# THE INTERDISCIPLINARY RESEARCH OF VIRTUAL RECOVERY AND SIMULATION OF HERITAGE BUILDINGS. TAKE LINGZHAO XUAN IN THE PALACE MUSEUM AS AN EXAMPLE

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## 1. Introduction

3D digital technology, an effective key technology in digital museum, has been applied to the actual work of the heritage protection, research and development. And the VR technology based virtual restoration techniques has become popular in recent years in protecting and researching heritage buildings. It can create the virtual scene of present situation, recovery, or simulation of the heritage building by building the 3D digital models of them. The advantages of using computer graphics to conserve and research heritage building are minimal damage, reversible process, visible results and authentic.

There are more and more cases about virtual restored heritage building. Their processes are also similar: first is to collect the heritage buildings shapes, textures and other information, and then combine academic research to create digital 3D model, and finally displayed.

However, virtual recovery of heritage buildings is in a dilemma nowadays: the cultural heritage digitization staff (hereinafter referred to as digital heritage protection group), and actual cultural heritage protector and academic researchers (hereinafter referred to as actual heritage protection group) as the two camps, they do not establish an effective coordination mechanism.

Because of professional limitations, whether the actual or digital heritage protection group, it is difficult for them to obtain detailed needs from each other without active communication.

Professional physical evidence and historical research are the basic premises to restore and recovery. Without these premises, digital heritage protection group will not have enough time to devote to the most valuable digitized research points, and the results are also greatly reduced.

In a new era with rapid technological changes, the plight of this poor communication for heritage buildings' protection and research is a serious obstacle. To break this deadlock, the most direct and effective way is to create interdisciplinary cooperation mode.

"Stone from other hills, can last jade." Aiming at a virtual heritage recovery, simulation and exhibition project, personnel in two different academic camps should cooperate and understand each other initiatively, and then conduct research and make achievements. They need to master both concepts of 3D digitalizing and actual protecting methods of heritage buildings, set a common standard and create a win-win situation together.

So, how to carry out interdisciplinary collaboration effectively? Through ten years' 3D digitalize working, the Palace Museum have explored and summed up a more effective interdisciplinary cooperation mode. Besides, the "virtual recovery" concept of heritage buildings has been widened and deepened and the "virtual simulation" concept has been joined for the first time in project as a means of scientifically virtual design heritage building. This paper will combine the latest Lingzhao Xuan's virtual recovery and simulation experience, trying to summarize concepts and values of virtual recovery and virtual simulation of heritage building, as well as the effective interdisciplinary collaboration mode of operation and the significance. It will provide a reference to regulate the application of 3D digital technology to benefit the protection work.

## 2. Concepts and values of interdisciplinary virtual recovery and simulation of heritage building

First, we must make clear some concepts of the specialized vocabulary.

Recovery: means "restitution", which refers to restore the existing building to its original appearance and condition by removing various attachments on heritage building, replacing the missing parts, cleaning, painting and other repair methods.

Simulation: suppose the original appearance; make the characteristics clear by imitating.

*Chinese cultural relics protection guidelines* states clearly that all protective measures must comply with the principles of not changing the original historic state. The principle includes two aspects: preservation status and restitution.

In *International Charter for the Conservati-on and Restoration of Monuments and Sites*, conservation principles such as "minimum intervention", "identify", "reversibility" are also proposed, which should be followed carefully. Renovation of heritage buildings includes repair and scientific recovery and so on. It is the most important heritage conservation means. The aims of restoring ancient buildings are not only to prevent damage and prolong its life scientifically and technologically, but must also maximize preservation of their historical, artistic and scientific values.

Based on these principles, the entity of cultural heritages cannot be restored or even simulated (design) on a large scale in actual operation. But the historical, artistic, technological and other important values of cultural heritage cannot be fully demonstrated or intuitively reflected by its own entity.

The emergence of digital archaeology museum makes the scope of conservation and recovery's concepts expand, and the computer display has been added into the purpose of repair and recovery work and an auxiliary means of physical display has also been added.

In the 3D digital context, virtual recovery has the same meaning as the definition of recovery in real environment, but in order to facilitate the description, the concept of virtual simulation is broadened. For the heritage buildings whose original appearance cannot be verified, virtual simulation means virtualizing and assuming the original appearance by mimicking the characteristics that have already been made clear. For unfinished heritage buildings, virtual simulation means virtualizing and assuming the finished appearance by mimicking the characteristics that have already been made clear.

There are important values in use and education in launching research into the computer-aid recovery and simulation technology.

The value in use is shown in two aspects. The first one is to guide the work on the

recovery of cultural relics and to promote the protection of the heritage building entity through the process of computer-aid recovery of cultural relics. The second one is to create the 3D digital model of recovery and simulation of cultural relics to be the original materials in virtual exhibition.

The value in education is the ultimate objective of protecting cultural relics. And research is the lifeline of such protection. The value of every protection project of cultural relics is weighed by the quality of protection and propagation. A great collection will have real value only when it is added to people's colorful life.

What virtual recovery and simulation can achieve is to show the public large amounts of research materials (in written language or 2D image) by simple means of VR interactive works and 3D application (such as 3D digital scene). Thus the value in the heritage building can be shown in a more vivid, straightforward and interesting way. Besides, as a beneficial supplement, it will become one of the effective ways for people to understand cultural heritage in depth.

Interdisciplinary cooperation mode is the mode to combine professional strength of two different subjects together to study on virtual recovery and simulation. Its value lies in the innovation of achievement. Considering the difference of restored and simulated ancient architecture, the majors involved is different too. The most important value of it is to combine the heritage building's digitalization and entity protection together to increase work productivity and get more comprehensive and deeper achievements.


### 3. Case analysis: the background and objectives of the Lingzhao Xuan project

Next, the paper will take the virtual recovery and simulation of Lingzhao Xuan as an example to explain the way to apply the virtual recovery and simulation to cultural relics and the utilizations of these achievements.

The Palace Museum based on the Forbidden City, which is the priceless ancient cultural heritage of Chinese nation and the whole human being. From 2011 to 2013, the Institute for Digitization of the Palace Museum Heritage, which is the main strength of the project, cooperates with multiple departments and social forces to apply the virtual recovery, simulation and exhibition to the heritage building Lingzhao Xuan in the Forbidden City (Figure 1.).

Lingzhao Xuan, located in Yanxi gong of the Palace Museum, was first built in 1909 by the government of the Qing Dynasty. It is commonly known as "Crystal Palace". This crystal palace, using the steel-structure technology (which is very trendy at that time), was built to avoid catching fire because the previous architectures here had frequently caught fire. It was used to store water and raise fish, and it was the unique place to enjoy the sight of fish. But soon after, the construction was stopped because of the lack of money. This architecture has been undergoing the vicissitudes afterwards; it is unfinished and so dilapidated that it is difficult for the audience to appreciate the characteristics of the times and the architectural feature.

There are important values of utilization and education in applying the virtual recovery and simulation to Lingzhao Xuan. It can not only help us to explore more deeply into the history of this unique architecture in the Forbidden City, but also explain the characteristics of the times and the architectural feature of Lingzhao Xuan by virtual exhibition which is easy to understand for the audience.

The objectives of this project are to do research about the present situation's virtual

construction (Figure 2.), virtual recovery and stimulation (Figure 3.) of Lingzhao Xuan by using 3D digital technology, mainly VR technology. And these will be exhibited in the virtual form of the VR work "Lingzhao Xuan" (Figure 4.) to make sure the achievements of this project to be timely spread and be effectively used.



*Figure 1: Photo of Lingzhao Xuan in 2012*



*Figure 2: VR rendering picture of Lingzhao Xuan's present situation in virtual scene*



*Figure 3: VR rendering picture of Lingzhao Xuan in virtual simulation scene*

*Figure 4: Photo of "Lingzhao Xuan" VR work' live show*

## 4. The interdisciplinary method of virtual recovery and simulation of heritage building

The guideline for the virtual recovery and stimulation of the heritage building Ling-zhao Xuan is shown in the following table. The tasks are mainly divided into three steps: to draw up the plan of recovery and simulation; to do 3D digitalization; to utilize the achievements.

In these three steps, aiming at specific heritage building, different majors need to be participated. The members of actual heritage protection group are personnel major-ing in the scientific technology about the protection of the cultural relics, architecture, and the court history and so on. The members of the digital heritage protection group are personnel majoring in photography, CG modeling, VR programming and so on. Personnel majoring in broadcasting, director and music are also related to the virtual exhibition. The simple division of labor is in the following table. The most difficult thing is, considering the difference of majors, the actual cooperation needs many extra ef-forts to explain the objectives, the technical means and the division of tasks.

| Group | Major | Task stage |
|---|---|---|
| Actual heritage protection group | Scientific technology about the protection of the cultural relics | Draw up plan;<br>3D digitalization |
| | Architecture | |
| | Court history | |

| Digital heritage protection group | Photography | 3D digitalization |
|---|---|---|
| | CG modeling | Draw up plan; |
| | VR programming | 3D digitalization; |
| Virtual exhibition group | Director | Use achievements |
| | Broadcasting | Use achievements |
| | Music | |

*Table1: The simple division in the Lingzhao Xuan project*

### 4.1 Draw up a plan

To make sure the scientificalness of virtual recovery and simulation, the first thing need to be done is to collect the related data about Lingzhao Xuan from the professional personnel and survey the Lingzhao Xuan scene. Experts on material science and ancient architecture in the Palace Museum are responsible to provide the related literatures, material characteristics and architecture drawings and other data and survey the whole appearance and details. Besides, they need to analyze and refine the function of building unit, write detailed report on present situation and draw up the proposed plan of recovery and simulation. Experts on the court history need to aim at the function of Lingzhao Xuan and combine it with historical background at that time to provide important theme giving reference to the VR work. Experts on the digitalized protection is responsible to collect the present digital images about Lingzhao Xuan and decide original plan of virtual recovery, simulation and exhibition from three aspects: protection of entity, academic research and virtual exhibition.

It can be seen from the survey of scene that Lingzhao Xuan has masonry and steel hybrid bearing structure and it is a western-type iron building with five top towers. The first floor of underground main building and the edge of bank can be the places to conserve water. As for the building on the first floor on the ground, the interior walls are covered with incomplete ceramic tiles and the outside white marble walls are engraved and decorated. There are pavilions at every corner of the second floor. There are doors and windows on every corner but only the iron window frame and door frame remain. The building units of Lingzhao Xuan such as iron and steel units are mostly rust and have serious defect. The stone walls are broken partly and weathered and brick walls are loose partly or falling off. The ceramic tiles have serious defect and the glass units remain little, which are taken apart to be stored elsewhere. There are three floors in this building but without stairs to connect these. Besides, there are a lot of information which can be used in recovery and simulation remaining on the spot, for example, there are some regular holes remaining on the window frame and some plinth remains on the ground and so on.

The materials used in recovery and simulation mainly include architectural drawings, survey report about the heritage building scene, digital images, historical documents and academic research data.

Because Lingzhao xuan's construction hasn't been finished yet, all the present 14 architectural drawings that can be collected are drawn by ancient building design de-

partment of the Palace Museum in September, 2009, which contain rather completely units and size of every side of Liangzhao Xuan (Figure 5.). It is hard to do the recovery because the design drawings have been missing and other related literature and research data are very few.
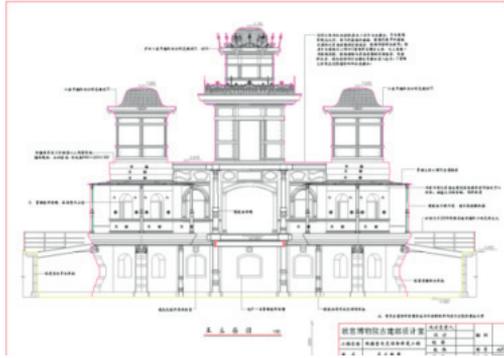


*Figure 5: A drawing of Lingzhao Xuan( 2009)*

Because preliminary data are few, more supporting data are needed to do this recovery and simulation. The project group studied out a simple preliminary plan in the end of the first step: firstly to make 3D virtual scene of Lingzhao Xuan's present situation and make sure it can be the high precision version to record present situation; at the same time to analyze the details of present situation as many as possible and collect related research data more broadly. The restored and simulated 3D virtual scene will not be made until all these data have been prepared fully.

### 4.2 3D digitalize

#### 4.2.1 *Supplementary materials*

The supplementary materials are divided into two parts.

The first part includes historical documents, present academic research achievements and contemporaneous data about Chinese and Western architecture, which are collected by the actual heritage protection group.

The second part includes comprehensive 2D digital images of Lingzhao Xuan, parts of 3D digital images and manual measurement about building's size data and so on, which are done by the digital heritage protection group. These works need the coordination and cooperation between photographers and CG modelers. Photographers collect 2D images, CG modelers collect important data about building's size and 3D scanning personnel collect 3D images.

Because the 3D virtual scene of Lingzhao Xuan needs to reach the storage level of high-precision record of the Imperial Palace's present situation, there are two requirements for photography. The first one is that the lens for the shoot should be perpendicular to the building's plane. The second one is that every plane's photograph should be taken according to the required precision. The larger plane should be divided into

several pars and shoot successively. Generally speaking, these 2D digital images should be collected in the same precision. But considering their achievements will be the source materials of VR works on virtual exhibition, thus the architectural details which need to be given close-up in VR works should be pointed out to photographs by CG modelers on the spot that these details should be collected in higher precision such as the holes and bulges in window frames and the holes on the ground.

Such requirements for photography in shooting images of heritage building make it rather difficult in real shooting because it is limited by heritage building's exhibition and the characteristics of the building itself.

Lingzhao Xuan is a three-layer western building, whose height makes it hard to set the camera. Besides, there are no units such as stairs to get to the second floor of the building because of the unfinished construction, which makes the vertical shooting of some units' images become impossible, only the digital images with geometric deformation and color that is not exactly correct are available.

It is one of the major difficulties that being unable to shooting the images of all architectural details in strict accordance with the photography requirements and to get the best 2D image materials.

There are great achievements in putting 3D digital image into practice. But 3D digital image technology will not be used in project on a large scale for the time being because of its immaturity. However, out of scientific research, a set of relief units' 3D digital images are collected to get the effective mode to use 3D digital image data on units' 3D virtual scene. The digital heritage protection group uses 3D laser scanner to collect the 3D digital image of a white marble high relief in the north-west side of Lingzhao Xuan (Figure 6.).



*Figure 6: 3D digital image of high relief of Lingzhao Xuan*

### 4.2.2 Construct 3D virtual scene

The constructions of 3D virtual scene are divided into three steps. The first thing is to construct the 3D virtual scene of present situation. The second thing is to do the virtual recovery, which is based on the 3D virtual scene of present situation. And the third step is to do the virtual simulation, which is based on the restored 3D virtual scene.

In the whole process, the team will explore and integrate the research achievements related to Lingzhao Xuan continually and keep discussing and correcting until a scientific and reasonable plan is made for the recovery and simulation finally.

**A Construct present situation's virtual scene**

Firstly the standard for construction aimed at 3D models of this project should be discussed and set by CG modelers and VR programmers. Before the 3D digital models building begins, VR director need to draw up a VR script so that it will easier for CG modelers divide 3D models' precisions according to the script and the project development period will be shorten. In order to guarantee VR work's quality and operation speed, VR programmers will provide the standard for construction related to VR effect, such as model segmentation, making bump map and light map.

Because the 3D virtual scene of Lingzhao Xuan needs to reach the storage level of high-precision record of the Imperial Palace's present situation, the main building and surrounding circumstances are 3D digitalized by manual modeling. CG modelers can construct 3D virtual scene of present situation based on sufficient image materials.

There are four major difficulties of constructing 3D virtual scene.

The first one is the problem of building's size. Architectural drawings are idealized drawings and the image materials collected have the problem of geometric deformation, thus they cannot be the very correct standard of size.

The best solution is get from experiment: getting the building's outline from the architectural drawings to be the basic standard for model construction. As for some small units such as relief, they can take the size measured data on the spot as the standard. These can make sure the constructed 3D models to be the same as far as possible. But still, the error can only be controlled on the centimeter level.

The second one is about precision. There are many building units of Linagzhao Xuan, thus how to keep the unity of precision becomes a problem.

The best solution for the time being is as follows: firstly to set the corresponding standards between building size and texture resolution. The highest precision is A level, which requires the actual size range of 1 square meters should correspond at least 2048 x2048 resolution; the lower level is B level, which requires the actual size range of 1 square meters should correspond at least 1024 x1024 resolution, and so forth. Next, the unit models should be cut reasonably to meet the requirements of standard precision. In the making process, A-level precision version will be made first and then VR version will be made according to VR work's requirements for precision and making.

The third problem is about the geometric deformation and color correction. Since some image materials have some problems such as geometric deformation and color errors, how to correct these becomes a problem.

The present solution: use graphics processing software (Photoshop) to apply geometric deformation and color correction to images. But inevitably there are some limitations in such software correction which lead to inaccurate geometry and color. Therefore better solution is still needed to be found out.

The fourth one is about the effective application of 3D image data. On the premise of reserving details of every pattern, the collected 3D image data of high relief reaches up to 1,000,000 polygons and the error range is on millimeter level. It can be regarded as the most precise method now to record and exhibit heritage building. But because of the limitations of computer performance, such high data cannot be integrate into the restored 3D virtual scene of Lingzhao Xuan and it needs a heavy workload of reducing patches and making maps based on the data.

The effective solution now: use these data as blueprint and construct models again

in a reasonable way, which can keep error level, keep almost the same and finish the making of models and maps effectively.

Theoretically, 3D image data can solve the above 3 problems. But considering present technology level, if personnel construct the whole 3D scene by means of combination of "3D scan and manual model construction", the workload will be heavy. If the data can be used more efficiently, this method will become the best to collect and use data of heritage building. Thus using data efficiently is an important research area that worth exploring.

3D virtual scene of present situation with high precision is not only the 3D modeling data base of recovery and simulation, but also the important remaining materials of digital heritage. The final VR rendering picture of Lingzhao Xuan in virtual construction scene is shown in figure 2.

### B Construct recovery and simulation's virtual scene

The virtual recovery and simulation can be done on the basis of 3D virtual scene of Lingzhao Xuan's present situation. This part of work is a little more difficult because of few bases for recovery. It is done by actual heritage protectors, CG modelers and VR programmers. Actual heritage protectors are responsible for extracting effective basis for recovery and simulation from the collected data, deciding the final recovery plan and guiding digital heritage protectors to make and correct models. CG models are responsible for making 3D models of recovery and simulation. VR programmers are responsible for making VR effect to simulate the designed scene effect in the recovery plan.

Firstly carry on virtual simulation in strict accordance with recovery plan and on the basis of 3D virtual scene. It should be done according to the principles of cultural relics' restoration and the original appearances and patterns of cultural relics should not be changed. That is to clean up some surface attachments on Lingzhao Xuan such as blots, weeds and so on; to repair the obvious missing or broken parts; to add some units such as glass. Finally the restored virtual scene is constructed.

The simulation work next is very challenging.

The first challenge: there are some obvious unfinished parts in the remaining units. Then how to carry on simulation?

Solution: finish the unfinished parts virtually according to the pattern of remaining units.

To take the high relief in the north-west side of the first floor (Figure 7.) as an example, it can be seen on the spot that the pine and cypress pattern is engraved, thus the unfinished flower patterns can be engraved according to the finished patterns. It can be concluded that such simulation plan is much more precise according to the 3D virtual scene of present situation and VR rendering picture of 3D virtual simulated scene (Figure 7.) and wireframe (Figure 8.).

The second challenge: there are some units with similar structure in present situation. Then how to simulate these units?

*Figure7: VR rendering picture of 3D virtual scene of present situation (left)
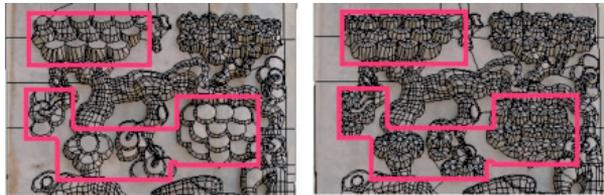and 3D virtual simulation scene (right)*



*Figure8: Wireframe of 3D virtual scene of present situation (left)
and 3D virtual simulation scene (right)*

Solution: analyze all the units with similar structure and extract elements from these units and combine them together to make a new 3D model containing all these important elements. And then correct all 3D models with such structure to 3D models with new structures.

For example, the iron pavilions are constructed according to such idea for simulation. The structure of central iron pavilion is preserved more completely than others and it is probably the finished pattern. But the remaining structures of iron pavilions on four sides are different from each other. Therefore the structure of central iron pavilion is taken as a reference and the characteristics of another four iron pavilions' units are also combined together to infer scientifically the probable structure and then models can be made to carry on simulation.

The third challenge: According to the completeness of architectures and the record in literature, it is obvious that there should have been some units such as doors, windows and stairs of Lingzhao Xuan, but now they are missing. How to carry on simulation when there are no concrete descriptions about these units whether on the spot or from data?

Solution: The obvious missing units must be simulated completely to guarantee the completeness of architectures. The miss parts should be completed according to the principles and characteristics of Chinese and Western building and simulation of the architectural styles of contemporaneous similar architectures. And then models should be constructed to carry on simulation.

For example, the simulation of doors and windows can refer to the drawings of contemporaneous Haiyan tang which has the most similar drawing as Lingzhao Xuan (Figure 9.). According to the 3D virtual scene of present situation and the VR rendering picture of simulated 3D virtual scene of the windows in Lingzhao Xuan's first floor (Figure 10.), the simulated structure of windows is very close to the whole architectural style. Although the original structure is not available, the 3D models for simulation

can to some extent provide the breakthrough points for experts and a more complete architecture history for tourists.
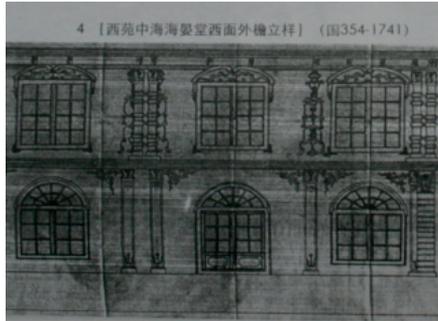


Figure 9: Drawing of contemporaneous Haiyan tang



Figure10: VR rendering picture of present situation' virtual scene (left)
and virtual simulation scene' window (right)

The fourth challenge: how to simulate the water in Lingzhao Xuan's pool? This problem can be divided into two parts. The first part is: how to make VR water effect in the pool? The second one is: how can water play role in "Crystal Palace"? Water highlights the important architectural function of Lingzhao Xuan, but the depth and source of water and others are unknown. There is some evidence of quite large outlet of pipe on the wall on underground first floor and there are some parts of pipe lying on the first floor on the ground. Apart from the pool on the first floor underground, was there spring on the ground?

The first problem will be explained at length in the following parts, but there is no conclusive evidence on the spot or the literature.

To guarantee the scientificalness of simulation, the simulation were only done on the water in the pool on the underground first floor. After simulating water in VR environment, architecture experts analyzed visually on the basis of water's 3D virtual scene and inferred the depth of water scientifically. These experts also inferred that there should be sideboards on the bank (Figure 3.) according to the usual practice of

Chinese architecture. Other units related to water and their functions can only wait to be simulated until further research.

In virtual recovery and simulation, actual heritage protectors can have a more visual understanding of details of architecture and infer some new ideas that don't think of before through construction of virtual recovery and simulation. Thanks to the cooperation of the whole team, Lingzhao Xuan's construction is "finished" in the virtual world. The ultimate virtual scene is as figure 3. The complete Lingzhao Xuan looks like a white pearl embellished in The Forbidden City.

### 4.3 The use of achievements based on the virtual recovery and simulation

Many scientific research achievements have been gained after the virtual recovery and simulation of Lingzhao Xuan.

#### 4.3.1 *Digital heritage*

First achievement of digital heritage is precious digital materials. In the project, nearly 8500 digital images (with a total size of 34.7GB) of Lingzhao Xuan's present situation in 2011 comprehensively have been gained. There is 1.58GB in total size when construction documents (obj format) of 3D images and 2D images data. These are precious data recording and researching the architecture and history of Lingzhao Xuan.

Cultural heritage have been changing all the time. The state on a certain age is irreversible no matter it is under slight natural aging or manual restoration. Therefore these image materials and analytic results are very precious, which are the important basis of comprehensive research of cultural heritage in the future.

Second achievement of digital heritage is 3D virtual scene of heritage building. In the Lingzhao Xuan project, the virtual scene of Lingzhao Xuan's present situation with high precision provides the basis for further virtual research and use.

There are multiple values in using virtual scene of present situation with high precision as the reflection of real environment. One is value in preservation; it can be preserved as the digital data with the basic materials. Another one is value in use; it can be used in virtual exhibition or carrying on simulation and experiment on the behavior and event that cannot be accomplished in real world.

Virtual recovery and simulation have gradually become the important ways to support the protection and repair of cultural heritage. The key points of it are interdisciplinary research and scientific inferences. The characteristics and history of cultural heritage can be expressed visually by simulating the functions of cultural heritage and historical scene in a most possible and reasonable way.

#### 4.3.2 *Virtual exhibition—VR digital work*

In the Lingzhao Xuan project, virtual exhibition with the theme of Lingzhao Xuan is developed based on the 3D virtual scene of present situation, recovery and simulation and so on. It is done by VR programmers, CG modelers, VR directors, music professional personnel and broadcast professional personnel together.

This work mainly describes the architectural style and characteristic of Lingzhao Xuan itself and shows comprehensively Lingzhao Xuan's value as the cultural herit-

age. Before the work is released, it is checked and reviewed by experts and scholars of cultural heritage's protection and architecture in The Palace Museum and universities and then it is under repeated modification and improvement according to these advices. The finished VR work Lingzhao Xuan is released to the public (Figure 4.), which is a shortcut for people to understand Lingzhao Xuan's history and architectural style, not only meeting the aesthetic needs of normal tourists closely and comprehensively, but also meeting the research requirements of experts and lovers of cultural heritage. At the same time, it can go out of The Palace Museum to combine with the actual exhibition, which increases heritage building's expressive force and artistic appeal.

### 4.3.3 *Academic research achievements*

Academic research achievements include two aspects. First of all, Actual heritage protectors had deeper understandings of details of every unit in Lingzhao Xuan and studied out the plan about Lingzhao Xuan's virtual recovery and simulation through the cooperation of professional personnel in multiple disciplines, which provided effective reference for the protection of actual heritage building and new breakthrough point for further research.

Second, this project put the application of graphics in the field of digital museum to a new level, which is a very effective experiment. In order to exhibit more vividly the visual effects of virtual recovery and simulation and highlight the importance of virtual recovery and simulation, 3D real time rendering technology is necessary.

The application and research of 3D real-time rendering technology is done by VR programmers and CG modelers. The effect need to be discussed and finished together by VR directors, radio announcers, VR programmers and CG modelers. VR directors decide the required VR effect and radio announcers decide the way of exhibition (which will affect the choosing of 3D real-time rendering technology).

In developing VR work Lingzhao Xuan, in order to be closer to the descriptions in the historical documents and highlight the function of the architecture more authentically, 3D real-time rendering effect which bases on OpenGL's Shader language was adopted, including HDR (High Dynamic Range) effect(Figure 11.), water real-time effect (Figure 12.) and glass real-time effect and so on. These can not only improve the rendering quality, but also make sure that the rendering speed will not too low. And then the rendering speed was increased by adopting technologies such as culling and MipMapping and so on.



*Figure 11: Rendering picture of Lingzhao Xuan present situati-on's virtual scene without HDR (left) and with HDR (right)*

*Figure12: Lingzhao Xuan present situation's virtual scene (left)*
*and virtual simulation scene (right, water surface)*

## 5 Conclusion

It can be inferred from Lingzhao Xuan project that it is of great importance in application of heritage building's interdisciplinary virtual restoration and simulation. It can create abundant digital heritage achievements with historical values, provide valuable reference to actual cultural heritage's protection and provide abundant digital works to aid in the entity exhibition. Furthermore, the digital heritage achievements also can be important source for the database of 3D digital models in the future. Virtual exhibition can exhibit the achievements of virtual restoration, construction and design, which is one of the effective ways to aid in the entity exhibition and is beneficial to the spread of it. Such interdisciplinary pattern can be extended into other cultural heritage types.

However, according to the process and effect of present restoration and simulation, although the ultimate achievements are abundant, there are some concrete problems without being solved properly, such as: how to obtain the best 2D images? How to collect 3D digital images on a large scale and use them efficiently? How to obtain better plan to carry on restoration?

Developments in the future lie in two aspects. One is the setting of interdisciplinary restoration and simulation mode standard. Two camps should establish the concepts of heritage building's virtual restoration and simulation and set adaptable standards. Boarder and more initiative participation are needed to make sure that the most precise and valuable restoration plan can be obtained from every project, such as the participation of more academic researchers and public. Another one is to keep up closely with the scientific developments and keep trying new technology means to apply more multiple-field knowledge to digital museum's work such as graphics and 3D scan technology and so on. With rapid development of technology, it can be foreseen that the ongoing improvements of digital technology such as 3D digital images and VR in many aspects such as simplicity, authenticity and interaction will bring simpler and more precise means of virtual restoration, construction, simulation and exhibition, which will bring more abundant achievements in heritage building's protection and utilization.

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### Summary

Due to natural disasters, economic development, tourism development and other factors, many precious heritage buildings have been in endangered situation. How to protect, research and develop these heritage resources effectively has become very urgent and important. Three-dimensional (3D) digital technology plays a more and more important role in protecting and using cultural heritage. The article will take the synthetic study on the mode of virtual construction, recovery, simulation and exhibition of Lingzhao Xuan (a heritage building which stopped construction for some reason in the Palace Museum) as an example to explore and summary an effective interdisci-

plinary cooperation mode. Besides, we broaden and deepen the concept of "virtual recovery", and add the concept "virtual simulation" by means of virtual design and the new achievements which are created by such mode for the first time. This research is aimed to provide reference for the standard application of 3D digital technology and perfect the protection work of heritage buildings.