

## Research and Display of the restoration of Zhaoxi-ling based on VR and AR technology

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**KEY WORDS:** Display, Virtual museums, VR, AR, Zhaoxi-ling, Restoration design

### ABSTRACT:

Zhaoxi-ling, the tomb of the Empress Xiao Zhuang who was one of the greatest female politicians of Qing Dynasty, is located in the southeast of the Xiao-ling of Eastern Royal Tombs of the Qing Dynasty. This paper is based on the repeated mapping and research of the Zhaoxi-ling by the School of Architecture of Tianjin University, and a comprehensive mapping work was conducted with digital techniques such as three-dimensional laser scanning and photogrammetry from 2012 to 2018. In addition, the historical research and restoration design of Zhaoxi-ling has been deeply studied by the School of Architecture of Tianjin University since 2011, and a wealth of basic materials and design achievements has been formed, including both the restored 2D drawings and restored 3D model. The paper uses VR and AR technology to build a virtual museum for visualizing the restoration study of Zhaoxi-ling, so that the majority of scholars have the opportunity to further research Zhaoxi-ling. At the same time, a unique display would be designed for Zhaoxi-ling by using VR and AR technology, breaking through the traditional display method and showing the unique value of Zhaoxi-ling.

### 1. RESTORATION STUDY OF ZHAOXI-LING

#### 1.1 The Status Quo of Zhaoxi-ling

Zhaoxi-ling, the tomb of the Empress Xiao Zhuang who was one of the greatest female politicians of Qing Dynasty, is located in the southeast of the Xiao-ling of Eastern Royal Tombs of the Qing Dynasty. It was founded in the 27th year of Kang Xi Dynasty (1688). At that time, it was called "Zan Anfeng Temple (a temporary temple with coffin)". Then it was converted into the mausoleum by the Emperor Yong Zheng, so that the regulation was finally completed. Zhaoxi-ling which was transformed from "Zan Anfeng Temple", not only retains the old buildings of the Kang Xi Dynasty, but also takes into account its relationship with Zhao-ling, so many characteristics that are different from other mausoleums of Eastern Royal Tombs of the Qing Dynasty was formed. The change of construction created its unique and extremely high research and display value.

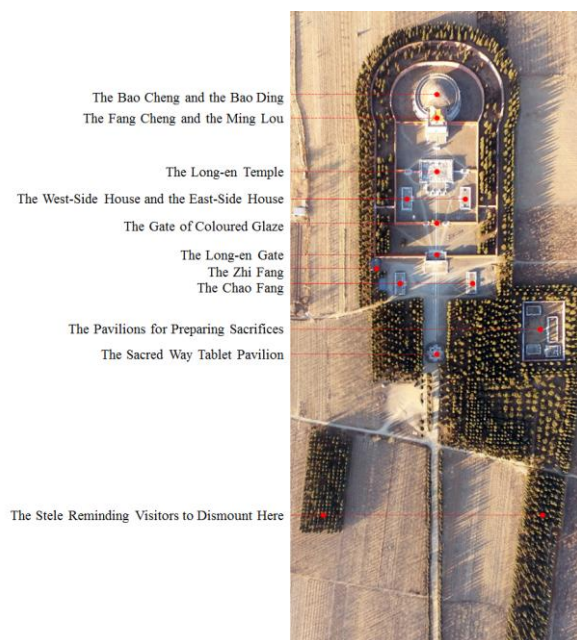


Figure 1. The status quo of Zhaoxi-ling

However, the Stele Pavilion of Zhaoxi-ling was burned down by lightning strikes in the early days of the founding of the People's Republic of China. The Long-en Temple collapsed seriously because it was in disrepair, so that its' structure was dismantled to protect it by the government in the 1960s. In addition to Fangcheng Minglou and Baocheng Baoding, the rest of the buildings only remained base site. The current situation of the buildings is dilapidated in Zhaoxi-ling, therefore, it is extremely urgent to design a repair solution for the buildings. It has been more than 70 years since the structure of Long-en Temple was dismantled for protecting, moreover, many components have been lost and damaged.( Figure 1)

#### 1.2 Restoration study of Zhaoxi-ling

This paper is based on the repeated mapping and research of the Zhaoxi-ling by the School of Architecture of Tianjin University, and a comprehensive mapping work was conducted with digital techniques such as three-dimensional laser scanning and photogrammetry from 2012 to 2018. In addition, the historical research and restoration design of Zhaoxi-ling has been deeply studied by the School of Architecture of Tianjin University since 2011, and a wealth of basic materials and design achievements has been formed, including both the restored 2D drawings and restored 3D model.( Figure 2)



Figure 2. The restoration design of Zhaoxi-ling

At the same time, this paper is based on the project "Protection and Display of Zhaoxi-ling based on the Research" supported by the Zunhua Municipal Government of Hebei Province, China. The academic seminar was successfully held in Eastern Royal Tombs of the Qing Dynasty on June 5th.( Figure 3)

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Figure 3. The academic seminar

### 1.3 The feasibility and necessity of technology display

The significance and value of Zhaoxi-ling is very important, so it must be displayed in detail. However, the traditional display of cultural heritage and the way museums display objects have not changed much in the past few hundred years. The vast majority of historical information is transmitted to the audience in a unidirectional manner, and the dimension of information is mainly limited to the static state, text, and two-dimensional image. This kind of display is extremely unsuitable for Zhaoxi-ling, because most of its physical objects are no longer exist except for the base. The rapid development of VR and AR technology has brought about a revolution in the field of architecture that has completely changed the way people accept information. The dissemination of information is no longer limited to the unidirectional manner, but expands into a bidirectional interaction, and the content of information also spans the limitations of time and space. In addition, the restoration of Zhaoxi-ling must rely on repeated and in-depth study of the components of the various parts of the buildings, and VR and AR technology can make people's research results display intuitively, which is convenient for further research.

Therefore, thinking about the corresponding heritage display methods, and even the deep role and value of VR and AR technology in architectural disciplines would be the core of the research and design of this paper in the era of VR and AR technology becoming more and more popular. The complete restorative research also provides a solid foundation for technology display. (Figure 4)

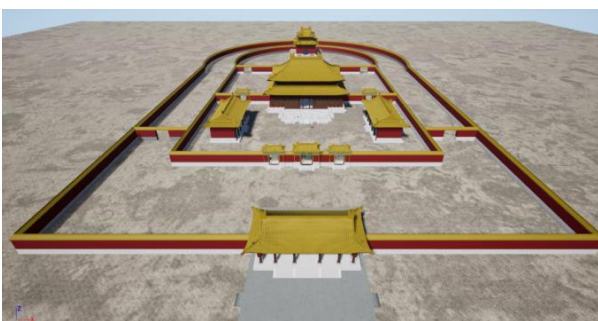


Figure 4. The complete restorative research of Zhaoxi-ling

## 2. DISPLAY BASED ON VR IN ZHAOXI-LING

The experts experienced the display based on VR in Zhaoxi-ling and gave a high appraisal at the seminar. (Figure 5)



Figure 5. Experience VR at the seminar

### 2.1 Overview of Display

The scenes of the display based on VR include the Sacred Way Area, the Sacrifice Area and the Ming Lou Area in Zhaoxi Ling. The scene's nodes of the Sacred Way Area include the Stele Reminding Visitors to Dismount Here and the Sacred Way Tablet Pavilion. The scene's nodes of the Sacrifice Area include the Long-en Gate, the Gate of Coloured Glaze, the Long-en Temple, the Fang Cheng and the Ming Lou. Among them, the scene of the Long-en Temple includes the exterior of the Long-en Temple and the interior of the Long-en Temple. (Figure 6)



Figure 6. Divided area

### 2.2 Interactive Design the Display

Passive interaction (The subsequent story will be triggered automatically after the visitors reach a certain condition.) and positive interaction (The subsequent scenario is triggered by the operation after the visitors reach a certain condition.) are designed in the display.

Passive interactions appear with the specific items. New plots are triggered when the visitors approach a specific item, including reels, ink circles and glasses. (Figure 7)



Figure 7. Reel, Ink circle and Glasses

Positive interactions often appear with text prompts, and usually occur after passive interactions. Visitors trigger specific text prompts through passive interactions, and then follow the text prompts to trigger new scenarios. The text prompt message is shown below. (Figure 8)





Figure 8. Text prompt

### 2.3 Technical Essentials

The application and development of this display in VR is carried out on the platform of Unreal Engine 4. The technical route mainly includes the following steps: building the models, building the scenes in Unreal Engine 4, implanting information, designing interaction. (Figure 9)

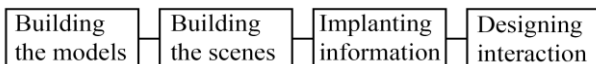


Figure 9. Technical route

#### 2.3.1 Create a set of lightmaps for the model

The models in the scene need to have a set of lightmaps when building lighting in UE4. However, the models built in Sketch Up or Revit cannot be used directly as lightmaps. Although a set of lightmaps will be automatically generated if one model is imported into UE4, it only works for one simple model. The method used in this development is to create lightmaps by 3D Max.

#### 2.3.2 Give An object multiple materials

Material ball is used to assign a material to an object in Unreal Engine 4. One object usually corresponds to one material ball, the properties of the material ball affect the texture of the object. However, one object sometimes needs to be given many different materials in this practical application, such as a bucket arch needs to be given a variety of colour materials. The solution in this development is to assign multiple materials to the object by 3D Max, applying the logic of ID of the material.

#### 2.3.3 Make the location of each model correct

It is difficult to import all models at once in the scenes. However, if the models are imported in batches, the main problem need to be solved is how to make the location of each model correct. The method used in this development is to make the world coordinates of each object identical.

#### 2.3.4 Switch virtual scene

Because the models of Zhaoxi-ling are very large, it is necessary to build multiple scenes according to different needs. Therefore, the switching of these virtual scenes needs to be implemented. There are three main methods:

1. Open level (Set a transfer point that is triggered when a person is close.)
2. Open Stream Level (Hide the current scene and display the next scene.)
3. Switch the position of the character (Control the coordinates of the character.)

### 2.4 Demonstrated node

#### 2.4.1 Sacred Way Area

The visitors enter the Zhaoxi-ling's VR scene from the Stele Reminding Visitors to Dismount Here and begin the tour. The first thing that catches your eye is a specific item (a reel). Reel will open with information about the history of Zhaoxi-ling after the visitors approach the reel.

The reel will close when the visitors are away from the reel. The visitors will watch the Sacred Way Tablet Pavilion by turning the angle of view, and walk toward the pavilion by using the movement function of the handle. The reel next to the pavilion will introduce the information of the owner of the tomb and the construction of the pavilion.

Later, the visitors can walk on the Sacred Way and arrive at Long-en Gate. The transfer point (Figure 10) next to Long-en Gate allows the visitors to come to the Sacrifice Area.

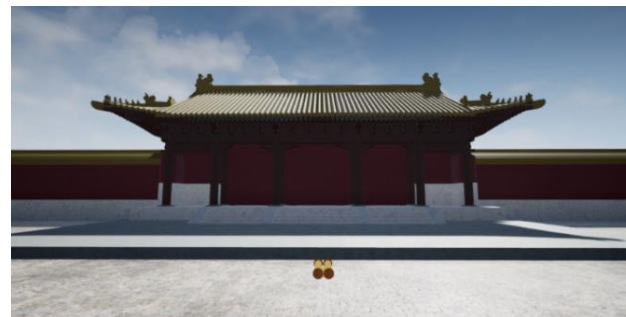


Figure 10. The transfer point next to Long-en Gate

#### 2.4.2 The Long-en Gate and the Gate of Coloured Glaze

After entering the Sacrifice Area, the visitors will come between the Long-en Gate and the Gate of Coloured Glaze. The reel will introduce the pattern of Zhaoxi-ling by using the pictures and texts.



Figure 11. Comparison of column grids

The second reel is a comparison of the column grids of the various Long-en Gates of the Qing Dynasty (Figure 11). The column form of Long-en Gate in Zhaoxi-ling is unique. Subsequently, the floor plan flies out of the reel and generates the models (Figure 12) that allow the visitors to intuitively feel the difference in the column grid.

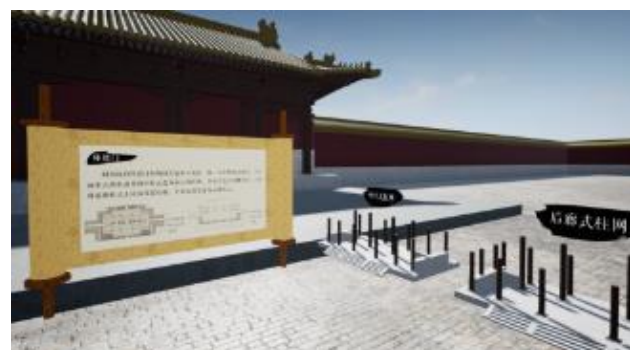


Figure 12. Model generation

The contents of the reel next to the Gate of Coloured Glaze are the unique position of the gate and the comparison with other emperors' Gate of Coloured Glaze (the level of the Gate of Coloured Glaze in Zhaoxi-ling is higher than other emperors').( Figure 13)



Figure 13. The reel next to the Gate of Coloured Glaze

The visitors continue to move forward and walk through the Gate of Coloured Glaze, arriving at the scene of the Long-en Temple.

#### 2.4.3 The exterior of the Long-en Temple

The first scene is the outdoor scene of the Long-en Temple after the visitors enter the scene of the Long-en Temple. The visitors can perform the corresponding operation to see the information that extracted from Yangshi Lei Archives (Figure 15) under the guidance of the prompt text that is located above the glasses (Figure 14).

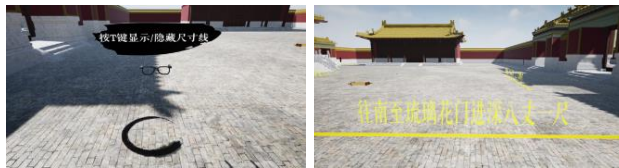


Figure 14. Glasses and Text prompt

Figure 15. The information that extracted from Yangshi Lei Archives

The specific items in front of the Long-en Temple will trigger the animation of the reconstruction of the temple (Figure 16). The visitors can move freely and watch from different angles during the animation, allowing the visitors to understand the reconstruction of the temple more intuitively and comprehensively.



Figure 16. The animation of the reconstruction



Figure 17. The animation of the reconstruction

The visitors could enter the interior of the Long-en Temple through the transfer point.

#### 2.4.4 The interior of the Long-en Temple

Two specific items (the glasses and the ink circle) would be found if the visitors enter the indoor scene. Visitors can see the hidden pattern of Yangshi Lei Archives (Figure 19) according to the prompts in the glasses (Figure 18). The animation of the reconstruction of the temple would be triggered if the visitors operate to the text above the ink circle. Watching the animation indoors will give the visitors a different visual experience and allow the visitors to have a deeper understanding.

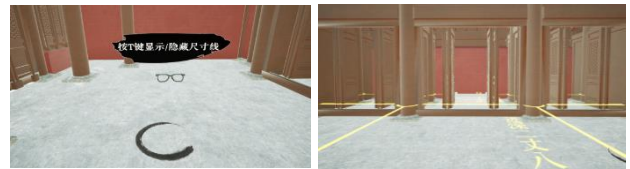


Figure 18. The glasses in the temple

Figure 19. Hidden pattern of Yangshi Lei Archives

The visitors could find the prompt texts near the ceiling after the animation. The prompt text will show the visitors how to hide the ceiling so that the structure could be seen. (Figure 20, Figure 21)



Figure 20. The ceiling of the temple

Figure 21. The structure of the temple

The visitors could enter the scene showing the bucket arch through the transfer point here, which allows the visitors to experience the beauty of the component at a close distance.

#### 2.4.5 Component display

This scene is designed for displaying components such as bucket arches and frontal cymbals, consisting of two parts, one part is the exhibition space, which is used to display the information of the components, such as the colour and shape. The other part is the interactive space, where the visitors can experience the process of disassembly and installation of the bucket arch (Figure 22). At the same time, the visitors can transfer to the Ming Lou Area through the transfer point.



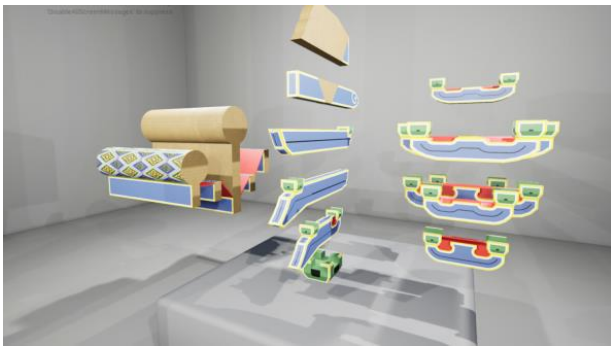


Figure 22. Disassembly and installation of the bucket arch

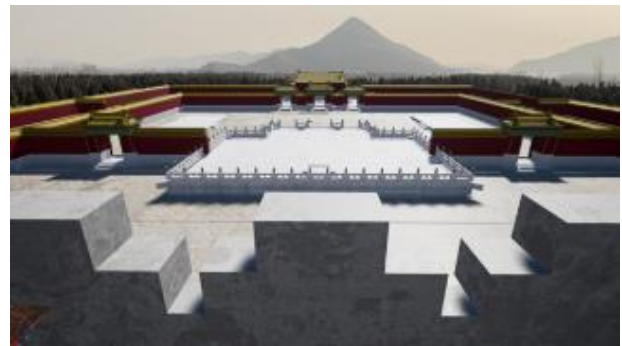


Figure 28. The status quo of Zhaoxi-ling

#### 2.4.6 The Ming Lou Area

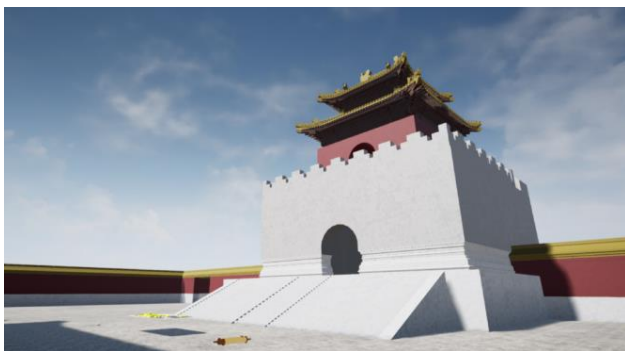


Figure 23. The Ming Lou Area

The information of the Ming Lou is displayed by reel when the visitors have not yet reached the top of the Ming Lou. At the same time, the ink circle can be activated to display the construction process of Zhaoxi-ling in an animated form (Figure 24, Figure 25, Figure 26, and Figure 27). Then the visitors can reach the top of the Ming Building via the transfer point.



Figure 24. The beginning of the construction  
 Figure 25. Site selection process of Zhaoxi-ling

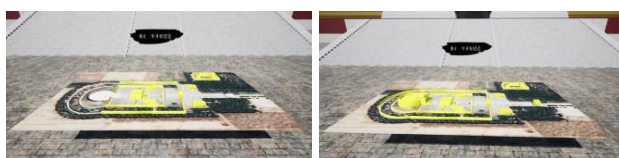


Figure 26. Zhaoxi-ling in Qianlong Period  
 Figure 27. Zhaoxi-ling in Yongzheng Period

Then the visitors can reach the top of the Ming Building via the transfer point, overlooking all buildings of Zhaoxi-ling. At this time, the scene expresses the status quo of Zhaoxi-ling (Figure 28). In addition, the visitors are able to rebuild each building in the scene.

This kind of setting can greatly increase the interest of the visitors, improve the visitors' sense of participation, and allow the visitors to feel the great influence of the building on the base in the comparison between the current situation of the site and the reconstructed Zhaoxi-ling.

### 3. DISPLAY BASED ON AR IN ZHAOXI-LING

The development of AR technology has brought new possibilities for the display of the research of Zhaoxi-ling. The combination of AR technology and cultural heritage displays exposes the incomprehensible and fascinating parts of academic research to more people.

The experts experienced the display based on VR in Zhaoxi-ling and gave a high praise at the seminar. (Figure 29)



Figure 29. Experience AR at the seminar

#### 3.1 Overview of Display

The Stele Reminding Visitors to Dismount Here is the starting point for tourists. Afterwards, the tourists will pass through the four exhibition areas of the Sacred Way Tablet Pavilion, the Long-en Gate, the Sacrifice Area and the Ming Lou Area. The visitors will see the designed image in these areas, scan the picture and then launch the scene in the software to experience the augmented reality.

#### 3.2 Interactive Design in the Display

##### 3.2.1 Triggered scene



Figure 30. Scanning enhanced images

This development based on the SDK provided by Google's ARCore platform uses enhanced images to interact. On the one hand, the scanning picture adapts to a wider range of people. On the other hand, the way to use enhanced images is more adaptable, no matter how complex the display scene, as long as the developer sets it in advance, the model can be positioned by the images accurately. (Figure 30)

### 3.2.2 Interaction within the scene

The displayed content can be triggered by clicking the button if the visitor enters the scene by scanning the image. The buttons are presented in the form of ink dots in this development. There will be prompt text next to the ink dots, if necessary, to facilitate the visitors to adapt to the interactive interface more quickly. (Figure 31, Figure 32)

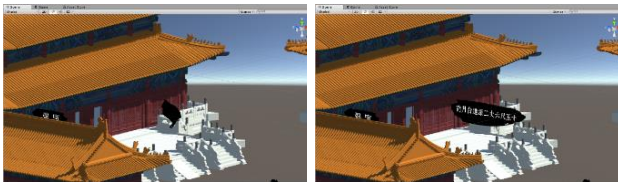


Figure 31. The buttons (the ink dots)

Figure 32. The buttons triggered

### 3.2.3 Interactive interface design

The interactive interface of the display can be divided into three levels, the welcome interface, the main interface, and the interface within the scene. The welcome interface is the first interface if the visitors open the software, the main interface appearing a few seconds later. In addition, interface within the scene will appear if visitors scan the enhanced pictures. (Figure 33)



Figure 33. The welcome interface, the main interface, the scanning image interface, the interface within the scene.

## 3.3 Technical Essentials

### 3.3.1 Determine the location of the models

The location of the models must be determined in order to accurately integrate the virtual model and the real world in the screen of a mobile phone. The first method is to recognize a plane and manually place the models by using a phone. However, the planes recognized by each phone would not be the same and there are great uncertainties in letting visitors to place models. The second method is to scan the enhanced picture to determine the location of the models. This development uses this method because the operation is simple and the results are accurate.

### 3.3.2 Build interaction

In each scene, many buttons are designed to interact. The method is to save the designed button graphic in PNG format, import it into Assets, and then select the image to change the Texture Type to Sprite (2D and UI). Finally, drag the created button into the

scene and adjust the size, orientation, and height of the button according to the model in the scene.

### 3.3.3 Build animations

This development adds animation to the show based on AR in Zhaoxi-ling, which uses a tool named Timeline from Unity. Timeline makes it easy for developers to create and modify animations in Unity. In addition, objects, animations, sounds, and special effects can be integrated by Timeline, thereby generating the desired animation.

## 3.4 Demonstrated node

### 3.4.1 The Sacred Way Tablet Pavilion Area

Visitors can activate the scenes in the software by scanning the specified picture at the Sacred Way Tablet Pavilion. If visitors point the phone at the pavilion, four buttons will appear (Figure 34). The first button is the introduction to the pavilion. The second button is the introduction to Xiaozhuang Empress. The third button shows the location of each building in the field of view at the moment (Figure 34). The fourth button lets visitors view the restored pavilion on the screen.



Figure 34. Four buttons

Figure 35. The third button is triggered

It should be noted that the phone lens cannot be blocked after scanning the active scene, otherwise the scene will disappear. If the scene disappears, the visitors can rescan to activate the scene.

### 3.4.2 Long-en Gate

A display node will be set up to show the selection of site and the construction process of Zhaoxi-ling at the front porch of Long-en Gate that was decided to repair the Long-en Gate at the seminar.



Figure 36. The booth in front of Long-en Gate



The visitors will see the showcase when they arrives at Long-en Gate. Visitors will be able to trigger an animation showing the construction of Zhaoxi-ling (Figure 37, Figure 38, Figure 39, and Figure 40) by scanning the Zhaoxi-ling master plan on the booth.



Figure 37. Scan the master plan  
Figure 38. Site's selection of Zhaoxi-ling

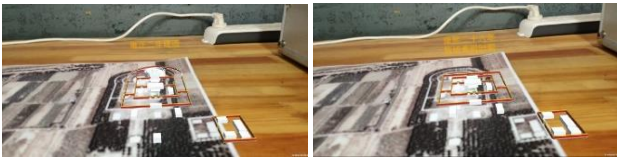


Figure 39. Zhaoxi-ling in Qianlong Period  
Figure 40. Zhaoxi-ling in Yongzheng Period

### 3.4.3 The Gate of Coloured Glaze

The content shown here is the difference among all Gates of Coloured Glaze in Qing Dynasty's mausoleums. On the one hand is the position of the gates, on the other hand is the style of the gates.

Visitors can simultaneously view the location and appearance of the Gate of Coloured Glaze in other mausoleums of the Qing Dynasty on the screen. ( Figure 41)

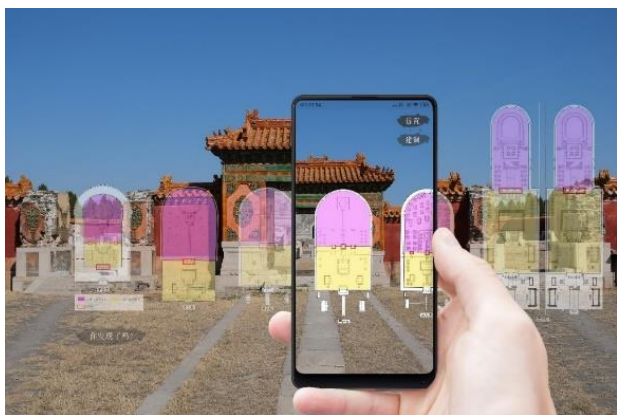


Figure 41. All Gates of Coloured Glaze in Qing Dynasty's mausoleums

### 3.4.4 The Sacrifice Area

The specified picture could be scanned to activate a particular scene if the visitors enter the sacrifice Area. Visitors will see three buttons named by the names of the buildings in the phone screen. If the three buttons are activated, the restored model of the three buildings (Long-en Temple, West-Side House, and East-Side House) will be saw. As visitors walk around the site, they can experience a restored scene from all angles. (Figure 42)



Figure 42. Reconstruction of Zhaoxi-ling

In addition, some buttons will appear next to the temple if the restored model appearing. Some buttons hide the data of Yangshi Lei Archives. (Figure 43)



Figure 43. The data of Yangshi Lei Archives appears by clicking the button

There is a button representing the construction process of the building next to the Long-en Temple. If the visitors click the button, the Long-en Temple will be generated in the order of construction. The first models that appeared are the bases and columns. Secondly, the bucket archs and the beams are installed. Thirdly, the walls, the doors and the windows are generated. Finally, the installation of the tiles on the roof is completed. The name of each component will appear during the model is built so that the visitors could understand the relevant knowledge of ancient Chinese architecture more concretely. (Figure 44, Figure 45, Figure 46)



Figure 44. The structure of lower cornice is completed



Figure 45. The structure of upper cornice is completed

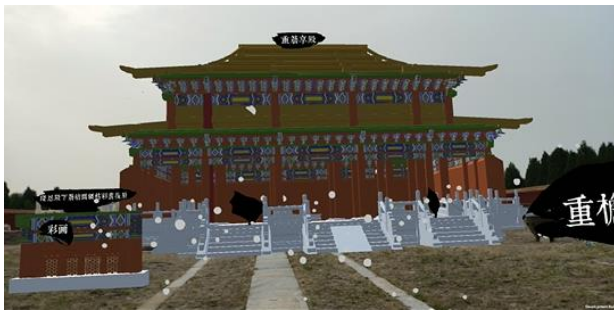


Figure 46. Building the walls

If the visitors want to know more about the building's components, he can click on the corresponding component. The components that are clicked will be separated from the building and come to the front of the tourists, allowing visitors to watch them at close range.

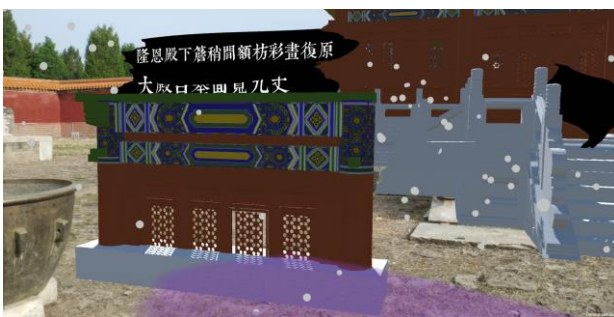


Figure 47. Components that are separated from the building

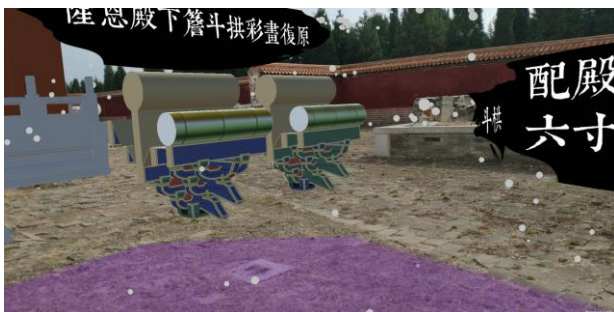


Figure 48. Bucket archs that are separated from the building

### 3.4.5 The Ming Lou Area

This development has set up two display scenes in the Ming Lou Area. The grid technique of ancient design method will be displayed on the screen if the visitors reach the top of the Ming Lou to overlook the Zhaoxi-ling (Figure 49). On the other hand, the other mausoleums' name and descriptions will be displayed on the screen if the visitors use a mobile phone to watch them (Figure 50).



Figure 49. The plain grid technique on the screen

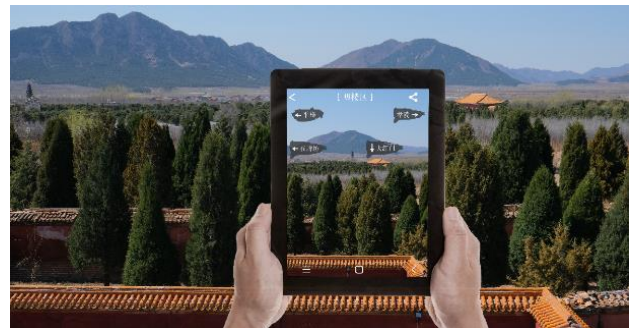


Figure 50. The other mausoleums' name on the screen

## 4. SUMMARY

Zhaoxi-ling has unique and extremely high research and display value. The paper uses VR and AR technology to build a virtual museum for visualizing the restoration study of Zhaoxi-ling, so that the majority of scholars have the opportunity to further research Zhaoxi-ling. At the same time, a unique display would be designed for Zhaoxi-ling by using VR and AR technology, breaking through the traditional display method and showing the unique value of Zhaoxi-ling.

## ACKNOWLEDGEMENTS

Thanks to the support of the Zhunhua Municipal Government, Eastern Royal Tombs of the Qing Dynasty, and the experts who attended the seminar.

Thanks to the teachers and students of Tianjin University, such as Yuan Sinan, Gao Yue, Kang Xinyu, Liu Xinjia and Meng Xiangru.

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