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Mobilizing Digital Museums with 3D Photography

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Abstract: In order to achieve a higher level of knowledge dissemination, many museums have been digitizing 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 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. A set of design guidelines specific to the NPM's services is formulated and a few edutainment systems were implemented based on these guidelines: (1) Qingming Painting and (2) Mao Gong Ding Inscription graphical exhibition systems. A low cost rapid 3D photograph production technology including the Drunk-eye 3D viewing skill that enables a user to view 3D stereograms using naked-eyes as well as a set of script based software tools is also developed to overcome the difficulty of 3D content production to support 3D archiving. With mobilization, the NPM and other museums will be able to lift their world-class services to another level for the benefit of all.

Keywords: Mobile computing, Digital archive, Edutainment, 3D

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 [1,2]. 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 [1].

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 various attributes such as time, location, event, etc. Users are able to choose their viewing points for exploring the digital archives to fulfill their demands, for either educational or research purpose. For instance, a person researching Chinese porcelain might want to classify porcelain collections by time to study the evolution of porcelain techniques, or by production kilns to compare kiln styles. The rigid format of a physical museum exhibition cannot provide this type of service, whereas a digital museum can easily do so.

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 concentrates on the mobilization of the NPM's digital archive using mobile computing and cloud computing technologies [3,4] for the benefit of mobile users.

This paper is organized as follows. The analysis of mobile computing environment is shown in Section 2. A set of design guidelines for information presentation on mobile devices is presented in Section 3. A few prototype systems designed based on the proposed design guidelines are shown in Section 4. A low cost rapid 3D photograph production technology is presented in Section 5.

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2. ANALYSIS OF MOBILE ENVIRONMENT

Over the past few years, rapid advance 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, the population of mobile users with smart phones or tablet PCs has far exceeded that of desktop PC users. The characteristics of the mobile computing environment in terms of hardware, software, and use model has been analyzed in our previous study [5].

A. Characteristics of Mobile Devices

- Powerful 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 mobile devices have neither a mouse nor a keyboard, such that their use model is quite different from that of a conventional computer. However, most Web pages are designed to operate with mouse and keyboard, to the detriment of touch-screen operation. Web page design for mobile users must thus minimize the need of keyboard typing.

- Small Screen Size

The screen sizes of tablet PCs or smartphones are generally smaller than those of regular PCs, and thus are 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

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. Worse, due to the 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.

- Limited 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 except the newest 4G or future 5G cellular networks. Additionally, many Web pages may embed unnecessary audio and video streams that consume excessive bandwidth, affecting the performance of mobile devices. Many fancy Web designs may not be suitable for mobile users before large scale high speed wireless networks are widely available.

B. Behavior Characteristics of Mobile Computing

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 of a mobile device, a user may have to pay attention to the surrounding environment simultaneously, resulting in extremely short visual attention to the screen. The information on the mobile device must therefore be presented in a manner that allows the user to grasp the demanded information instantly and clearly. As a consequence, the design of mobile information presentation faces great challenges in all aspects.

- 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.

- Easy to slide and hard to tap

It is much easier to slide than to tap a capacitive multi-touch-screen using finger gestures because tapping on a specific area of a screen requires a precise visual gaze and a precise finger tap. However, most Web pages are designed to be easier to click using a mouse, but not easy to tap on a mobile device. For example, many checkboxes are usually too small to tap.

C. Capacity Requirements for Cloud Computing and P2P Communication Protocols

When the traffic of the NPM's web-site services increases, the NPM's server capacity and network bandwidth may not be able to scale up accordingly due to its funding constraint leading to the decline in service quality. Cloud computing based services will solve part of this problem.

3. DESIGN GUIDELINES FOR INFORMATION PRESENTATION ON MOBILE DEVICES

The analysis described above shows clearly that the design philosophy of current popular Web sites is not suitable for mobile devices. Although there exist documents that offer design guidelines for mobile devices, they may not well cover digital museums especially those museums with Chinese archives [6]. 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 [5,7]:

- make use of the multi-touch screen to compensate for the inconvenience caused by the lack of mouse and keyboard;
- support the traditional Chinese-style layout (up-down style) including operations such as automatic-word-splitting (hyphenation);
- support various types of text input;
- size up graphic user interface (GUI) objects 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;
- allow automatic-adjustment of line width to avoid line overflow on a change in font size or zooming;
- provide a context-sensitive automatic-word-completion feature to minimize the need of text typing;
- provide pull-down menus (or similar mechanisms) as much as possible to reduce the demand of text input;
- provide automatic page scrolling with adjustable scrolling speeds;
- keep information presentation as simple as possible (be user-friendly);
- 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. Further, 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 Web technologies such as HTML, CSS, and JavaScript, etc., 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 even 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.

4. PROTOTYPE SYSTEMS

We followed the guidelines presented in Section 3 to design and develop several prototype edutainment systems for NPM, as described below. We used two famous artifacts 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 second prototype used the Mao Gong Ding Inscription exhibition. Both systems were implemented in both Web based and the Android based systems. The standard HTML language suite was used for web based version and Eclipse development environment was used for the Android systems.

A. Qingming Painting Inscription Graphical Exhibition System

The Qingming Painting documents the real life of the general public of Northern Song Dynasty 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 painting skill 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. Therefore, users must constantly scroll left/right/up/down and zoom in/out of the screen to view the image of 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 wants 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 its meta-data from the back-end database. The Qingming Painting Inscription Graphical Exhibition System thus offers not only visual appreciation, but also an educational and research function.

B. Mao Gong Ding Inscription Graphical Exhibition System

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 Graphical exhibition system using the 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 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 Android App, as shown in Fig. 1. To further stimulate users and extend the learning efficiency, we also designed and implemented an edutainment system for each platform, as explained below.

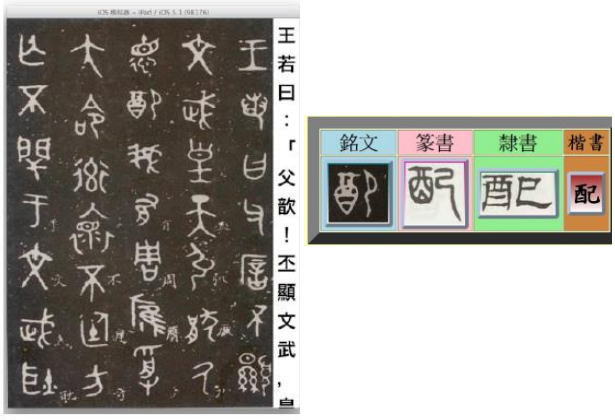

Figure 1. Mao Gong Ding Inscription exhibition system

C. Game Based Edutainment Systems

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 to implement. With their sophisticate 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 the Mao Gong Ding inscriptions and the 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 Fig. 2 to 4, 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 inscription shown in Fig. 2 is composed of two sub-inscriptions: a jar and a spoon. The correct answer is the fourth choice: distribution.

Figure 2. Mao Gong Ding Inscription Guessing Game system

Fig. 3 and 4 show another two guesses in Qingming Painting Guessing Game system. In Fig. 3, a clipped image showing a child riding on a cow is shown to the user and the users is to make a choice to answer the question: "What the child is doing?" To answer this question, user must study the painting thoroughly to understand the story told by the painting.

Figure 3. A guess in Qingming Painting Guessing Game system

Fig. 4 shows a man who is pulling a monkey with a leash. The question is "Where is the man in the painting?"

Figure 4. Another guess in Qingming Painting Guessing Game system

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. Furthermore, the implementation demonstrates that the standard HTML language suite without any fancy plug-in software is sufficient to implement a game based system over the Web for mobile users.

Nevertheless, there are some problems associated with the current implementation of web browsers. Many UI gadgets are not designed for touch screen, but rather for mouse. It is yet to be corrected by browser vendors.

A joint project between our research team and the NPM was established to provision the systems with real meta-data and to evaluate the systems in a real-use environment. Unfortunately, content provisioning for a world class digital museum requires a very strict and long bureaucratic process due to its stringent correctness requirement and IPR (Intellectual Property Rights) issues such that it may take several years to accomplish the task.

5. 3D PHOTOGRAPHY FOR 3D ARCHIVING

Thanks to the huge business success of several impressive 3D movies, 3D display technology has gained a significant improvement over past few years. Many television sets, monitors, tablet PCs, and smart phones nowadays are equipped with various 3D display capability at reasonable price. For instance, some 3D tablet PCs and smart phones can be purchased with only approximately one hundred US dollars higher than a 2D counterpart.

Unfortunately, 3D tablet PC and smart phone markets have not gained a sensible momentum yet mainly due to the difficulty of 3D content production. Nevertheless, some world class museums, such as Smithsonian Institute [8], have launched some projects to proceed with 3D archiving. In the near future, users can access 3D archives from the Internet using a 3D device.

In this project, we have been developing a low cost rapid 3D photograph production technology to facilitate 3D archiving. We believe that 3D archiving may have a significant impact to the mobile edutainment making it more attractive and more effective in mobile learning.

Human stereoscopic is to enhance depth perception in the human brain by providing the eyes with two different images, called a stereogram or a 3D image pair, representing two perspectives of the same object, with a minor deviation equal or nearly equal to the perspectives that both eyes naturally receive in binocular vision [9].

The 3D content (stereogram) production requires at least three different tasks: 3D image generation, format conversion, and stereogram preview. The most popular approaches to produce stereograms are the Geographic Model approach and the Photography approach. In the Geographic Model approach [8], a geographic model of an object is first created with mathematical data by various means such as manual input, algorithmic computing, or scanning and then stereograms are generated by 3D graphic computing. Since a geographic model is able to generate the entire coordinates of an object, the object can be viewed from any angle without any blind spot and be manipulated using a specific software. However, this approach is very labor intensive and only world class museums can afford this approach to create 3D models for a few selected artifacts. Furthermore, some particular objects, such as a big cathedral or temple, are difficult to create a realistic 3D model. On the other hand, in the Photography approach, a stereogram is created by taking photographs (or by drawing or painting) directly from the subject of concern. This approach is much more cost effective. The drawback of the Photography approach is that each stereogram can only represent a particular view of a subject. It takes numerous stereograms to represent the entire view of a subject. Furthermore, it is very difficult, if not impossible, to manipulate stereograms. Finally, a low cost 3D photography is yet to be developed to product high quality stereograms.

This project takes the challenge trying to develop a rapid low cost 3D photograph production process to support the Photography approach. Currently, there are a few dual-lens 3D cameras and video camcorders available on the commercial market. Users can take a 3D stereogram right on a simple click. These 3D devices use a fixed dual-lens such that they cannot adjust the length of their baselines, which is the distance between the two lenses, according to the zooming distance. Therefore, they all have very limited zooming capability. A sophisticated mechanical apparatus, which is estimated very expensive, is required to support the adjustment of the baseline length. Furthermore, the quality of stereogram generated by a 3D camera is much lower than what a regular DSLR (Digital Single Lens Reflex camera) can provide. In summary, a DSLR quality 3D camera is not available on current commodity commercial market yet.

An alternative way to produce high quality 3D stereograms is to use one or more DSLR to take two or more pictures from several different angles and convert them into a stereogram in the post editing process. Experienced 3D photographers could use a single camera to take pictures twice consecutively with a horizontal movement. This approach can product high quality stereograms at the cost of DSLRs.

However, due to the inevitable errors, the pairs of pictures may be misaligned, and thus need to be corrected in the post editing process. Major tasks in the post editing process includes picture-selection, cropping, rotation, alignment, left-right swapping, format conversion, etc. These editing tasks are very difficult to operate on a conventional 2D image processing software such as the famous Photoshop. For example, it requires a user much longer time and more effort to crop a picture with the horizontal and vertical sizes exactly the same as

the sizes of another picture. There are some software available to do the 3D post editing processing such as StereoPhoto Maker [10]. These software are far from perfect such that they all have a big room to improve.

The lack of a 3D previewer in the post editing process is another big obstacle yet to be overcome. In practice, a 3D photographer may take many trial picture-pairs for one desired stereogram because he/she cannot preview the results right on the camera as what can be done in a 2D camera. Therefore, one major task in the post editing processing is to select wanted picture-pairs out of many trial picture-pairs. Due to the lack of a 3D previewer, one cannot proceed the selection right in the middle of the post editing process and has to wait until all trial picture-pairs are corrected, format converted, and be installed into a 3D display device. Not only the post editing process is prolonged, most post editing effort will be wasted. In summary, current 3D post editing process is time consuming and inefficient. Consequently, 3D content production becomes an Achilles' heel of 3D archiving harming its advancement.

It has long been known that some people can view a side-by-side 3D stereogram directly using their naked eyes with proper training. We have designed a Drunk-eye naked-eye 3D picture viewing technology, (Drunk-eye 3D viewing skill, in short) allowing more users to preview a side-by-side 3D stereogram, up to three inches each side, right on a web page using their naked-eyes. (Approximately, ono out of three in our research team can gain the stereo view by using our Drunk-eye 3D viewing skill. Unfortunately, we have not been able to conduct a formal experiment to test this technology for general public yet.) In addition, we developed a set of script based post editing software tools to accelerate the 3D post editing process. Finally, many experimental 3D archiving projects have been undergoing for two years.

The major component of the Drunk-eye 3D viewing skill is a special dynamic repeated pattern background, called the Drunk-eye 3D viewing background, as shown in Fig. 5. This dynamic pattern background may attract user's eyes into a "drunk" state having his/her brain "see" double vision of the picture. By manipulating eye muscle, some people could fuse the two "0"s in Fig. 6 into an "8". By applying this skill on a side-by-side stereogram such as that in Fig. 7, user will be able to gain a stereo view. (Note that Fig. 6 is not a stereogram.) The theory behind this effect is yet to be researched by optic neuropathy experts and is far beyond the scope of this paper. Because the Drunk-eye 3D viewing skill has a limitation on the width of the stereogram of three inches each side and requires eye muscle manipulation, it is only good for 3D preview, but not for the replacement of 3D display devices. This skill can also be used to train our eyes enabling a user to use naked eyes directly to view a stereogram without our dynamic pattern background.

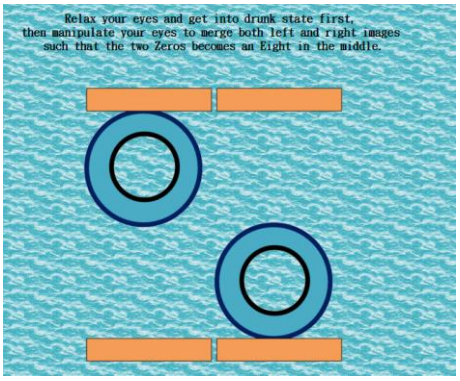

Figure 5. A training page of Drunk-eye 3D viewing skill

The 3D display devices we used in this project are Dromax 10 inches Tablet PC, HTC EVO 3D smart phone, and Infocus M550 3D smart phone. All three devices are equipped with a naked-eye 3D screen. HTC's is a four year old model and Infocus M550 is the newest model on the market right in 2015. While Dromax tablet has been available on the market for approximately one year. Because the display of a stereogram depends on the physical parameters of 3D screen, such as the size and the number of lenticular lines per inch, a stereogram must be customized for each 3D device to obtain the best quality. Not surprisingly, the newest model, Infocus M550, has the best displaying quality.

We have been using this technology successfully in our 3D archiving experiments. Thousands of stereograms were produced from many museums, gardens, zoos, and temples. These experiments prove that our 3D photograph production technology has greatly improved the productivity of 3D photograph production. A few minutes of work can produce a single stereogram out of a pair of misaligned pictures. With the assistance of batch processing capability of our software as well as the Drunk-eye 3D viewing skill, several hundreds of stereograms can be produced in one day by a single 3D photographer.

3D digital archiving further extends the capability of conventional 2D digital archiving in various ways. The 3D stereogram of an artifact is much more realistic than its 2D counterpart and thus it may enhance the recognizability of the object as a consequence. For instance, a geological object on the Mars may not be recognizable on a 2D picture, but may be recognizable on a 3D stereogram. Fig. 6 shows a 3D stereogram of a pottery puppet stuck on the roof of a Taiwanese temple, Fengyuan Mazhu Temple (Ci Chi Gong). It is too small to be recognized by the people standing on the ground. Further, the complicated background makes 2D pictures hard to appreciate even though the pictures were taken by a high quality DSLR with a telephoto lens. Such an artifact is much easier to recognize and be appreciated on a 3D stereogram.

Figure 6. A pottery puppet on the roof of a Taiwanese temple

Fig. 7 is a particular life style artifact carved on a dragon pole of a Taiwanese temple, Songshan Mazhu Temple (Ci You Gong), which was built in the 18th century. The stone carving were decayed by the negligence to barely recognizable and are found more recognizable in a 3D stereogram.

Figure 7. A stone artifact carved on a dragon pole of a Taiwanese temple

Fig. 8 is a delicate stone artifact carved on the wall of the St. Stephen's Cathedral in Vienna, Austria. The cathedral is constructed in the 12th century with limestones. Several hundred years of soot and air pollution turn its color from the original white into black. It is over 100 meters high such that the delicate stone carving near the top of the cathedral is difficult to recognize either on the site or on an enlarged 2D pictures due to its color and size. Again, it is very easy to recognize on a 3D stereogram. In summary, our experiments have demonstrated that 3D digital archiving has many advantages over 2D digital archiving.

Figure 8. A stone carving on the wall of St. Stephens' Cathedral, Vienna, Austria

6. CONCLUDING REMARKS

In this paper, we analyze 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 Web and the Android platforms. The implementation demonstrates that the standard HTML language suite without any fancy plug-in software is sufficient to support game based system over the Web for mobile users. Although a joint effort 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, it will take several years to overcome the strict and long content provisioning process due to NPM's stringent correctness requirement and IPR issues.

A low cost rapid 3D photograph production technology including the Drunk-eye 3D viewing skill that enables a user to view 3D stereograms using naked-eyes as well as a set of script based software tools is also developed to overcome the difficulty of 3D content production in 3D archiving. We have been testing this technology to create many 3D stereograms for many museums, zoos, gardens, and temples in several experimental projects. The experimental results show that our technology can not only significantly improve the efficiency of 3D archiving but also enhance the recognizability of artifacts.

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