Design Research of Interactive Picture Books of Cultural Education Based on Augmented Reality Technology

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2021 16th International Conference on Computer Science & Education (ICCSE) | 978-1-6654-1468-5/21/$31.00 ©2021 IEEE | DOI: 10.1109/ICCSE51940.2021.9569391

***Abstract*—The application of augmented reality technology shows a new thinking of cultural education. What is different from the traditional cultural education is that it enhances user experience not only in the aspect of story but also ideological connotation of culture. In this paper, augmented reality technology will be applied to the design of picture book Xi Shi Dance. By using of Unity development engine and Vuforia SDK, we studied and developed the interactive augmented reality works. Been ranked among the first batch of intangible cultural heritage in 2006, Xi Shi Legend is a household story in china. The classic plot and character of Xi Shi Legend are used in this third-person puzzle solving interactive picture book, so as to achieve the purpose of inheriting excellent Chinese culture and popularizing traditional cultural knowledge.**

Keywords—culture, education, interactive picture book, augmented reality technology

I. INTRODUCTION

Story is an important carrier of human civilization inheritance and an important means of cultural education. With the popularity of mobile intelligent terminals and the comprehensive digitization of content, cultural education books are facing innovation in the aspect of experience design. Augmented reality technology has developed for more than ten years by now, the technology costs gradually reduced. Therefore, the practitioners and scholars in the publishing industry combine this technology with the publishing industry, and a new type of books appears, which is the AR books. Currently, the digital multimedia education market in the personal mobile terminals grows rapidly, which is the firm foundations for digital display of cultural education content. It can introduce Chinese traditional culture though texts, pictures, images and animation films, in order to make it possible to continuously spread it to every corner of the world by gaining more understanding, appreciation and passion.

AR is a new technology developed on the basis of VR. In 2015, Rauschnabel P. A. with other scholars had proposed that by using devices such as mobile phone or head-on display, especially smart glasses, AR presents the virtual digital information superimposed in the real environment and enhances the users' perception of real environment. With the continuous maturity of AR technology, it widely enhances the users' perception of real environment. With the continuous maturity of AR technology, it has been widely used in the field of digital reproduction and cultural education, as a new method to protect history, improve user experience and optimize learning effectively. C. H. Huang and Y. T. Huang developed a serious game named Papaq-Waka and discovered that, AR game helps to promote students' learning and understanding of local life and cultural history. Tom Dieck M. C. believe that AR products break the space restrictions on intangible cultural heritage, and make more intangible cultural heritages revitalized, in addition, the unique experience of AR makes it benefit to personalized education. In 2018, Schaper M. M. with the team designed a new kind of interactive product named World-as-Support to show the design process of the air raid shelter built during Spanish Civil War. On this basis, they evaluate and approve the benefits of educational experience with AR application.

AR books use augmented reality technology and graphic recognition technology to visually display the content in the mobile terminal. In picture book Xi Shi Dance, virtual character animation is superimposed over the background scene that exists in the paper book, the information of 3D virtual objects generated by computer is recorded dynamically, in order to match the real scenes and increase user experience of multi-sensory and immersion. Generally, AR books can be considered as a system consisting of marker recognition module, three-dimensional registration module and rendering module. Marker recognition module is the foundation of augmented reality technology, marker has been found out and tracked. Three-dimensional registration module according to the specific algorithm to find the accurate location of the virtual object in the real world, to make real-time tweaks. In the rendering module, virtual information and real environment are superposed, which achieve the accurate matching effect between virtual object information and real scene. Figure 1 shows the technical system of AR books.

The authors received financial support from Beijing Institute of Graphic Communication for the research, the number is: 27170120003/028.

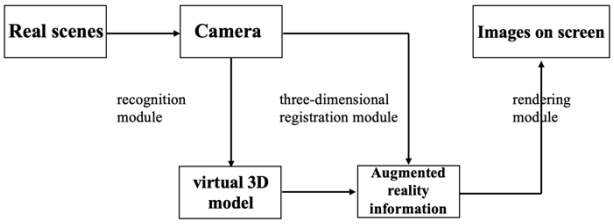

Fig. 1. Technical system of AR books.

Although the cost of augmented reality technology has been gradually reduced, many AR books are just the display of a new technology, lacking of creativity and interactive interest in cultural education. How to combine technology and content deeply, how to carry out cultural education smoothly in this kind of information media, and how to give full play to the advantages of AR books are the problems that need to be considered, practiced and explored.

As far as cultural education, interactive picture book Xi Shi Dance with augmented reality technology is an exploration. Non-visual and non-physical cultural content will be presented through interactive audio-visual content. Xi Shi Legend has been ranked among the first batch of intangible cultural heritage in 2006, which fully shows the humanistic education value. Based on Xi Shi Legend, picture book Xi Shi Dance adapted the story for the interactive multimedia works. Users will get interactive experience and cultural knowledge in a better way while solving puzzles, which shows a prospect of cultural education based on augmented reality technology.

II. PUZZLE SOLVING INTERACTIVE PROCESS

A. The Plot

The picture book Xi Shi Dance adapted the ending of Xi Shi Legend, on the basis of massive historical materials of the Spring and Autumn Period. With the transition of contemporary China, the idea of universal love is a common ground in Chinese and foreign culture, which is the topic of Xi Shi Dance. the story is told in reverse, from the moment Xi Shi becomes an old woman and no one knows who she is. As a non-player character, the child who called old Xi Shi grandma guides users through the application and helps users to solve the mystery of the missing Xi Shi. Figure 2 shows the threads of the plot.

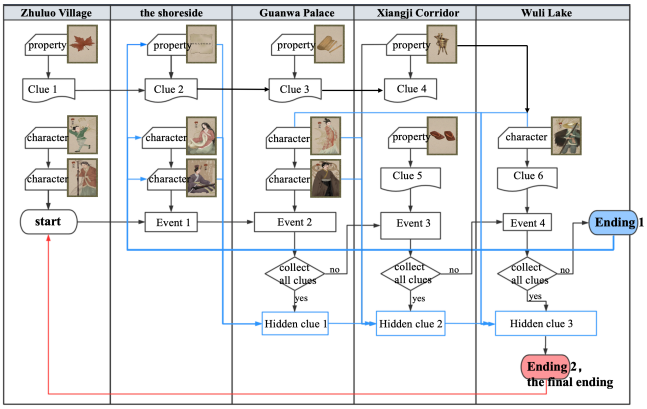

Fig. 2. The threads of the plot.

Classic plots in Xi Shi Legend are organized in a solving puzzles way, and involve historical event, recalling words and other details from stories. Some of them are shown when users read this book the first time, then at the end of the story Xi Shi is unaccounted, which is similar with Xi Shi Legend and not satisfactory. It is the time to dig for the other clues hidden in the book and put all of them together. When users collect all plots, they will find out the child's grandma is Xi Shi and her whole experience after Wu kingdom is conquered. The truth is Xi Shi's experience in Wu and Yue makes her deeply aware of the harm caused by the war to people, and finally she returned to Zhuluo village where she was born and cared for war orphans in the rest of her life.

B. Interactive Mode

In order to make users got drawn into the experience of the book rather than spend a lot of time in learning and recalling, the interactive mode in each page is similar, which includes one stand-up background made of paper, some marker card painted character such as the card of Xi Shi and some marker card painted key property such as the card of clogs. When video stream from camera with one marker image representing character or key property is tracked, it will show the character classic motion or the key property image with texts, voice-over and background music. When video stream from camera with more than one marker images are tracked, it will show an animation film related to these marker images.

III. REALIZATION OF AUGMENTED REALITY TECHNOLOGY

Vuforia is an effective tool used to develop augmented reality applications for mobile terminal. It can add computer vision functions to applications and enable them to recognize images and objects, or even reconstruct and show the real world environment. In this interactive picture book, Unity development engine and Vuforia SDK are used to achieve the augmented reality effect, in which virtual characters are superimposed over real background in the book accompanied by multiple audio-visual content. The picture book reveals the relationship between the characters in Xi Shi Legend by means of various ways of interaction, which increases users' pleasure when reading this book.

A. Marker Definition

The graphics in the marker card can be used as definition features in augmented reality applications. In the picture book Xi Shi Dance, different marker images represent different virtual content. These marker images can be combined in a multitude of different ways that activate the hidden plots. In the first stage, graphics in the marker card are designed and painted. Then upload the completed pictures of characters and key property to the database of Vuforia platform, the feature points data will be generated. Figure 3 shows the feature points data of the well-dressed Xi Shi.

Fig. 3. The feature points data of the well-dressed Xi Shi.

In the process of picture identification on the Vuforia platform, the more feature points the picture has, the more irregular these feature points distributed over the whole picture and the lager the available graphic is, the more efficient the identification is. Equation (1) is used to calculate the time of marker identification:

$$t = \frac{K \sin ax}{ndS} \tag{1}$$

In this equation, letter t is the time from the moment camera open to the augmented reality image appear, letter x represents the orthophoto distance from the camera to the picture used in identification, letter S represents the available area of the real-time image the camera can acquire and upload, letter n is the number of feature points in the picture, letter d represents the irregularity of feature points distribution, letter K and a are constants.

In order to improve the efficiency of identification of image feature, some measures could be taken, including increase the number of feature points in one picture and enhancing the irregularity of feature points distribution. Vuforia platform evaluates the pictures by stars after you upload them, 5 stars means it is easy to identity, 0 star means it is ineffective. Ensure that the rating is above 3 stars at least, in case of unnecessary trouble caused in future testing.

B. Augmented Reality Information Matching

As an AR SDK favored by developers, Vuforia platform encapsulates a large number of functions required for AR applications development. The feature point extraction function allows developers to call the interface to extract and match features of images. Vuforia SDK performs related work and return results automatically.

In Unity development engine, the data package of marker identification downloaded from Vuforia official website is assigned to the image target, the picture just uploaded on Vuforia official website will be available. Corresponding augmented reality content could be related to the marker card, and its position will be adjusted according to the marker card, then the process of augmented reality information matching is completed.

For single marker image assignment, the augmented reality information and image marker will match one-to-one, Equation (2) is used to express the mapping relationship between them:

$$F_a(X, Y, Z) \rightarrow G_b(X, Y, Z) \tag{2}$$

In this equation, letter a and b are natural numbers, and the set of a and the set of b are equal.

C. Three-Dimensional Registration

After augmented reality Information matching, it is necessary to transform the objects in real world to the images on the mobile phone screen, which is called three-dimensional registration. Three-dimensional registration is a process of projection transformation in different coordinate systems, including world coordinate system, camera coordinate system, image coordinate system and pixel coordinate system. Figure 4 shows the relative positions of the four coordinate systems.

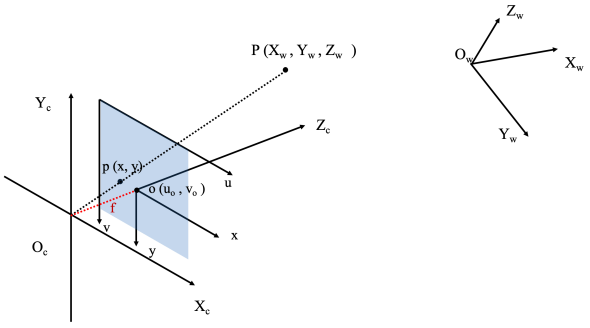

Fig. 4. The relative positions of the four coordinate systems.

The world coordinate system (O_w—X_w Y_w Z_w) represents the absolute position of objects in the three-dimensional space, which describes the and the basic positional relation of the camera and the real scene. In the camera coordinate system (O_c—X_c Y_c Z_c), take the camera optical center as the origin of the coordinate system, the direction in front of the camera is Z-axis direction. The image coordinate system (o—x y) takes the imaging center of the camera coordinate system as the origin, the distance from the camera optical center to the origin is equal to focal length of the camera (f). Pixel coordinate system (o-u v) takes the upper left corner of the digital image as the origin, it could be considered as the image coordinate system in pixels.

Equation (3) describes the transformation from the world coordinate system to the camera coordinate system, in which letter R is the orthogonal rotation matrix and letter T is the translation vector of the camera relative to the world coordinate:

$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \end{bmatrix} = R \begin{bmatrix} X_w \\ Y_w \\ Z_w \end{bmatrix} + T \Rightarrow \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = \begin{bmatrix} R & T \\ 0_3^T & 1 \end{bmatrix} \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} \tag{3}$$

The transformation from camera coordinate system to image coordinate system can be explained directly by the principle of pinhole imaging, which transform the three-dimensional objects to two-dimensional images. Equation (4) describes to the transformation relationship from camera coordinate system to image coordinate system:

$$Z_c \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} \tag{4}$$

The third coordinate transformation is the transformation from the image coordinate system to the pixel coordinate system. Equation (5) describes the transformation relationship, in which (u_o , v_o) represents the position where the origin of the image coordinate system is in the pixel coordinate system, dx and dy represent respectively the physical dimensions of each pixel points in the X-axis and Y-axis directions:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \frac{1}{dx} & 0 & u_0 \\ 0 & \frac{1}{dy} & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \tag{5}$$

Equation (6) describes the transformation relationship from world coordinate system to pixel coordinate system, which can be obtained from Formula (3), (4) and (5).

$$Z_c\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \frac{1}{dx} & 0 & u_0 \\ 0 & \frac{1}{dy} & v_0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}\begin{bmatrix} R & T \\ 0_3^T & 1 \end{bmatrix}\begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix}$$
$$= \begin{bmatrix} \frac{f}{dx} & 0 & u_0 & 0 \\ 0 & \frac{f}{dy} & v_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}\begin{bmatrix} R & T \\ 0_3^T & 1 \end{bmatrix}\begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} = KM\begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} \quad (6)$$

Letter K represents a matrix of the camera internal parameter, which is determined by the optical parameters of the camera itself and can be considered as known. Letter M represents a matrix of the camera external parameter, which is related to the spatial relationship (R and T) rather than the optical parameters. Therefore, we can calculate the exact superposition position of augmented reality contents over the background in the paper book, according which it fused virtual characters and real environment. Figure 5 shows the three-dimensional registration in the picture book Xi Shi Dance.

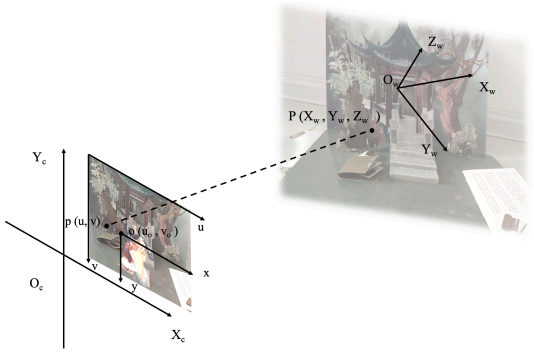

Fig. 5. Three-dimensional registration in the picture book Xi Shi Dance.

IV. Augmented Reality Presentation

Stylization is an effective way to combine technology and content deeply. In order to reproduce the characteristics of clothing to the greatest extent, the three-dimensional modeling software ZBrush, Marvelous Designer and 3D Max are used to construct the model for the characters in the application. On the base of a great deal of reference literatures, the solid background, characters modeling, texturing and animation are all in the unified style, which reflect Chinese knowledge, aesthetics and values, and carry out cultural education smoothly through augmented reality applications.

A. Solid Background in the book

The background scenes in the picture book are paper models, which are based on the historical environment and architecture in the Xi Shi Legend. Benefit from the scatter perspective in Chinese painting, the scenes in the picture book Xi Shi Dance are shadowless, which is easier for fusing virtual characters and real environment. According to the 3 changes of Xi Shi's identity, the story spaces presented in the picture book has been divided into five parts: Zhuluo Village where Xi Shi grow up, the shoreside where Xi Shi washed silk, Guanwa Palace where Xi Shi lived in Wu Kingdom, Xiangji Corridor where Xi Shi danced and Wuli Lake where is said to be the place Xi Shi disappeared. Figure 6 shows solid background of Guanwa Palace.

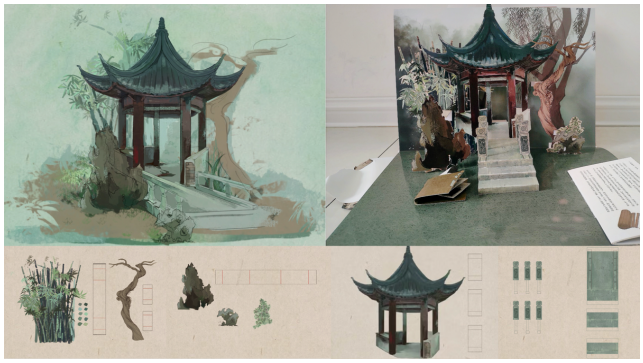

Fig. 6. Solid background of Guanwa Palace.

B. Modeling and Texturing

In terms of character design, the book makes full reference to historical materials and documents. Seven sets of costumes including Fan Li, Fu Chai, the boatman, the child and Xi Shi in three periods are determined. Take Xi Shi as an example, there are different styles in different periods. When Xi Shi was a young girl washing silk on the shoreside, her beauty in a natural style with the simple low bun to the neck. In Wu Kingdom, Xi Shi was well-dressed with a high-vertebra bun to show her dignity, and worn headdress made of gold and jade. She worn skirt sewed many small bells and clogs, which are the special look for dancing. In Xi Shi Legend, Xi Shi was missing when she still young. In the picture book, Xi Shi was designed as an aged figure by imagination. Figure 7 shows the looks of Xi Shi in young age(left), adult age(middle) and old age(right).

Fig. 7. The looks of Xi Shi in young age(left), adult age(middle) and old age(right).

C. Character Animation

The detailed depiction of the characters' actions could enrich the characters' personalities, improve the integrity of the story, enhance the sense of substitution and immersion for users during the experience process, which convey the core theme of the work imperceptibly. The characters' motions refer to the etiquette records of the Spring and Autumn Period. The animation film design focuses on the Xi Shi dance that draws on the relevant dance and drama works, and integrates the actions including sleeve swinging and rotation in Chinese classical dance. Figure 8 shows classic action in Xi Shi dance.

Fig. 8. Classic action in Xi Shi dance.

V. Conclusion

The augmented reality technology has changed the traditional cultural education ideas, it enhances user experience not only in the aspect of story but also ideological connotation of culture. Whether in the past or now, good stories have appeal and charisma, which arouse users' passion and help to construct the identity of nation, identity of state and identity of culture. The combination of augmented reality technology and cultural education is the inheritance and innovation, which meets the requirements of the new age. following the aesthetic and cultural principles, augmented reality applications will present the permanent charm of Chinese culture and spread to the world.

Acknowledgment

First and foremost, I would like to express my gratitude to all those who helped me during the researching. A special acknowledgement should be shown to Prof. Huang Xinyuan, a respectable and responsible scholar, who has provided me with valuable guidance. My heartfelt thanks also go to Dr. Wang Rui and my colleagues, they supplied me with reference materials of great value especially in the research fields I'm not familiar with before.

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