

Lessons Learned from Designing a Virtual Heritage Entertainment Application for Interactive Education

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Abstract. Digital Koguryo is a virtual reality reconstruction of a Koguryo mural tumulus, Anak No. 3, designed to help educate visitors in the cultural background and life style of the ancient Koguryo. The focus of Digital Koguryo was to give users an interactive, entertaining experience and to feel engaged in the activity of finding the life aspects of the Koguryo culture and enjoy the spectacle of historical events. This paper presents the findings and lessons learned from the development and public demonstration of Digital Koguryo in the creation of a virtual heritage.

Keywords. VR, Cultural Heritage, Edutainment, Interactive Education

1 Introduction

Research in virtual reality and cultural heritage has shown a considerable growth in recent years. Virtual heritage applications employ the immersive virtual reality technology to recreate or interpret cultural heritage artifacts as they are today or as they might have been in the past. It gives users access to digital reconstruction of cultural heritage that would normally be inaccessible due to the location or the fragile condition of the artifacts. It also provides the opportunity to visit historical sites with no archeological remains or the excitement of reliving historical events. However, the majority of virtual heritage applications are archeological reconstructions of past cultural artifacts for digital preservation and restoration, which have been more concerned with the accurate restorations of original appearance [3].

Cultural heritage is particularly valuable for studies of ancient society, culture, and history. It contains all the data such as pictures and materials of architectural structure, cultural setting, artifacts and people. It is an excellent first use material in understanding ancient cultures. Therefore, it is important that the designers develop the applications that will enable visitors to learn cultural perceptions and understand the meaning of local cultural activities and stories behind the historical artifacts. Recently the designers have considered adding user interactivity (or activity) to increase user engagement in the virtual heritage environment. Examples include using

actor dialogues [5], game-like interfaces [1, 2], and storytelling through user feedbacks [4].

Digital Koguryo is a virtual heritage application that reconstructs the Koguryo mural tumulus, Anak No. 3. The Anak No. 3 Tumulus is a large stone-built multi-chamber structure with mural paintings drawn on its walls and ceilings. Koguryo mural paintings illustrate the life and historical events of the Koguryo civilization and details of the customs special in the ancient Korea. They are rich in color and tone, and still retain their distinct colors even after fifteen hundred years. The goal of the Digital Koguryo project is to help visitors learn and discuss the culture and customs of Koguryo. Digital Koguryo has been demonstrated to the general public in a variety of art and technical exhibitions.

It is a challenging process to create virtual heritage environments that are both engaging and educational. In this paper, we present the findings and lessons learned from the development and public demonstration of Digital Koguryo. It will show the design and implementation of Digital Koguryo, with an emphasis on interactivity. It will then discuss some of the important practical issues involved in the design and public demonstration of virtual heritage applications to increase user engagement.

2 Digital Koguryo

Koguryo (37 BC – 668 AD) is one of the three kingdoms of ancient Korea. The cultural background of Koguryo is revealed to have been of considerable complexity with various layers of artistic, religious and cultural influences upon its neighboring countries. There are thousands of Koguryo tombs spread out in North Korea and China of which, so far, only a hundred have been discovered to have wall paintings. Among the mural tumuli, the Anak No. 3 is the oldest and the biggest so far discovered. It is located in Anak-gun, Hwanghae-province, North Korea, and it is not open to the public due to its current fragile conditions. North Korean scholars claim it is the tomb of King Gugugwon.

Digital Koguryo recreates the fifteen hundreds-year old mural paintings in dynamic three dimensional computer graphics and animations. It is designed to create an interactive learning environment that can enrich user understanding of the past and to comprehensively present the history, life, and values of Koguryo cultural heritage. In Digital Koguryo, the game begins when the players enter at the front entrance of the tomb. The players can explore the painted chambers and corridors as they exist at the present time. As the players move closer to the paintings, the two dimensional painted figures become life-sized three dimensional characters, giving narrations about cultural artifacts, and interactively ask and answer questions on the context of the paintings.

Digital Koguryo is designed to run on a passive stereoscopic virtual reality system that is built using the passive stereoscopic polarization filters attached on two low-cost LCD/DLP projectors, a polarization-preserving screen, and a PC rendering the virtual world scene. Users wear a polarizing glass to see the immersive three-dimensional content. They can navigate and interact with the virtual environment using a wand or a joystick. Audio is enabled through the use of loudspeakers to give



Fig. 1 A demonstration of Digital Koguryo in the CAVE (on the left) and on the passive stereoscopic virtual reality system (on the middle), and the players are surrounded by the mural paintings printed on the walls in the exhibition room (on the right).

narrations. Digital Koguryo also run on a fully immersive CAVE virtual reality system. Fig 1 shows a large number of people who've participated in Digital Koguryo experience, which was demonstrated at the opening reception in the Center of Digital Ocean Virtual Environment (on the left image), at the SCIART 2004 (on the middle), and at the Game Expo 2004 (on the right) in Korea.

3 Game Design

Digital Koguryo is a collaborative effort between multidisciplinary research teams including archeologists, artists, and computer scientists in the creation of educational and exhibition contents of the Koguryo cultural heritage. In the design of Digital Koguryo, we wanted to create an interactive and entertaining virtual environment which enable users to feel engaged in the activity of finding cultural artifacts and enjoy the spectacle of the past historical events. Hence, we employed game-like design to improve user's cultural experience for interactive learning. This approach is similar to 3D adventure games that use popular culture as a game setting in a sense that they also cater to teaching history by playing. However, we were more focused on effectively conveying historical materials in Digital Koguryo.

3.1 Learning Materials and Scenario-based Game Design

The Koguryo mural tombs are historical relics, which had a big influence on the painting and architectural development of eastern culture in the medieval ages. In the absence of contemporary historical texts from the Koguryo kingdom, the mural paintings are valuable resources for understanding Koguryo's life and spirit. In Anak No. 3, the mural paintings depict the portraits of a king and a queen in the left chamber, everyday life and culture of Koguryo society in the right chamber (such as, a woman cooking in the kitchen, using a tread mill, drawing water from a well, the three-legged crow, horses and carriages standing on a stable, etc), a musical performance in the inner middle chamber, and a long procession featuring as many as two hundred warriors in the corridor. Fig. 2 shows the architectural structure and the three-dimensional models reconstructed from the mural paintings as experienced in Digital Koguryo.



Fig. 2 The reconstructed 3D model of the tomb structure (on the left), and the carriage in the right chamber (on the middle), and the foot soldier in the corridor (on the right).

It is quite a challenging task to recreate the Anak No. 3 Tumulus in virtual reality because little is known about the detail structure of the tomb and its mural paintings. It is not possible to take measurements of the tomb nor can it be photographed due to its current location. So, a variety of resources were used to collect information, such as old documents, slides, old photographs, books, a TV documentary, and a multimedia CDROM. This is then assorted by architecture, people, domestic animals, historical relics, and other ornaments to build the database.

We developed the 2D scenario-based animations and 3D reconstructed models for historical relics to convey the learning materials in a more effective manner. To this end, there are about ten items hidden behind the mural paintings in the virtual tomb. This includes a king's crown 'Baeklakwan', a queen clothing, a cooking pot, a carriage, a trumpeter, a Korean lute 'Geomoongo', a walking soldier, a metal shield, a Korean ancient harmonica 'So', and a drum for pairs. We wanted to encourage our visitors to carefully investigate the mural paintings and direct them to recognize historical relics shown in the paintings. As the players move closer to the paintings, they will receive a riddle to find the 3D reconstructed models matched to the items shown in the paintings. When they solve the riddle, they will then see a 2D animation depicting an historical episode – for example, the 2D kitchen animation shows a woman cooking, a pot boiling, the three-legged cow flying away from the roof of the kitchen to the sky, etc. They may also see some animations automatically triggered by their proximity to the murals, such as Korean traditional exercise 'Taegen.'

3.2 Digital Restoration of 2D Mural Painting Images and 3D Models

The existing surfaces of the original mural paintings are damaged in various places, and do not provide enough detail. Therefore, we had to perform a digital restoration of the 2D mural painting images to create the texture maps for Digital Koguryo. The artists scanned the photographs taken from the murals and the books, created the illustrations for the base to reconstruct the restored image. They then corrected for color, hue, and intensity of the digital images and filled the abrasion parts. This process is based on the historical research and documents on the polygenetic natural dyes of Koguryo and how the colors would change with moisture and how the texture of the painted walls would interfere with the colors.

We then digitally restored the Anak No. 3 tomb as if it existed today, such as the interior and exterior architectural structure and the mural paintings using the 2D

restored images. We also created the 3D reconstructed models of historical relics that are identical to the excavated objects, which were used for the riddles that were given to the visitors. We also developed the scenario-based 2D animations to portray the Koguryo cultural spectacle which cannot easily be rendered in real-time using 3D modeling.

3.3 VR Interaction and Surrounding Interior Design

We used a high-level VR toolkit called Ygdrasil (YG) [6] to construct the virtual environment and user interaction in Digital Koguryo. Ygdrasil is a set of C++ classes designed to simplify the construction of behaviors for virtual objects using re-usable components; and on sharing the state of an environment through a distributed scene graph mechanism. In the public exhibition, we provided a game joystick as a primary user interface. By using the familiar game interface, most people can easily navigate and select items in the virtual environment, except for the narrow corridors due to its lack of finer control. For example, some people tried to move or rotate in this corridor which made them get stuck in the walls.

We also had to consider the design of the surroundings to assist in immersion in the virtual environment. Digital Koguryo was first shown in an art exhibition installed in a room painted white. This made the room look rather empty. To better blend the exhibition room with the virtual environment and to make it look more like a tomb, we adjusted the illumination dimmer by covering the lights with Korean traditional paper. We then put the mural paintings printed on a long strip of silkscreen on the walls surrounding the VR display, so that users would feel as if they entered an ancient mural tomb. Many people said that they were delighted by the prints on the walls which helped to draw their attention to the virtual environment.

4 Issues and Lessons Learned from Design and Demonstration

Virtual heritage environments are a promising medium for interactive education but it is still difficult to construct due to limited historical documents and resources, and requiring close collaboration between multiple designers, and various kinds of conflict resolutions between these designers. In the design of Digital Koguryo, geographically distributed, multidisciplinary researchers (such as archeologists, artists, and computer scientists) had worked closely together for over six months from initial planning to final deployment. One of the main problems we encountered was in trying to compromise over the desire of building accurate digital reconstruction and rendering performance for real-time, interactive virtual reality experiences, such as reducing the size of 3D models and 2D texture images. Hence, we had to meet several times online or offline to adjust the models, interaction design, and other technical details.

In the demonstration, we found that visitors wanted tactile feedback on virtual objects. We also found that the 3D models reconstructed as the exact replications of original form seemed to cause problems. The long procession mural painting (while it is the most important mural paintings in the Anak No. 3) is located in the narrow

corridor, and some people seemed to have difficulty in navigating this corridor and observing the animation at the same time. Moreover, we did not provide a navigational aid (such as, a map with the item locations) in Digital Koguryo thinking the tomb small enough, but it resulted in some people missing some of the important lesson— e.g., the horn riddle nearby the entrance, the inner chamber riddle, and three riddles with the long procession mural painting.

5 Conclusion

The Digital Koguryo project was a collaborative effort among multidisciplinary researchers in the creation of a VR cultural heritage entertainment environment for interactive cultural and historical education. In Digital Koguryo, we have employed a game-like design to improve user engagement, to better give a rich sense of cultural learning experience. Game is a familiar medium to users, and they can better engage in tasks in the game environment. In Digital Koguryo, the players walk through the chambers and interact with the mural paintings inside the tomb. As they move closer to the paintings, they are given a riddle about the cultural artifacts drawn on the painting and must choose from possible answers.

In the development and public demonstration, we learned that the virtual heritage environment with interactivity encouraged users to be more immersed and engaged in cultural experience. However, we also learned the need for blended surroundings during demonstrations and a need for developing other user interface such as a tactile feedback to give richer sense of the VR experience. We will continue to explore more ways in providing an interactive, entertaining, and educating experience for the visitors to help them better immerse in the past cultural perspectives.

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