Mobilizing Digital Museum with Chinese Digital Archive

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Abstract

In order to achieve highest level of knowledge dissemination, many museums have been digitalizing their collections and disseminated them to the world through the Internet. On the other hand, cloud computing and mobile communication technologies will further enhance the penetration capability of digital information, enabling mobile users surfing the wave of information world at anytime and anywhere through mobile devices such as smart phones or tablet PC. Nevertheless, both technologies have their own limitations, especially in handling Chinese artifacts that may hinder their applicability to the digital museums.

We use the National Palace Museum (NPM) as a reference museum for the application of cloud computing and mobile communication technologies to mobilize digital museums with Chinese digital archives. A set of design guidelines specific to the NPM's services is formulated and a few prototype systems are implemented based on these guidelines: (1) Qingming Painting and Mao Gong Ding Inscription graphical exhibition and edutainment systems; (2) Mobile Digital Museum Explorer. By mobilizing, the NPM and other museums will be able to lift their world-class services to another level for the benefit of all. [1]

Keywords: mobile computing, digital archiving

1. Introduction

An important trend among museums worldwide is the digitization and archiving of national cultural heritage in electronic databases for public retrieval through the Internet [3,11,12]. Due to its long history, the Chinese civilization has a very rich cultural heritage. The National Palace Museum in Taipei is known internationally as an archive for the treasures of Chinese civilization. Since 2001, the NPM has been digitizing and archiving its precious collections. Through the Internet, most of its digital archive is available for public retrieval to fulfill the museum's mission of dissemination and exchange of museum collections for educational, research, and commercial purposes [11].

After digitization, the next important issue is how best to present its material to the world to achieve the highest level of dissemination of knowledge. Currently, the most popular presentation format for most digital museums is statically structured, HTML-based Web presentation that mimics the presentation of the physical museums. One of the biggest advantages of a digital archive over a physical archive is the flexibility of document retrieval. For example, collections can be arbitrarily classified according to attributes such as time, location, event, etc. Users are able to choose their viewing points for exploring the digital archives to achieve their goals, for either educational or research purpose. The rigid format of a physical museum exhibition cannot provide this type of service, whereas a digital museum can easily do so.

Furthermore, the rich and irregular formats of Chinese artifacts is far beyond what a typical mobile device can support. For example, the famous "Kang-Xi Dictionary" collects 47,035 Chinese characters, which is several times of the number of modern Chinese characters; many ancient Chinese paintings are in long-roll format such that it is difficult to present on a small mobile devices; traditional Chinese documents are written in right-to-left vertical style. It is essential to extend the design guidelines of Apps on current mobile devices specifically for Chinese digital archives.

It is our long-term mission to develop the necessary technology for enhancing digital museum features to achieve the goal presented above using the available information and communication technologies. This study focuses on the mobilization of the Chinese digital archive using mobile computing and cloud computing technology [5] for the benefit of mobile users.

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2. Analysis of the Mobile Environment

In recent years, advances in mobile communications and cloud computing, plus the emergence of tablet PCs have led to the daily emergence of many new types of applications. Users of the new equipment, have sparked a new social style. In many developed countries, a large proportion of the population has become heavy users of smartphones or tablet PCs. It is common on commuter trains or buses to see all kinds of people with their heads bent over their smart phones or tablet PCs, quickly moving their fingers over the screen. The population of mobile users has far exceeded that of desktop PC users. This section provides an analysis of the characteristics of the mobile computing environment in terms of hardware, software, and use model, aimed at the supporting of the mobilization of the digital NPM.

Characteristics of the Mobile Devices

Mobile devices have both advantages and limitations inherent in their human─machine interaction mechanisms, screen sizes, hardware and software capacities, communication bandwidths, and so on, as described below.

- **Human-Machine Interaction Capability**

  Most mobile devices are equipped with powerful human─computer interaction capabilities, in particular a capacitive multi-touch screen allowing users to use their fingers to manipulate mobile devices. Unfortunately, many devices have neither a mouse nor a keyboard, so their use model is quite different from that of a conventional computer. However, Web pages currently are designed to operate with mouse and keyboard, to the detriment of touch-screen operation; for example, clickable objects on a Web page are usually too small for a finger to tap. Furthermore, it is generally inconvenient to type in much information on a mobile device due to the lack of a keyboard. Web page design for mobile users must thus minimize the need for keyboard typing. The web-site of the NPM (and many other museums) should be redesigned for this particular type of interaction.

- **Screen Size**

  The screen size of tablet PCs or smartphones is generally smaller than that of regular PCs, approximately 3-5 inches for a smartphone, and 7-10 inches for a tablet PC. These sizes are generally smaller than typical Web pages necessitating constant scrolling up-and-down or left-and-right to browse a full Web page. Furthermore, the font sizes of many Web pages are usually too small for mobile users to view, in particular for far-sighted seniors.

- **Limited Software and Hardware Capacities**

  It is well known that most mobile computing devices have fewer hardware and software resources, lower processor speeds, less memory, and narrower network bandwidths. In addition, some popular PC software is not available on mobile devices; for instance, Apple Inc.'s iPad does not contains a built-in Flash Player and thus many Flash-based Web pages are not viewable on an iPad. Worse, due to constant innovation in Web authoring tools, Web designers often endow their designs with unnecessary fancy features that inevitably consume more computing resources and create trouble for mobile users.

- **Communication Bandwidth**

  The wireless network bandwidth on a mobile device, delivered via either a cellular network or WiFi, is usually much lower than that of home or office PCs. Additionally, many Web pages may embed unnecessary audio and video streams that consume excessive bandwidth, affecting the performance of mobile devices. Furthermore, as cell-phone operators have gradually abolished the "all you can eat" flat-rate tariff model, mobile users now are more sensitive to the amount of data transmitted over wireless networks. Many fancy Web designs may no longer be suitable for mobile users. How to use text-based HTML codes to achieve a more pleasing Web design is an important issue for the NPM.

Behavior Characteristics of Mobile Computing

In addition to the resource constraints described above, the use model and environmental constraints of mobile computing are quite different from those of desktop computing, as outlined below.

- **Very short visual attention**

  When gazing at the screen, a mobile user may have to pay attention to the surrounding environment simultaneously, resulting in the period of visual attention to the mobile devices being very short. For example, a bus passenger may hold a hanging safety strap in one hand and a smartphone in the other. The information on the mobile device must therefore be presented in a manner that allows the user to grasp the required information instantly and clearly. The design of mobile information presentation faces great challenges in all aspects: color, layout, fonts, frame, hypertext structure, and other arrangements. Most existing Web design styles do not meet the requirements of mobile devices.

- **Information pages will be frequently zoomed or scrolled**

  Because the screen size of a mobile device is usually very small, and therefore often unable to present a page of information in its entirety, users must frequently zoom in/out and scroll up/down the page of information. Although multi-touch screens make zooming and scrolling operations easy, Web pages are usually not designed to accommodate this requirement.

- **Easy to slide and hard to click or tap**

  To manipulate a capacitive multi-touch-screen using finger gestures, it is much easier to slide than to tap the screen because tapping on a specific area of the screen requires a precise gaze and a precise tap. Gazing increases eyes' tension, while tapping is difficult for

large fingers or less conductive fingers. Worse, due to the convenience of mouse-clicking on a conventional computer, most Web pages are designed to be easier to click on than to tap. For example, many checkboxes are usually too small to tap.

Capacity Requirements for Cloud Computing and P2P Communication Protocols

When traffic in the NPM's web-site services increases, the NPM's server capacity and network bandwidth cannot be scaled up accordingly due to its funding constraint, leading to a decline in service quality. Cloud computing based services will solve part of this problem. We have been using a cloud platform provided by Chunghwa Telecom to implement a digital video service using NPM content. However, due to network bandwidth limits, it cannot support a large number of concurrent users. The P2P communication paradigm will be substantially useful in increasing the number of concurrent users while maintaining service quality.

3. Requirement Analysis for Chinese Information Interface on Mobile Devices

Ancient Chinese documents are written in a right-to-left vertical layout

All ancient Chinese documents are written from right to left and from top to down. It has no problem if a document is archived as a digital image. However, if it is archived in text format and is required to be presented in right-to-left and vertical layout, current mobile devices will not be able to support it. There is a need to accommodate this demand.

Chinese writing characters are hieroglyphical and has a large set of vocabulary

Different from alphabetic writing system in which every word can be composed from a limited number of basic "letters", Chinese writing characters is a hieroglyphical system in which every word or characters has its unique stroke structure such that it has a large set of virtually non-decomposable vocabulary.(In fact, some Chinese characters are nearly decomposable. However, there doesn't exist a general systematic way to decompose a Chinese character.)

Ancient Chinese has many hieroglyphical writing systems

Modern Chinese writing system is actually created and used by "Han" ethnic, one of many Chinese ethnics. Unfortunately, in the 5000 years of Chinese history, some non-Han ethnic dynasties have their own writing systems. For example, Qing dynasty is established by "Man" ethnic and has its own writing system. Even the Chinese writing system used by Han ethnic has many version of calligraphic styles evolved from time to time. "Oracle" and "Zhongding-Wen" are two famous styles that are quite different from the style used by modern Chinese writing system. Under this circumstance, text input to the mobile devices (for example, database search by entering keywords) becomes a big issue to be addressed.

Some Chinese paintings are painted in long-roll canvas

Many Chinese paintings are painted in long-roll canvas of one or two feet width and several hundred feet long. When its digital image is displayed on a mobile device, it shows a very slim non-viewable stripe. It can only be viewed part by part. A special screen manipulation method is needed to facilitate easy viewing such a long-roll format image.

4. Design Guidelines for Chinese Information Interface on Mobile Devices

The analysis described above shows clearly that the design philosophy of current popular Web sites is not suitable for mobile devices. Through a variety of experiments carried out in this study, we have identified a set of design guidelines for mobile applications, specifically for the digital NPM. The design of a mobile Web page should [8]:

- make use of the multi-touch screen to compensate for the inconvenience caused by the lack of a mouse and keyboard;
- support the traditional Chinese-style layout including operations such as automatic-word-splitting (hyphenation);
- support various types of text input (for example, when a user wants to retrieve documents written in Oracle calligraphy, the user must be able to enter Oracle characters);
- size up graphic user interface (GUI) objects, such as check-boxes and radio buttons, to facilitate precise finger tapping;
- allow users to take advantage of multi-touch features to quickly and easily zoom in/out of a Web page (note that some Web pages cannot be zoomed in/out on some tablet PCs);
- allow right-to-left and vertical layout;
- allow automatic-adjustment of line width to avoid line overflow with a change in font size or zooming especially for right-to-left and vertical layout;
- provide a context-sensitive automatic-word-completion feature to minimize the need for typing (Automatic-word-completion is a feature provided by many Web applications and text editors. It involves predicting a word or a phrase that the user wants to type in without the user having to type it in full. Context-sensitive automatic-word-completion is able to predict a user's input based on the document he/she is reading. For example, when retrieving a document of the Xia or Shang dynasties, if the user types "乾" as the first word of search key, the system can prompt with "乾坤" or "乾卦" but not "乾隆" for the user to choose from. However, if the document to be retrieved is a late Qing Dynasty document, "乾隆" will be prompted to the user. This feature saves users much tedious typing.);
- provide pull-down menus (or similar mechanisms) as much as possible to reduce the demand for text input;
- provide automatic page scrolling with adjustable scrolling speeds (This feature is useful for small screens and long Web pages that lead to frequent page scrolling such as long-roll painting.);
- keep information presentation as simple as possible (be user-friendly); (Because a user's visual attention to a mobile device is usually very fleeting, colors, frames, fonts, and other artistic details must be

designed to clearly highlight the information of interest, allowing users to instantly capture this information clearly and unambiguously. Complicated information must be appropriately divided and organized using hyperlinks to allow easy navigation of structured information.);

- save bandwidth by avoiding unnecessarily complicated screen pages and using standard script languages such as HTML, CSS, and JavaScript to make pages attractive.

The current popular Web designs use many images or non-HTML tools such as Flash and ActiveX to make Web pages more vivid and attractive. Large images on Web pages may consume considerable bandwidth. Non-standard tools may hinder the viewing of these pages on mobile devices that do not support the required software. On the other hand, the browsers on both the iOS and the Android system support standard HTML, CSS, and JavaScript, which are sufficiently sophisticated to support many artistic designs. Designing Web pages using the standard HTML language suite has many advantages and should be encouraged.

Creating attractive Web pages by using artistic drawings is also very popular. However, artistic drawings are not only time-consuming but also very expensive. Moreover they require intensive communication and coordination between Web designers and artists, which is even more of a burden. The use of the standard HTML language suite will reduce or eliminate the participation of artists. Web designers working alone can create and modify Web pages. Not only will productivity be increased dramatically, but design costs will also be significantly reduced.

5. Prototype systems

We have designed and developed several prototype systems, as described below [1,2,6,8].

Qingming Painting and Mao Gong Ding Inscription Graphical Exhibition and Edutainment Systems

We used two famous collections of the NPM to develop two prototype graphical exhibition systems. The first is the famous painting *"Along the River During the Qingming Festival"* (Qingming Painting in short), created by Zhang Zeduan during the Northern Song Dynasty. The Qingming Painting documents the real life of the general public in its capital city, Bianjing, which was the most populated city in the world at the time. The preciousness of this painting lies not in the skill with which it was painted or its artistic value, but in its realistic recording of the life-styles of the Northern Song Dynasty. It is a valuable historical record. A small electronic screen cannot display the entire painting, which is painted on a long roll of canvas; users must constantly scroll left/right/up/down and zoom in/out of the screen to view the painting. This may be readily accomplished with a multi-touch screen tablet. However, the process is still very cumbersome because of the length of the Qingming Painting. In our prototype, we used hyperlinks to connect each digital object; these hyperlinks act as an index of knowledge exploration served by a back-end knowledge (meta-data) database. If a researcher wanted to study wagon or boat styles in the Northern Song Dynasty, he or she could easily explore the digitized painting to locate each desired object and tap it to retrieve the meta-data from the back-end database. The design of this system follows the guidelines presented in Section 3. A joint project between our research team and the NPM was established to populate the system with real meta-data and to evaluate the system in a real-use environment. The Qingming Painting exhibition thus offers not only visual appreciation, but also an educational and research function.

The second prototype used the Mao Gong Ding Inscription exhibition. The Ding, a bowl with three sturdy legs made of copper, was widely used in ancient Chinese dynasties as a ritual vessel and became a symbol of political hierarchy distinguishing the political status of the superiors from subordinates. In addition to its use in worship and ritual ceremonies, the ding was also used to record the meritorious quality of its owner. Such records were often closely related to important events and historical legends, and therefore are of great historical value. The Mao Gong Ding, cast by Mao Gong who was a relative of the emperor of the Zhou Dynasty, features 497 characters in a special calligraphy, called Zhongding-Wen, engraved on its surface to record a special event. As the government of the time was weak and incompetent, the emperor delegated to Mao Gong a special and powerful political position, similar to that of today's British Prime Minister. To encourage Mao Gong to work hard and love his people, the emperor also gave him various ceremonial gifts. Mao Gong cast the ding to record the event and express his gratitude. We developed a Mao Gong Ding Inscription exhibition system using images of the inscription. Each character in the inscription has an embedded hyperlink linked to its meta-data, which includes not only the relevant explanation, but also the information about the evolution of the character in calligraphy history. A user can study Zhongding-Wen by clicking on any character to gain access to this information. The system is available as a conventional Web site and as an iPad App, as shown in Figure 1. To further stimulate users and extend the learning efficiency, we also designed and implemented an edutainment system for each platform, as explained below.

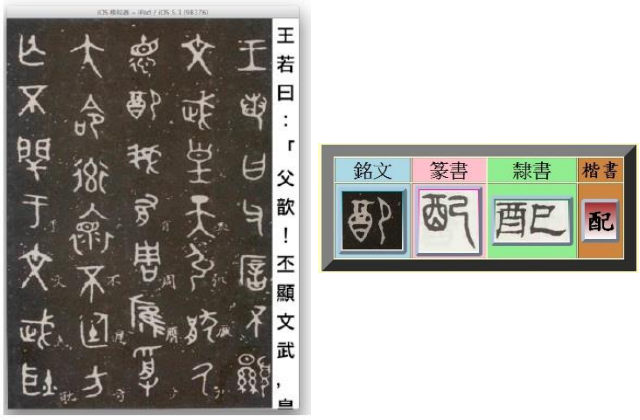

Figure 1: Mao Gong Ding Inscription exhibition system.

Edutainment, a buzzword for "learning by entertainment", has long been recognized as an outstanding method of achieving highly efficient learning. However, the creation of such a system has many challenges, requiring many hardware and software resources for its implementation. With their excellent and inexpensive human-machine-interaction, multi-media presentations, and mobile computing capabilities,

smartphones and tablet PCs are good platforms on which to implement edutainment systems for lively, vivid and joyful presentation of museum artifacts. We designed a "guessing game" for each of Mao Gong Ding inscriptions and Qingming Painting to stimulate users and enhance their learning efficiency. Through playing these games, users can learn the Zhongding-Wen more efficiently and gain a deeper knowledge of the Qingming Painting. In Mao Gong Ding guessing game, as shown in Figure 2, the system iteratively shows an inscription (a character in Zhongding-Wen) on the screen, and provides the user with a number of choices of modern characters. The implementation of these games shows that smartphones and tablet PCs are ideal platforms for edutainment system, and that such systems can stimulate users' interest. If greater development resources were available, more sophisticated games for edutainment could be developed.

Figure 2: Mao Gong Ding Inscription Guessing Game system

Mobilizing Digital Museum Explorer

The Mobilizing Digital Museum Explorer (MDME) is a ubiquitous media exhibition platform that we have designed to allow mobile users to browse museum artifacts. The MDME can enhance museum services by providing users with an utterly new experience during their museum visit. We used PaaS (Platform as a Service) in cloud computing, allowing users to access museum information at anytime and anywhere. The cloud server for the MDME is able to monitor and analyze user behavior and preferences, and provide personalized information to individual users. We also used Augmented Reality (AR), 3D-imaging, and path-planning technics to give users a brand-new browsing and navigation experience. The MDME is customized for the NPM, but all of the techniques developed are applicable to other digital museums.

Exhibition Platform Architecture

The explorer has two components: a cloud service system and a mobile exhibition platform. On the mobile side, Qualcomm Vuforia was used to make AR even more interactive. OpenGL ES was used to generate 3D artifact models. On the cloud side, the cloud service was built on the Heroku PaaS. The Ruby on Rails framework renders the code clean and concise. Urban Airship can expedite development and provides cross-platform (iOS, Android, Windows Phone) support.

Cloud Service System

Cloud technology is able to provide inexpensive high-performance computing capability and data storage via the Internet. In supporting a mobile digital museum, it is able to reduce the hardware requirements of mobile devices by transferring major computing loads and data storage from mobile devices to cloud servers. We used Heroku's PaaS platform together with Ruby on Rails to rapidly develop a server management interface. Ruby on Rails is based on the MVC (Model, View, and Controller) framework, so the front-end and back-end components can be separated easily. An advantage of this management interface is that administrators can readily synchronize updated data between all of the platforms. Mobile users can pre-load or update information from the cloud server on their way to a museum. When they arrive at the museum, they will be able to read the pre-loaded information offline. Users can also subscribe to specific services provided through the cloud server. When information that has been subscribed to is updated, it can be pushed to the subscribers via a push notification service. Designing the system in this way places most of the responsibility or cost-intensive computation on the cloud server. As a thin client, a mobile device can thus experience smooth browsing and navigation.

A. Data Management and XML-Based Data Exchange

With Ruby on Rails, database administrators can use the *scaffold* command to easily create and edit a variety of database tables and management interfaces. Museum staff can then use these tables to create and update digital archive entries for artifacts and exhibitions.

XML-based data exchange between mobile devices and Web pages is easily performed with the Ruby on Rails framework. By using the XML data format, mobile devices are able to exchange data with cloud servers via HTTP Get/Post mechanisms.

B. Push Notification Service

Mobile users can subscribe to various services, e.g. artifact exhibitions, special events, etc. As each mobile device has a unique device token, that can be used to determine what services have been subscribed to by a specific mobile user, the cloud server can then push personalized information to the individual users using a push notification service once the information subscribed to has been updated.

We implemented a push notification service using the Urban Airship push service library, which supports cross-platform services. When museum staff update data on the cloud server, the system determines the list of users who have subscribed to this updated information and triggers a push notification to them.

Mobile Exhibition Platform

Rather than using middleware such as PhoneGap, we chose to develop the proposed exhibition platform using iOS native programs, to preserve the native features and interfaces provided by the iOS and to achieve better system performance.

A. Exhibition Floor Plan

We used Scroll View to enable users to intuitively switch between floors and zoom in/out of the floor plan. Users are able to check the detailed exhibition information in each exhibition room by tapping the room icon.

B. Artifact Browsing

The platform supports the following innovative features for artifact browsing: asynchronous picture download, intelligent artifact search, interactive 3D artifact model browsing, and AR artifacts.

- Asynchronous picture download: Artifact information is updated through the network. However, this type of information usually involves large image files. Synchronous downloading may slow down information display due to either large image sizes or limited bandwidth. We therefore used an asynchronous operation downloading text before images to speed up information display. In subsequent browsing, the system pre-caches a number of forthcoming images based on the navigation sequence. The experimental results show that asynchronous image downloading is able to make artifact browsing smoother without noticeable lag.

- Intelligent artifact search: We made use of the iOS Search Bar to expedite type-in artifact searches. Once a user has typed in any initial part of a word string, the system uses the embedded "LIKE" function to match the characters against a keyword database, and offers a list of possible matches for the user to choose from without further typing.

- Interactive 3D artifact model browsing: This feature offers users an intuitive close-up view of an artifact, which may be physically impossible due to the distance between a displayed artifact and the visitor and to the static nature of physical exhibition with its non-viewable coffin-corners. Users may explore the 3D models by zooming in-and-out, and rotating in all four directions with no coffin-corners. In addition, artifact images are tagged, allowing users to tap them to obtain further information. We used the OpenGL ES library together with the native gesture-recognition function.

- AR artifacts: Wikipedia defines AR as a live, direct or indirect, view of a physical, real-world environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics, or GPS data. In this project, we used the Qualcomm Vuforia AR library to generate AR artifact models and tags. Using these models, users can obtain an utterly new experience of the artifacts. Figure 3 shows an AR teapot artifact popping out of a plane surface.

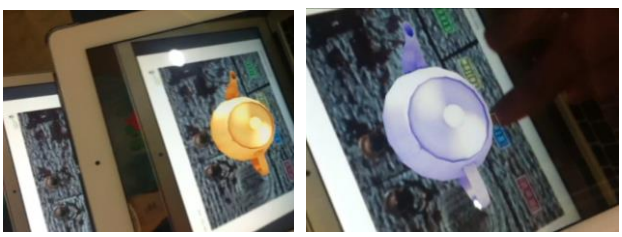

Figure 3: Viewing an artifact using AR techniques.

C. Push Notification of a Recent Special Exhibition

The push notification of a recent special exhibition is an example of a personalized push notification service. The app guides the user to the exhibition page when the user taps the message.

D. General Navigation of Artifacts

- Artifact information navigation: We used Table View to enable users to itemize artifact information. The information is optionally displayed in either "audio" or "video" mode.

- On-the-spot AR artifact direction guide: Even though a museum usually provides vistor with a floor map, they often get lost and cannot find their way quickly toward the artifacts they are interested in. Using OpenGL ES together with a camera, we developed an on-the-spot AR artifact direction guide. By simply tapping the icon of the current location and the icon of the target artifact, the system is able to calculate a route and display it on the screen, together with an arrow pointing toward the target, as shown in Figure 4.

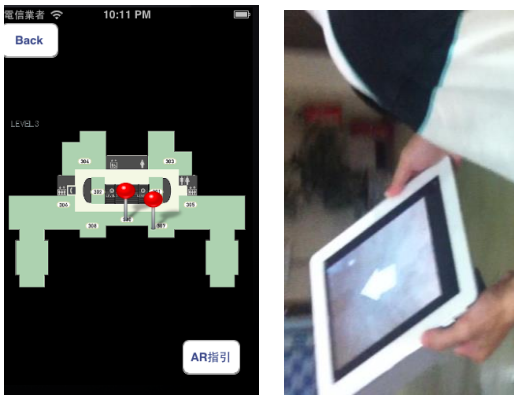

Figure 4: Floor plan map and AR direction guide.

The arrow is generated by OpenGL ES and is displayed perpendicular to gravity, determined using a gravity sensor (G-sensor). That is, the vector direction of gravity should be normal to the plane the arrow lies in. To simplify the problem, we assumed that the mobile device was placed on the horizontal plane. The system calculates the difference in degrees between the direction of gravity and the horizontal plane. The result is then used to adjust the rotation of the arrow so that it is perpendicular to gravity.

6. Concluding Remarks

In this paper, we analyzed the characteristics of the mobile computing environment in terms of hardware, software, and use model with the aim of supporting the mobilization of digital museums and of developing a set of design guidelines using the NPM as a reference. Based on this analysis and the design guidelines, we designed several application prototypes on both the iOS and the Android platforms. We also designed a live voice interactive interpretation system to assist with museum interpretation, in which the interpreter and the audience both use their smart phones. We expect that these technologies will be adopted by the museums around the world.

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