Ubiquitous Information System for Digital Museum Using Contactless Smart Cards

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Abstract— **This paper proposes a ubiquitous information system for digital museum. To deliver museum information to visitors effectively, it is important to adjust the museum information according to their characteristics and preferences, and to provide it at anytime and anywhere they want to obtain it. To accomplish this requirement, we have built a ubiquitous information system to enrich real-world exhibition of digital museums. In our system, visitors carry their own smart cards containing their personal profiles. Using these profiles, information KIOSK terminals customize museum information. In addition, visitors can capture their preferred information by a simple operation, and they can access it via the Internet from their homes.**

Keywords— **Personalization, Ubiquitous computing, Museum, Contactless smart card**

I. Introduction

This paper proposes a large-scale ubiquitous information system for digital museum.

Museums are places not only to collect and to investigate exhibits, but also to provide visitors with the environment for lifelong learning by delivering their museum information to visitors. To deliver museum information to visitors effectively, it is important to adjust the museum information according to their characteristics and preferences (we call this personalization), and to provide it at anytime and anywhere they want to obtain it (we call this ubiquitous information service).

There are a few advanced museum information systems which adopt high-level digital technologies, and are used in real-world exhibition halls. The most notable one is the Tech Museum [3]. Another prominent system is used in Exploratorium [2]. However, these approaches do not satisfy both functions: personalization and ubiquitous information service.

We propose a large-scale ubiquitous information system for digital museum that supplies personalization and ubiquitous information service. In our system, visitors carry contact-less smart cards which store parameters of visitors' characteristics and/or preferences. Information terminals in exhibition hall, such as KIOSK terminals, find visitors in front of them by polling smart cards, get their parameters of characteristics from their smart cards or servers, and change explanatory contents and indicate them according to their expression attributes dynamically. When visitors find some contents which they want to preserve, they can also let our system know it by pressing buttons on terminals. At this time, terminals notice their events to servers and servers generate visitors' profiles. When visitors access our system later, servers provide contents which they preserved according to their characteristics.

Our system provides two features which enable our system to be applicable to real museums. First, we consider the balance of effortless system operation and capability of devices and choose contactless smart cards as interaction devices between visitors and our system. Because contactless smart cards are cheap as a few dollars per sheet, they can control access to their data, and the rate of failure is low. Second, we design our system which complements storage capacity of contactless smart cards, by providing cooperation functions between cards and center databases in museums.

We design and implement our system, and apply it to two real-world exhibitions. More than 200,000 visitors used them. We confirmed the practicability of our system through tests carried out in these exhibitions.

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II. Related Works

There are a few advanced information systems which adopt high-level digital technologies, and are used in real-world exhibition halls. The most notable one is the Tech Museum [3]. In Tech Museum, at its entrance, visitors first register their ID numbers and several parameters such as physical characteristics and preferences into the Tech Museum system servers. In the museum, they always wear bar-code badges containing their ID numbers, which can tell computers in the museum exhibition hall who stands in front of the computer. Then, the computer extracts the registered parameters of the visitor from the servers, and it shows information adapted for the parameters. However, the limitation of this system is that the area of its information services is restricted into the museum building.

Another prominent system is used in Exploratorium [2]. In Exploratorium, visitors carry PDAs, called "personal scrapbook". They automatically get explanatory contents by only approaching exhibits. This system emphasizes on ubiquitous information access. However, it does not deal with the personalization of exhibited information at the real-world museum halls.

III. Our Exhibition Model

We have built a model to design a system ensuring personalization, and ubiquitous information service. In our model, our system in a real-world exhibition space consists of the following three kinds of elements: *visitors* who visit museum, *museum terminals* which provides museum information to visitors, and *museum information* which is whole information that museum terminals can provide. Our system assumes that museum exhibition consists of exhibits and explanatory contents.

A. Personalization

Adjusting explanatory contents according to various characteristics of visitors such as their knowledge levels or mother languages is important to deliver museum information to visitors effectively. In this paper, we call this function *personalization*, and define *attributes* as parameters which exert an influence on personalization.

Personalization consists of *personalization of contents* that terminals change languages and/or levels of explanatory contents, and *personalization of presentation* that terminals change size of letters and/or methods of output of the contents. Museum terminals ensure these kinds of personalization in the following way. When a visitor stands in front of a museum terminal, it obtains visitor's attributes first. Then, according to the attributes, it selects an appropriate explanatory content from museum information. This is the personalization of contents. Finally, the terminal converts the content according to his/her attributes. This is the personalization of presentation.

B. Ubiquitous Information Service

Until now, to recall the exhibitions and their information, visitors take notes. To support this, museums present fly sheets or books. We consider that it is effective to import contents in exhibition halls as electronic memos into certain devices using capture and access technology [1]. The capture and access technology enables users to capture information in ubiquitous computing environments, and to use the information by accessing the system later. Our exhibition model adopts this method, and visitors can fetch contents which museum terminals provide by casual operations such as pushing the buttons on museum terminals or putting cards on stands in front of museum terminals (*capture phase*), and later, they can access the fetched contents (*access phase*).

IV. Design

This section describes the philosophy and details of the design of our museum information system.

A. Target of Our System and Devices for Visitors

The main target of our system is not a small exhibition consisting of only a single room gallery, but a large museum such as national museums. We assume that our system consists of about hundreds of terminals, and that about a few thousands of people visit it in a day. In such large-scale museums, one of the most affordable and annoying operation works for museum information system is to manage rental devices for visitors. For example, we must check and exchange batteries of the devices, deposit money for lending the devices, and so on. Thus, in order to decrease the system operation effort, the device should be as cheap as possible and they should not need batteries.

Museums that we assume also have various services, such as museum shops, payment services, and point services so that visitors can go around museums happily. All services of these are not necessarily cooperating. Therefore, devices can control access to their storing data.

Here, we select appropriate devices for our system. We can use we can use PDAs, bar-code badges, magnetic cards, contact smart cards, and contactless smart cards as devices for our system.

Although Bar-code badges and magnetic cards are low-cost devices, they can not control access to their storing data. PDAs can control access to their data and enable effective personalization and ubiquitous information service on their displays. However, in the case of such a large-scale museum, we must prepare a lot of PDAs and must check and exchange batteries of them. It requires remarkable cost.

A smart cards is as cheep as a few dollars and can control access to its data. Moreover, since smart cards need no battery, there needs no effort for battery maintenance. We select contactless smart cards as devices for our system from the following two advantages. First, contactless smart cards and their reader/writer units have no mechanical parts, they seldom break down. Second, all visitors have to do is to put their cards on reader/writer units in front of terminals so that our system knows attributes of visitors. Consequently, we design our system in which contactless smart cards can provide personalization and ubiquitous information service as the same grade as PDAs can provide.

B. Requirements

Here, we describe the requirements of our museum information system, which are obtained from our experience of previous digital museum exhibitions [4, 6–8].

1. Facile user interface: People in broad social strata, from children to elders, visit our museum. All visitors are not always familiar with using electronic appliances. Therefore, intuitive and facile user interface is important for our system.

2. Changing attributes on-the-fly: Usually, visitors set up attributes before exploring the exhibition. For this purpose, there should be many terminals for setting the visitors' attributes nearby the entrance of the gallery. However, some museums might not have enough space at their entrance halls. On the other hands, visitors might want to adjust the size of displayed letters and the explanation level while seeing the exhibition. Therefore, all museum terminals should provide visitors with the function to adjust their attributes.

3. Applicable to existing museum information system: It is necessary that our system can be constructed on the basis of existing museum information systems and needs the fewest possible reconstruction. It enables our system to add functions of personalization and ubiquitous informa-

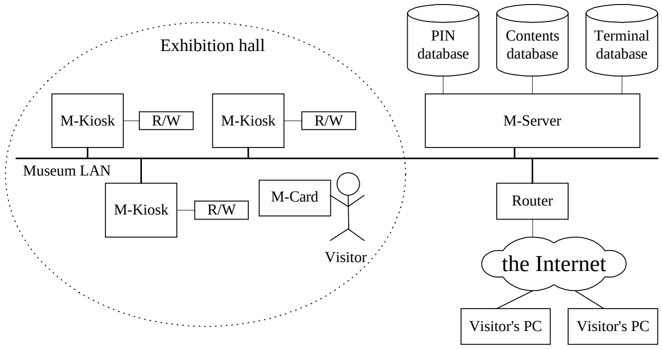


Fig. 1. Our System Overview

tion service to the existing system easily.
4. Easiness of modification: When some parts of museum exhibitions are replaced, the museum information system must be modified too. To deal with this replacement effectively, flexibility of the system is necessary to leave the system modification minimum.

C. *System Overview*

Our system consists of museum cards (M-Cards), museum kiosks (M-Kiosks), and museum servers (M-servers). In museum galleries, all visitors carry contactless smart cards, called *M-Cards*. *M-Kiosks* stand nearby exhibits and are equipped with reader/writer units for M-Cards (we call "R/W unit" after this). M-Kiosks can communicate with *M-Servers* via LAN. M-Servers have databases managing record data of visitors' behaviors and explanatory contents that M-Kiosks show. M-Server also contains a web server that releases the museum information for computers at home or schools connected via the Internet. (Figure 1).

We already described on M-cards in section IV-A. We describe other components of our system hereinafter.

C.1 M-Kiosks

Although M-cards can notify our system of exhibits about which visitors want to read the explanation, they can not provide information of these exhibits since they have no displays. M-Kiosks manage the user interface between our system and visitors as substitute for M-cards. There are three kinds of M-Kiosks according to their functions: (1)configuration terminals to set visitors' attributes, (2)guide terminals which show maps or announcements, and (3)explanation terminals to provide explanatory contents with visitors. We design common modules which deal with attributes of visitors in M-Kiosks to ensure our requirement 3. M-Kiosks consist of the following modules as basic common software architecture.
PIN Manager: PIN (Personal Information Number) manager deals with attributes which servers and/or M-Cards store.
User Interface Manager: User interface manager provides user interface for visitors to change their attributes dynamically.
Browser: Browser displays information of exhibits, such as public web browsers and DVD control modules.
Filter Manager: Filter manager performs data conversion between attributes which PIN manager has and data with which browsers or servers deal.

Customizing the above modules enables make-up of various M-Kiosks which a museum needs.

C.2 M-Servers

We design the following three databases which M-Servers access:
PIN database: PIN databases collect M-Kiosks and contents which visitors viewed and materials which visitors showed interest.
Content database: Content databases store explanatory contents of exhibits.
Terminal database: Terminal databases store contents which they provide to M-Kiosks and role information of M-Kiosks.

To satisfy our requirement 3, only M-Servers access the above databases. Because of this design, behavior of M-Kiosks depends on M-Servers, not databases.

In addition, to satisfy our requirement 4, M-Kiosk has no terminal-specific information. We store correspondence of terminals and contents which these terminals provide in a terminal database.

V. Implementation and Experiment

To confirm the effectiveness of personalization and ubiquitous information service, we have implemented our system and applied it to two real exhibitions: "Experience-Future Exhibition for 21st Century" (we call "Experience-Future Exhibition" after this) and "Digital Museum III" (we call "DM3" after this).

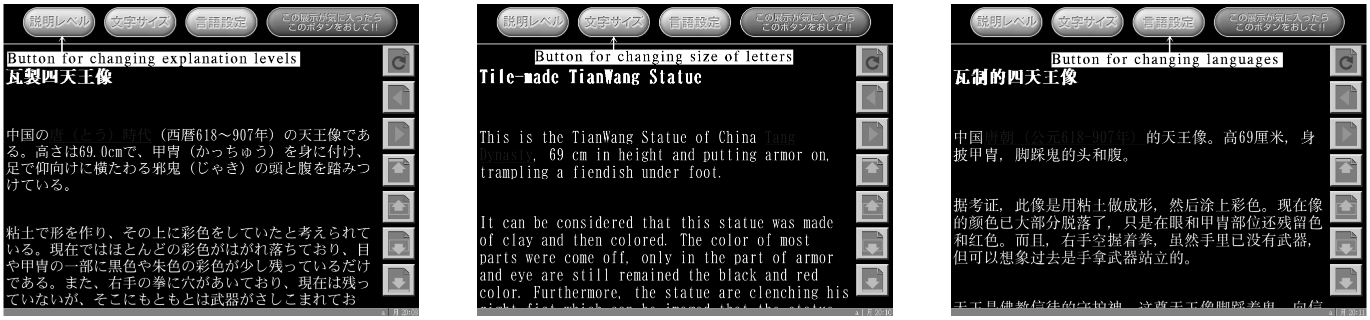
A. *Implementation*

We have developed our original contactless smart card [9] for M-Cards. Their physical shape is equivalent with ISO 7816 and their communication interface conforms to ISO 14443 Type-C. These cards contain 1792-byte EEPROM and take about a second to read or write data with encryption and authentication using DES. They take about 0.3 seconds without encryption and authentication.

We have used PostgreSQL [5] for databases and Tomcat [10] for a museum web server. We have implemented three kinds of M-Kiosks: (1)terminals using web browser, (2)terminals using DVD, and (3)terminals which has contents locally.

B. *Experiment 1: Personalization of Presentation and Contents*

DM3, held from January to February in 2002 in the Tokyo University Museum, was an exhibition to disclose the technology of digital museum. We prepared many kinds of abundant explanatory contents to each exhibit and tested a function that explanation terminals changed explanatory contents and displayed them according to characteristics and preferences of visitors. We created almost



(a) Japanese (b) English (c) Chinese

Fig. 2. Personalized Explanatory Contents (Digital Museum III : Sculpture of the Four Heavenly Kings)

(a) Capturing Portraits Using M-Cards (b) Lists of Captured Portraits (c) Explanation of a Selected Portrait

Fig. 3. Capture and Access Service in Digital Museum III

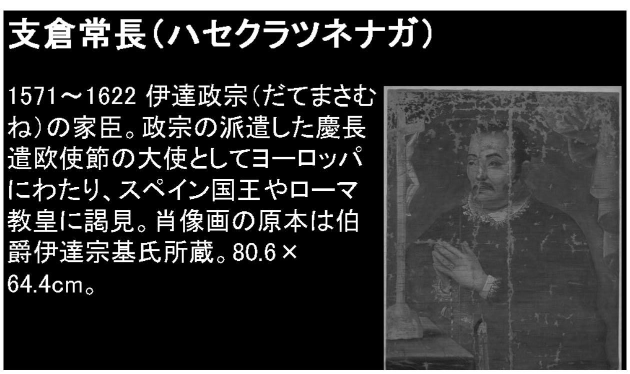


Fig. 4. Explanatory Contents of Personal Web Page

explanatory contents as HTML files and stored them in M-Servers because of flood of them. Explanation terminals using web browser chose an apposite explanatory content from M-Servers using attributes of a visitor stored in his/her M-Card and displayed the content as shown in Figure 2.

C. Experiment 2: Capture and Access

In the DM3 exhibition, we have tested two types of capture and access service.

We prepared about 300 high-resolution pictures of portraits as exhibits themselves. Nine plasma displays showed them one after another. When a display shows a portrait in which a visitor was interested, s/he put his/her M-Card on the stand in front of the display (Figure 3(a)). At this time, our system recorded the number of the portrait on the field of his/her interested contents in PIN database. This means that s/he captures the portrait into his/her M-Card. When s/he reached a prescribed terminal and put his/her M-Card on the stand in front of it, the terminal displayed his/her captured portraits (Figure 3(b)). The visitor could get contents of these portraits by clicking on them (Figure 3(c)).

In addition, explanation terminals had a "favorite button" (Figure 3(c)). When a visitor clicked on this button, our system recorded the pointer of this explanatory content on the field of his/her interested contents in PIN database. When the visitor accessed the M-Server via the Internet, s/he could get "personal web pages" indicated the explana-

Fig. 5. Guide Map in Experience Future Exhibition

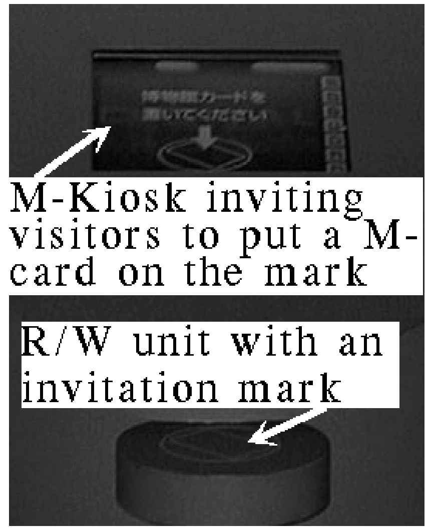


Fig. 6. M-Kiosks in Waiting Mode in Digital Museum III

tory contents which s/he had selected in the real museum exhibition (Figure 4).

D. *Experiment 3: Personalization of Routes*

Experience-Future Exhibition, held from July to September in 2001 in Kobe City, was an exhibition with adventure game taste. In this exhibition, we have tested personalization of visitors' routes. Our system changes each visitor's route according to histories of the visitor's behaviors. To support this function, M-Cards contain three kinds of parameters: (1)areas which visitors are interested in, (2)histories of visitors' behaviors, and (3)the number of M-Kiosks which visitors should go next. The last parameter is dynamically decided by the first two parameters. This decision algorithm generates dynamic and personalized route of visitors. By using this mechanism, we have realized an adventure game that provides different route for every visitor in the exhibition.

We have put 64 terminals in the exhibition hall and prepared 60 routes among them according to visitors' interests.

When a visitor reaches the correct terminal, it displays its explanatory contents and updates the history of behavior stored in his/her M-Card. When the visitor selects viewing a map, the terminal displays the map as shown in Figure 5 and suggests the location which s/he should go to the next.

VI. Evaluations

In this section, we describe evaluation of our system proposed in this paper based on the knowledge and statistics data obtained through tests carried out in these exhibitions.

About 200,000 people visited Experience-Future Exhibition and we used about 100,000 cards in 44 days during the exhibition held. On the other hand, about 12,000 people visited attended DM3 and we used 1,677 cards in 37 days during this exhibition held. Under such large-scale real exhibition environment, our system worked stably and did not have a big problem. We confirmed that M-kiosks and M-cards could provide personalization and ubiquitous information service as the same grade as PDAs could.

491 visitors accessed their personal web pages among 1,677 visitors who received M-Cards in DM3. It means that 29.3% of the visitors who received the cards used the personal web function from their home. These visitors took an average of 2.0 explanatory contents and 10.4 portraits per person in the exhibition hall of DM3. 50.9% of them viewed half or more of their captured explanatory contents and 46.2% of them viewed half or more of their captured portraits from their home.

Hereinafter, we look into particulars of our system along our requirements which we described at section IV-B.

Facile User Interface

In both Experience-Future Exhibition and DM3, when M-Kiosks waited on the standby screen "place a card on the mark" as shown in Figure 6, visitors could put their M-Cards on the position specified and see the explanations and/or the images which M-Kiosks provided. However, so that visitors set up positively their attributes which suited themselves more, our system had to explain the setting method of their attributes and the influence which their attributes had on M-Kiosks. To ensure this, we showed a video at the entrance and added explanations of attributes to configuration terminals.

In addition, adapting touch panels as input devices in M-Kiosks enabled visitors to input their attributes by only touching screen. However, it was not easy to input strings such as nicknames or e-mail addresses by selecting letters from dial on the screen.

Changing Attributes On-the-fly

Explanation M-Kiosk in DM3 have three buttons for changing explanation levels, size of letters, and languages (Figure 2). Visitors can change these attributes while reading contents. This function is used an average of 887.4

times per day. It means that a visitor uses this function 2.74 times in average per day.

Effortless of System Operation

Experience-Future Exhibition issued about 100,000 cards and had caused reissue of cards because of failure of cards themselves or data in cards 344 times. It means that the rate of reissuing cards is about 0.3%. We recognize that contactless smart cards have high possibility of system operation.

Applicable to existing museum information system

To adapt our public KIOSK browser to PIN manager, we built up the following three parts of our browser: (1)changing URL with clearing history, (2)making next/previous buttons disable when a visitor put on his/her M-Card on the R/W unit, and (3)setting whether or not a M-Kiosk display a menu box, which PIN manager sends to the browser using interprocess messages. We added change to eight pieces and 29 lines of our browser source.

VII. Conclusion

In this paper, we propose a large-scale ubiquitous information system for digital museum. First, we considered the balance of effortless system operation and capability of devices and chose contactless smart cards as interaction devices between visitors and our system. Because contactless smart cards are low-cost identification devices and they can control access to their storing data to enable our system to provide various services. Our system consists of M-Cards, M-Kiosks, and M-Servers. To add functions of personalization and ubiquitous information service to the already digitized conventional system easily, our M-Kiosks have common modules. Finally, we implemented our system and applied it to two real exhibitions. More than 200,000 people visited these exhibitions. We tested the function of personalization and ubiquitous information service, the possibility of system operation in case of using contactless smart cards, and that our system worked stably. We also confirmed that M-kiosks and M-cards could provide personalization and ubiquitous information service as the same grade as PDAs could.

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