advanced information.

When attracted by an exhibit, visitors would like to get more information. However, querying certain exhibits from guidebooks is always a cumbersome task because a visitor needs either to enter the query string or to browse a lengthy list. Although organizing exhibits effectively in hierarchical structure can greatly reduce search time, visitors still have to browse hierarchies. Moreover, the locating effort interrupts the visiting experience.

In this paper, we develop a panorama-based UI to improve the selection scheme, so that visitors can easily and quickly locate an exhibit with minimum user intervention. A panorama-based UI is achieved using a handheld device integrated with an orientation sensor. The orientation-aware handheld determines which direction the user is facing, and then automatically aligns the direction of the panorama with the real world (see Figure 1). The correspondence between the panorama on the handhelds and the physical environment provides an explicit and natural scheme. It also provides the facility to augment the panoramic view with extra information.

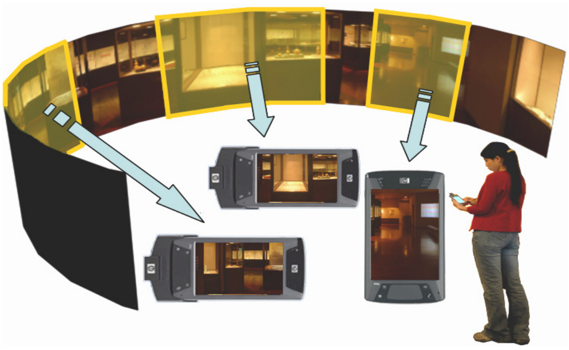


Figure 1. Users See Real World Views in the Handheld

2. Related Work
As a selection scheme, u-Photo [1] allows users to lookup information on devices by taking a photo. u-Photo Tool first recognizes devices in the photo, and then stores them along with contextual information for latter control. In order to find a desired device, users manually browse each u-photo, which turns out to be a time-consuming task when many devices exist in the environment. Woodruff et al. develop Sotto Voce [2], an

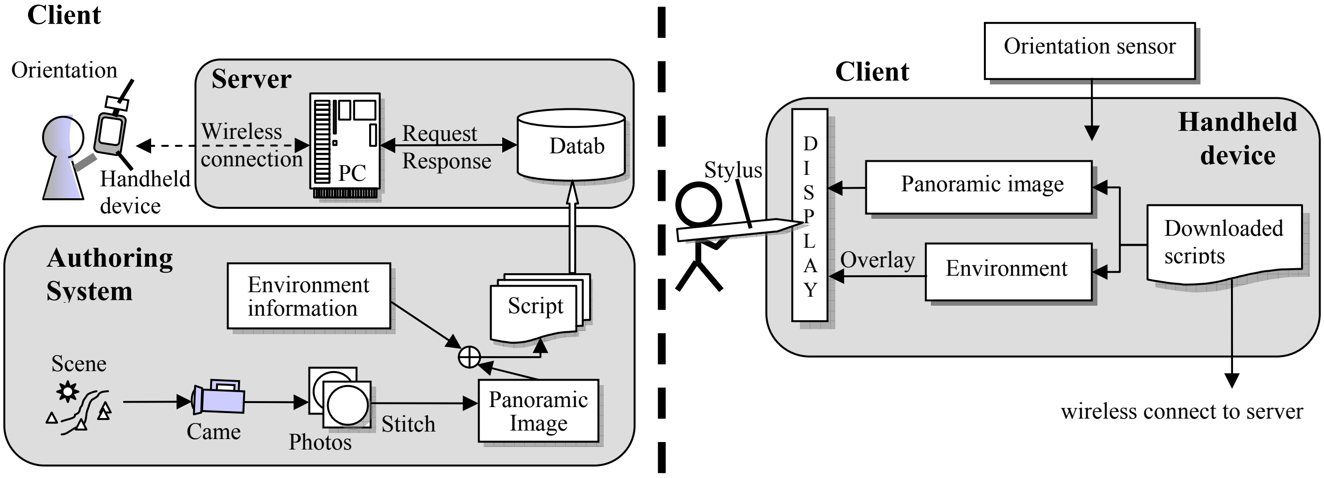


Figure 2. System Architecture

electronic guidebook, to improve social interaction by enabling visitors to share audio information. Their UI for selecting objects in the environment is similar to ours. However, they use a single photograph for each wall in a room, switching images by pressing a button. In contrast, a panorama is used to present a room and a user perceives the current view by simply turning their body.

There is other research on interacting with the environment. Ringwald [3] attaches a laser pointer to the PDA for users to select and control devices in the environment. Patel et al. present a 2-way selection method [4] to select objects in a physical environment. They integrate a handheld device with a laser pointer. When a tag placed in the environment is triggered by a modulated laser pointer signal, the tag then transfers its ID to the handheld device. Wilson and Pham propose the WorldCursorl [5], an evolution of their previous work on XWand, allowing users to select and interact with physical devices by positioning the cursor on the device and pushing the button on the wand.

3. SCENARIO AND FUNCTIONS

We now present our scenario in a museum, and then describe several functions provided by our system.

Susan enters a crowded exhibition room in the museum. Her PDA automatically downloads the panorama of this room. She looks around and is immediately attracted by a sculpture in the distance. However, she has trouble making her way to the sculpture due to the crowds. Susan holds her PDA, and the panorama displayed on the PDA is automatically aligned with Susan's orientation. She easily identifies the sculpture in the panorama and taps it with a stylus. A detailed description of the sculpture appears on the screen.

We can summarize the functions provided by our system. First, our system provides an intuitive way to choose objects by clicking them in the panorama. A panorama is a 360-degree viewing image. We install the orientation sensor on the handheld, as shown in figure 4. While the user operating with the handheld, we constantly update the partial view of the panorama on the handheld, according to the user's orientation. Figure 3 shows the workflow. A user sees the same scenes in the handhelds as in the physical environment; it is easy to recognize the object even if the object is obscured by others.

Second, additional information can be superimposed on the panorama. For example, the exhibits in the panorama are labeled for easy reading. The panorama may be annotated with private information, which is unsuitable in the physical environments.

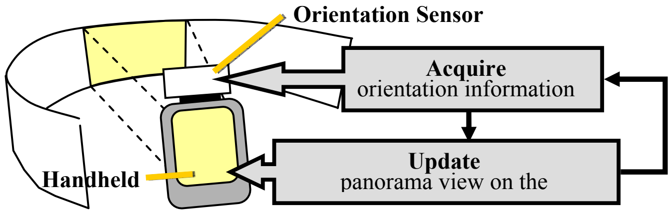


Figure 3. Working Flow of the Client

4. SYSTEM DESIGN

Figure 2 illustrates the system architecture. Our system comprises three parts: client, server and authoring system. The authoring system works offline in advance to generate panoramic images, and to edit environment-related information. The server and client work in real-time to interact with users.

In authoring system, we use a script to describe a scene in physical world. Each scene has its portrait script, which combines its panoramic image and environment information. These scripts are then saved in the database indexed by scene ID.

The server, which contains a computer and a database, is responsible for responding to clients' requests. The connection between server and client use a wireless technique. Clients request from server the scene-related scripts with scene IDs. Then, the server retrieves them from the database using the scene ID as the index.

5. SYSTEM IMPLEMENTATION

To confirm the performance of our proposed system, we build an experiment in our lab (see section 6) and an application in the National Museum of History. The following is the detailed implementation of our system.

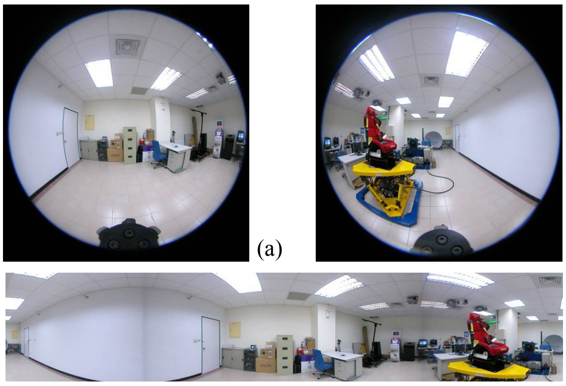

(a) (b) (c)

Figure 4. Creating a Panoramic Image from Fisheye Images
(a) The fisheye image taken from front side, (b) back side, and (c) the panoramic image created by Panoweaver from two taken fisheye images.

5.1 Authoring System

A panorama is an extremely wide-view image created by capturing a series of images at a fixed point. Constructing a full 360-degree panoramic image usually requires stitching ten to fifteen shots. This would take time and may cause bad stitching results because of changes of lighting and movement of people.

A fisheye lens has extremely wide angle of view, as much as 180 degrees. With a fisheye camera, as shown in Figure 4, we only take two photos of the scene, one for the front side and one for the back side. Constructing a panoramic image with at least two fisheye shots can significantly reduce the workload. Some commercial software, such as Panoweaver [6] and IPIX [7], provide powerful functions, which can provide users easy and automatic stitching in order to create panoramas.

To display the real scene on a handheld device, we do not need high-resolution panoramic images for the device's small–size screen. In our approach, the panoramic image is used mainly as an intuitive interface for users to contact information in a physical environment, not for virtual exhibition. Therefore, we acquire panoramic images, in our current implementation, from fisheye images captured by Nikon coolpix 5000 plus FC-E8 Fisheye Converter lens. We then use Panoweaver to stitch panoramic image from the fisheye images.

5.2 Client and Server

To acquire the orientation information, we use an iPAQ hx4700 connected to TruePoint orientation sensor released from PointReserch. It is a true 3-axis digital compass module, which can achieve 0.1 degree in resolution and 1 degree in accuracy. Figure 5 shows our client prototype. The server is IBM ThinkCentre A50 series, which is reliable to serve multiple clients in our deployment.

6. EXPERIMENTS

6.1 An application in Museum Guide System

We developed an application in National Museum of History. On deploying the museum guide system, we superimpose the exhibition room information on panorama, i.e., the exhibit labels,

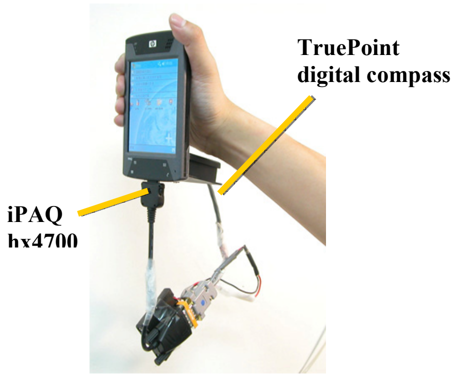


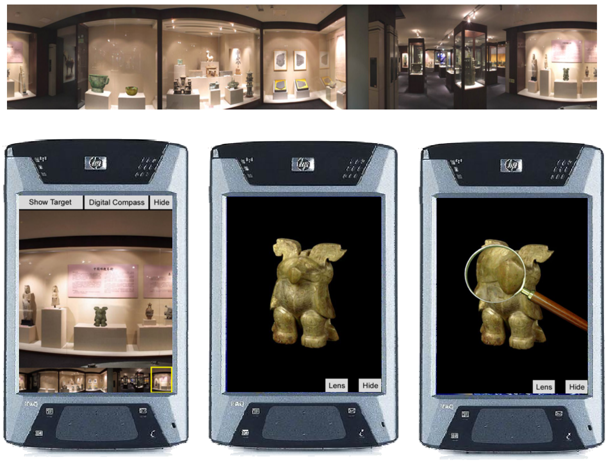
Figure 5. Client Prototype.

doorway indicators, etc.. We also generate object movies for part of exhibits. Users can select the exhibits when they navigate the panorama. After selecting an exhibit, users can see detailed descriptions of it or virtually manipulate the object movie of the exhibit. Our system also provides a magnifying glass which helps users view the details of the exhibit. (see Figure 6).

6.2 Experiment setting

In order to display a user's view of the physical environment on the handheld, we use panorama technique [8] to reconstruct a physical environment. The panorama is the most popular image-based approach for its photo-realistic view effect and for its ease of acquisition. It is widely applied to applications which require the exploration of real or imaginary scenes. However, if a user stands at a location not exactly where the panorama was shot, the user will perceive a slightly inconsistent view with the real world. We found such inconsistency does not affect the selection process due to human's excellent vision system. We conducted a user study with 35 volunteers, ranging from 15 to 60, to examine two hypotheses: (1) the panorama-based UI decreases seek time and (2) the inconsistency can be compensated by human vision appropriately. There are 19 males and 16 females. 4 participants are familiar with using the PDA, 12 participants used a PDA occasionally and 19 participants never used it before. The experiment includes: four sessions, a questionnaire and an interview. In each session, participants are instructed to finish ten randomly assigned selection tasks. Time and correctness are logged. In session Ⅰ, Ⅲ, Ⅳ, participants use panorama UI in distance 0, 1 and 2 meters away from the shooting point respectively.

Designing how to assign the participants selection tasks in the experiment, we considered various simulating conditions similar to those a visitor encounters in the museum. We first observed visitors' behaviors when they use the electronic guidebook.. We found that, while visiting with the guidebook, visitors are first attracted by the exhibits in front of their eyes. Then they use the electronic guidebook to find out information about the exhibit. Interestingly, while they use the electronic guidebook, their orientation is often roughly facing the exhibit. This pattern convinces us that the orientation-aware panorama-base user interface can provide visitors a fluid experience. Therefore, we add this pattern into the selection tasks. Each task, we assign a target item by notifying its direction (N, NE, E, SE, S, SW, W or NW) followed with emitting a laser point on the item. Participants



(b) (c) (d)

Figure 6. Experiment in Museum
(a) The panoramic image at the National Museum of History,
(b) navigating in the museum using the panorama,
(c) after selecting an exhibit for manipulation, and
(d) a magnifying glass showing details of the exhibit.

Figure 7. Direction Indications

recognize the target and pick it out in the panorama. As Figure 7 shows, we attach indicators at each test point so that participants can quickly turn to the correct direction while receiving a direction indication. In session Ⅱ, participants use a list-based GUI. When using list GUI as the selection scheme in guidebook, visitors look for target by browsing all exhibits on the list. The same occurs in this session, and we assign target item by simply noting its name in each task.

The result shows that, in table 1, the panorama-based UI performs 25% better than list-based GUI in average seek time and with a lower error rate. That is because, in Session I with the help of orientation information, users perform a local search on the panorama. In contrast, in Session Ⅱ, users locate an item by globally searching all items on the list. Table 2 shows that the seek time doesn't increase when the inconsistency occurs up to 2 meters away from shot point.

Other findings in the questionnaire and interview include: (1) most participants operate our interface well with merely 5 minutes of training, including explanation of the UI and practicing, (2) all but two say they can visually utilize relative position among items to turn their body and quickly find the target, and (3) participants also believe that familiarity with the environment helps speed the selection process.

Table 1. Target Seek Time (sec) and Error Rate (%) in Session Ⅰ and Session Ⅱ

	Session Ⅰ	Session Ⅱ (List GUI)
Average seek time	65.5	88.0
Error rate	5.7%	9.4%

Table 2. Target Seek Time (sec) in Session Ⅲ, Ⅳ.

	Session Ⅲ	Session Ⅳ
Average seek time	66.5	69.4

7. CONCLUSION

We proposed a simple yet intuitive UI for visitors in the museum to quickly locate an exhibit. As a selection scheme, the novel UI utilizes augmented panorama to display the surroundings. With the help of an orientation sensor, the panorama can be aligned automatically with the real world. Perceiving the same scene both on the handheld and in the real world, users can select target items quickly and accurately. We have presented our system design in detail and tested the system in sample environments, including our research laboratory and a science museum. A user study has been conducted to examine its performance and usability.

8. ACKNOWLEDGMENTS

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