POLITECNICO DI MILANO

Master in

Building Information Modelling

Taking Jichang Garden as an Example, an Attempt to Restore Jiangnan Garden of Ming Dynasty

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Many thanks to all of our professors and colleagues. Many thanks to European Union, for their establishment of Erasmus Mundus Programme. Many thanks to Erasmus Mundus Scholarship.
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SOMMARIO

L’hbim può portare nuova vita agli edifici antichi. Il giardino cinese è uno stile da giardino che si è evoluto nel corso di tremila anni, un tesoro che appartiene alle persone di tutto il mondo. Alcuni di loro sono già scomparsi a causa delle guerre coloniali.

In questa tesi, l’autore ha cercato di ripristinare la disposizione generale del giardino usando l’album fotografico del giardino di Jichang riscoperto nel 2017. Poi il modello a 3 schema semplificato di questo giardino è stato costruito per mostrare come appariva 5 centinaia di anni fa.

A causa dei limiti di tempo e della difficoltà di ottenere dati, il modello costruito in questa tesi è solo quello di determinare in via preliminare la disposizione generale del giardino della dinastia Jichang Ming, senza ricorrere a modelli parametrici, cosa che potrebbe essere fatta in futuro.

Parole chiave: Giardino classico cinese, album di materiale relico culturale, edificio storico, dinastia Ming, modello di disegno tridimensionale semplificato
ABSTRACT

HBIM can bring new life to ancient buildings. The Chinese garden is a landscape garden style which has evolved over three thousand years, a treasure that belongs to people all over the world. Some of them have already disappeared because of colonial wars.

In this thesis, the author tried to restore the general layout of The Garden by using the Picture Album of Jichang Garden rediscovered in 2017. Then the 3-dimentional sketch model of this garden was built to show what it looked like 5 hundred years ago.

Due to the time limitation and the difficulty in obtaining data, the model built in this thesis is only to preliminarily determine the overall layout of Ming Dynasty Jichang Garden, without the use of parametric modelling, which could be done in the future.

Keywords: Chinese classical garden, Cultural relics album, Historical Building, Ming dynasty, 3-dimentional sketch model
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1. INTRODUCTION

1.1. Introduction to BIM

BIM, fully called Building Information Model/Modelling, was first proposed by Autodesk in 2002.

In terms of the concept of BIM, there are various types of BIM understanding of users from all walks of life. According to Wikipedia, BIM is ‘a process supported by various tools, technologies and contracts involving the generation and management of digital representations of physical and functional characteristics of places.’ (Wikipedia, 2020) Meanwhile, the NBIMS-US (National Building Information Modelling Standard, 2015) defines it as ‘a digital model with both physical and functional characteristics in the construction project, a Shared Information resource to make any decision in the whole life cycle starting from the initial conceptual design of the project and Shared Information model based on standardized collaborative work’. In addition, according to the NBS (National Building Specification, 2019) of the UK, BIM is the process of creating and managing project information generated in the whole life cycle of a project.

Nowadays, BIM has been widely recognized by tremendous industries on a global scale. It can help realize the integration of building information. From the design, construction and operation of a building to the end of the building's life cycle, all kinds of information are always integrated in a three-dimensional model information database. Teams, construction units, facility operation departments, owners and other personnel can work together based on BIM to effectively improve work efficiency, save resources, and reduce costs to achieve sustainable development.

1.2. HBIM

1.2.1. Introduction of HBIM

Walking on the streets, alleys, and streets, both in Europe or China, we can often see some historical buildings, which are not only a historical witness of a region, but also a cultural carrier. In the past, it was rather difficult to repair historical buildings, but with the development of BIM technology, all this has become a possibility.

Historical Building Information Modeling (HBIM), which is based on BIM, is an emerging technical means for the preservation and management of the Information of ancient buildings at present. It is an interactive parameter object composed of Historical data representing architectural elements, which can be accurately mapped to point cloud or image-based survey data (Sacks, 2011). Building Information Modelling shows great potential for the refurbishment process.

HBIM was first proposed by Murphy (2009), and it was defined as a set of point cloud and photomodelling data mapped to cross-platform program, based on which a parameterized component library was constructed.
In China, HBIM was first proposed by the Institute of Architecture and Cultural Heritage Protection, Tsinghua University Design and Research Institute in 2009, and it is fully called ‘Heritage Building Information Model’.

In terms of content, the application of BIM is the technical core. Wu Cong et al. (2016) have a different understanding of HBIM. They believe that HBIM model is not a simple 3-D model (BIM model), but presents it as an n-D model by adding experimental elements, different variants of the same node and other variable elements to carry more information.

The HBIM model should not fall into the mold of BIM technology, but should emphasize that point cloud, photogrammetry and other technologies are only a means to build the HBIM model. Meanwhile, the HBIM model should also integrate historical documents, repair survey and design, and construct records during the construction.

Referring to the above existing concepts, the ‘HBIM’ in this paper is not an emerging technical concept, but a general term for the standardized application of BIM technology in the protection of historic buildings. It should have a set of scientific, perfect and standardized application process, and be able to coordinate the application of relevant professional advanced technologies into the protection work.

Compared with traditional data and information collection methods such as 2-D drawings, forms, text and images, HBIM can more intuitively and accurately express the original appearance of ancient architectural ontology. Parametric modeling of ancient buildings must follow the principles of ‘evidence-based restoration’, ‘ancient building modular system’ and ‘HBIM system’. The establishment of historical information model of ancient buildings can provide important materials for the protection of ancient buildings and help to inherit the traditional architectural heritage. HBIM is applied in the restoration and design of cultural relics, and the main advantages of the integration link are in three aspects:

(1) Cultural heritage protection is designed for multiple groups of people, and the design process involves many types of work. The adjustments and changes caused by repeated deliberations in the design are often multi-stage and multi-process; HBIM provides a new way of working, which combines management departments and protection. Units, designers, construction parties and the public are connected on a communication platform, so that all links of the protection work are closely connected, and the design method of synchronous adjustment is coordinated.

(2) Survey and record information, which is only required for cultural relic protection, but not for new design. In the HBIM design process, valuable information can be permanently retained after the BIM modeling data is completed, which has the meaning of establishing a new type of archive storage and retrieval method. Then the significance of BIM in the protection of ancient buildings is completely different from that of new design.
(3) In terms of construction design, the implementation process can be specified by BIM, and traditional construction techniques such as materials and structures can be reflected in the three-dimensional BIM house repair drawing. For cultural relics and ancient buildings, this approach makes disease diagnosis and treatment measures more intuitive.

For BIM technology, we will not only use it in the development of the construction industry in the future, but also protect and repair its historical buildings to ensure the transmission of culture to a certain extent. This is the meaning of exploring HBIM.

HBIM idealization is the final stage of the parameter model of the prototype library across software platform management system mapping point cloud and image data, parameter model to multimedia and documentary information compared with the actual building, associated 3-D objects, this can also be automatically generated from the parameter model complete engineering drawings of the flat, vertical, profile and 3-D model (Dore, 2012).

The ‘three-dimensional synergy’ advantage of historical building information Modeling (HBIM) runs through the whole process of exploration, repair, display, research and monitoring of ancient architecture protection. With the application of BIM technology, intellectualization and digitization have become the primary consideration for the management of advanced architectural heritage archives, which can also be more helpful for the research, analysis, repair, maintenance, display and utilization of buildings in the later period.

By constructing the three-dimensional model of ancient buildings, we can intuitively understand the geometric composition, construction mode, process, and even the data of each part of ancient buildings. By means of visualization, we can greatly reduce the risk caused by insufficient information in the maintenance process of ancient buildings.

At the same time, the simulation of the surrounding environment can avoid the impact of disasters, improve the emergency handling capacity, improve the level of ancient architecture protection.

1.2.2. Definition of Historic Buildings

It is generally believed that this concept of ‘Historic Building’ originated in 15C Italy and was not widely used in the field of heritage protection until the late 19C.

The first formal international reference to ‘Historic Building’ was in the 1975 Amsterdam Declaration. The proposal of this concept shows that the international charter on heritage protection has begun to broaden the horizon from important monuments to historic buildings that are relevant to People’s Daily life, which is of far-reaching significance.

In China, historical buildings in the broad sense refer to all ancient and modern buildings with a certain historical age and protection value, which is similar to the current contents of ‘Historic buildings’ in the world.
In a narrow sense, the first specific definition of ‘historical buildings’ was established in Shanghai in 2002. Since then, many state and local cities have put forward the protection concept of historical buildings with reference to Shanghai. Specifically, it shall meet the following conditions: 1. Architectural style, construction technology and engineering technology have architectural art characteristics and scientific research value; 2. Reflect the historical and cultural characteristics of Shanghai regional architecture; 3. Representative works of famous architects; 4. Representative workshops, shops, factories and warehouses in the history of China’s industrial development; 5. Other excellent historical buildings of historical and cultural significance.

1.2.3. HBIM Concept analysis

Compared with the daily reference to the application of BIM in historical building protection, HBIM is BIM technology applied in the field of heritage protection within a set of standardization. The application of whole life cycle flow process, not only includes the early stage of the effective information acquisition, but also scientific data processing and analysis, and analyses the construction of ontology for architecture, to create HBIM information model.

The benefits are obvious. The most obvious one is the detailed inspection of the exterior and interior of the building through HBIM models, which will greatly facilitate the non-professionals to better understand the building and participate in the conservation work. At the same time, as a central document, the model provides the possibility of 3D displaying in different periods, and can also be used in combination with other architectural analysis software for analysis and simulation research. In addition, the uniqueness and relevance of the data produced by HBIM models can greatly reduce the human error and even errors in the process of information transmission.

Therefore, HBIM is by no means just a application of new technology in the traditional protection process. It not only involves the integrated application of a variety of related technologies, but also a multidisciplinary collaborative work process, as well as the digital protection of the entire life cycle of historic buildings.

1.2.4. Application Prospect

With the continuous exploration of HBIM, various elements including time, space, text, picture and sound, etc. of HBIM will upgrade the original 2-DIMENSIONAL model to a multi-dimensional dynamic service system, and further transform the traditional professional application to the level of public-sharing and simultaneous professional application.

The application of HBIM models is divided into two categories according to their usage: traditional drawings, printing tables, and screen image display.

Traditional drawing and table printing: One of the features of the parameterized model is that it can directly generate the traditional planar graph, component detail and corresponding table, such as plane, vertical and profile.
In contrast, screen image display: drawing display can be divided into traditional drawing, table, dynamic diagram and thematic diagram. The advantage of parametric model is that the information contained in the model can be quickly inquired through the screen, personal computer and mobile terminal, so as to intuitively and accurately guide the construction process and education research.

The application of the model can be divided into three directions: teaching research, construction guidance and ancient architecture information management.

In terms of teaching research, HBIM provides accurate and intuitive model information for teaching and research, and can reflect the internal relations of components through parameters, so as to improve the quality of teaching and the efficiency of research.

When it comes to ancient architecture protection, the ancient architecture information management system can make clear the location of cultural relics and relevant parameter information at a glance and quickly inquire through the combination of HBIM and tag chip. This is very necessary for the formation of the digital museum system of ancient buildings.

However, due to the huge data contained in HBIM, the model reaches hundreds of megabytes to gigabytes, which is overwhelming for mobile phones and personal computers to deal with. Therefore, HBIM will develop towards lightweight in the future to meet the needs of browsing, viewing and education.

In terms of early warning for disaster, HBIM and the corresponding disaster analysis and simulation software can be used to simulate the process of disaster before the occurrence of disaster, analyze the causes of disaster, formulate measures to avoid the occurrence of disaster, as well as emergency plans for evacuation and rescue support after the occurrence of disaster.

When a disaster occurs, the HBIM model can provide rescuers with complete information about the emergency point, which will effectively improve the emergency response measures.

1.2.5. Existing Problems of HBIM Application

As a general term for the application of BIM technology, HBIM can more accurately express the status quo of building preservation and effectively map the current information of historic buildings to the initial design stage.

By analyzing the typical applications of HBIM at home and abroad, the author finds that there are mainly two prominent problems.

First of all, the existing research has not paid attention to the difference of information acquisition requirements among surveying, mapping and architecture majors.

With the gradual progress of surveying and mapping field related technology, to collected data is becoming more and more sophisticated, but the specific requirements of surveying and mapping and architecture of information collection is not the same. The former data authenticity is not the same as
the latter’s authenticity, and the higher accuracy of surveying and mapping results are not suitable for direct use architecture more instead.

There is nothing wrong with the existing HBM studies to collect information based on the principle of being used for our own purposes from the professional perspective of architecture. However, it is ambiguous that the process of how to scientifically process the acquired original data to be used in architecture, which is not only an unscientific processing method, but also a common omission and deficiency in the existing studies.

Secondly, there are many ways to map building entity information to virtual model. Under the technical background point cloud data and BIM platform cannot realize effective information docking, 3-D scanning technology is not the most ideal method suitable for popularization.

And existing research regarding point cloud model diagram, still stay in the simulation of historical building information at present stage stage. Although it can assist deformation survey and analysis of diseases such as some part of the work, it did not restore to repair and institute needs the information of the initial design phase. Therefore, the 3-D scanning is not scientific and effective information mapping.

1.2.5.1. Countermeasures study

First of all, it should be made clear that HBIM is an integrated application of multiple professional technologies. With the continuous technological progress, the application content of HBIM will be constantly being updated and improved.

For the first question, in order to realize the scientific collection and processing of information, it is necessary to ensure that the work in the stages of surveying and mapping, data processing, data integration and modeling conforms to the professional requirements of the leading discipline in this stage, so as to promote the standardization process of HBIM.

For the second question, the author believes that a more scientific and reliable research idea should be to study the mapping method of information based on the characteristics of BIM platform and building construction, rather than ignoring the professional analysis of architecture from the purely technical perspective.

1.3. Typical Cases of HBIM

Since BIM technology has been applied to the conservation of historic buildings, significant changes and progress have been made in the working mode, process and efficiency of archaeologists, designers, engineers and other relevant participants. From the initial BIM model construction to the introduction of more advanced technologies for building information collection, from BIM model visualization to parametric analysis modeling and information management later, the application of BIM in historical building protection gradually tends to be full process and full life cycle.

In terms of the development process, this term has not been mentioned in many previous studies and practices in China, but its core content is the application of BIM technology in building protection,
which belongs to the necessary exploration and paving stage of HBIM. Therefore, these cases are included in the development process of HBIM in this chapter, and the development process of HBIM at home and abroad is sorted out accordingly.

As can be seen from the development process of HBIM, its application is still in the stage of continuous exploration and improvement. Therefore, how to apply BIM to the protection of historic buildings more scientifically and systematically is a subject that requires continuous exploration, research and practice of all disciplines. The analysis, extraction and summary of existing studies are the necessary links to grasp HBIM, and the basic work to upgrade and improve HBIM.

1.3.1. Three Typical Cases

1.3.1.1. Henrietta Street, Dublin

Murphy (2013) from University College Dublin in Ireland elaborated the HBIM application process of Henrietta Street in his doctoral thesis with Graphisoft ArchiCAD as the software platform.

Referring to a large number of relevant books and literatures, this paper analyzes and extracts the evolution process of the classic architectural style rules of Ireland in the 18th and 19th centuries, as the basis of analyzing the case column; Next, with the actual surveying and mapping data, the parameter rules applicable to the case object are analyzed and designed. Finally, an architectural information model is created, which covers information such as material composition and construction method under the skin.

![Figure 1 HBIM Model of Henrietta Street and its Automatic Output](image)

(Murphy, 2013)
The HBIM model (Figure 1) is used in the case to automatically generate and export two-dimensional drawings such as architectural plane, vertical and profile, etc. according to the requirements. The model can also be compared with the actual situation to assist the repair and protection design.

In addition, the quantity of automatic output of documents between the 3-D CAD model and the HBIM model was compared, so as to prove that the HBIM model showed great progress in the type and quantity of document output, and could better meet the subsequent requirements.

1.3.1.2. Toronto Batawa Community Heritage Building

Stephen Fai (2011) in Batawa research projects proposed his projects contain all quantitative and qualitative information related to the historical building of BIM model, which can reflect the time dimension to help implement the existing heritage building protection and planning work.

In this stage, 3-D laser scanning (Figure 2) and photography are used for efficient information acquisition. He considers that the application of point cloud data in BIM workflow is still in the initial stage; 3-D scanning is only used as one of the auxiliary means. In addition, the collection of relevant historical drawings is emphasized as an important reference.

The project creates an overall 3-D environment for the community in the later stage. In order to integrate all the land parcels into one model, Navisworks, a BIM software with powerful integration function, is adopted as the project management tool, and it is used in collaboration with the previous model, providing a platform for the test of the model at both micro and macro scales.

![Figure 2 Point Cloud of Toronto Batawa Community Heritage Building](image)

(Fai, 2011)

1.3.1.3. Basilica of St. Maria of Collemaggio in L’Aquila of Italy

After the church was damaged in the 2009 earthquake, interventional protection was implemented. The researchers (Oreni et al. 2014) created a detailed BIM model (Figure 3) of the church to provide reliable
information support for the restoration project. The model can also be used in structure simulation and analysis, project evaluation and repair design.

![Image of HBIM Model](image.png)

**Figure 3 HBIM Model of Basilica of St. Maria of Collemaggio in L ‘Aquila of Italy**

(Oreni et al. 2014)

1.3.1.4. Case summary

Based on the analysis of the above cases, the author finds that the research and practice of HBIM abroad all attach great importance to the authenticity of data in the information acquisition stage, especially the application of 3-D scanning technology in building surveying and mapping. This indeed reflects the continuous progress and improvement of HBIM-related integration technology. However, it is insufficient to analyze the massive and highly accurate information collected and transform it into an applicable one in the field of architecture. This is a common and unavoidable problem after the introduction of various new technologies in the research, and it is also one of the source points for the author to repeatedly think about HBIM.

This is a common and unavoidable problem after the introduction of various new technologies in the research, and it is also one of the source points for the author to repeatedly think about HBIM.

In general, the typical process of HBIM application can be divided into four sections, which are respectively ‘information acquisition - information processing - parametric modeling - Model evaluation and application’.

1.3.2. Two typical Cases of China

With the continuous modern development of China’s economy and society, the protection of ancient buildings is facing great challenges, and many of them have become the ‘victims’ of urbanization. At the same time, China’s ancient buildings are also facing severe problems such as weathering of components, structural damage, foundation settlement and so on.

With the continuous use of unmanned aerial vehicle remote sensing technology in surveying and mapping engineering and the application of BIM technology in the field of ancient architecture protection, the construction of ancient architecture historical Information Model (HBIM) emerges at the
historic moment, which changes the limitations of the original two-dimensional drawings on the expression of complex components and meets the requirements of ancient architecture archive preservation and management.

1.3.2.1. Twin Towers of Baisikou in Yinchuan, Ningxia Province

Li (2019) tried to use HBIM technology when build the Twin towers of Baisikou in Yinchuan in order to further discuss the realization of UAV remote sensing technology (Figure 4) in the surveying and mapping of ancient buildings and research the construction and modeling of the ancient building family in HBIM, which aims to integrate the new technology into the protection of ancient buildings. The birth of a new form on ancient building protection is expected based on big data and cloud platform in the future.

![Figure 4 HBIM Model of Twin Towers of Baisikou in Yinchuan](Li, 2019)

1.3.2.2. Li-fen Building, Hubei Province

In order to improve the timely effectiveness of the protection work about Xian’anfang and start the process of quantitative analysis, Zhang (2018) used HBIM technology to solve the above problems and promote the digital protection process of Li-fen building and even historical buildings. The main achievements of this study include the HBIM application process and the component family library of Xian’an Fang (Figure 5), which can be directly used as the reference of the implementation process and the technology route guidance for the current digital protection of Li-fen building, and lay a detailed information foundation for the micro-quantitative research on Xian’an Fang.
Figure 5 HBIM Model of Li-fen Building

(Zhang, 2018)

1.3.2.3. Case summary

The concept of HBIM is not yet popular in China. However, since BIM technology has been applied to the conservation of historic buildings, the exploration process of its application has been developing rapidly. In particular, in the research field represented by colleges and universities, special topics are set up to carry out long-term sustainable research on HBIM, and many achievements have been made in the construction of HBIM model and the application of results.

However, the research on the integrated application process of HBIM is insufficient and deficient, especially the lack of in-depth discussion from the perspectives of surveying and mapping and architecture.

In general, the typical application process of HBIM in China is roughly divided into several stages: ‘Information Acquisition - Model Construction - Model Application and Management’.

1.4. Chinese gardens

1.4.1. Introduction to Chinese gardens

China has a vast territory, and the climatic and geographical conditions in the east, west, North and South are different from each other. As a result, gardens often show distinct local characteristics. It is mainly divided into Jiangnan gardens, Lingnan gardens and Northern gardens.

Jichang Garden is a typical Jiangnan garden. Among the classical gardens in the south of the Yangtze River, the four famous gardens in the South of the Yangtze River are represented by Nanjing Zhanyuan garden, Suzhou Lingering Garden, Humble Administrator’s Garden and Wuxi Jichang Garden. Chinese garden is called ‘solidified poetry, three-dimensional painting’.

Different from the fixed viewpoint of most western classical gardens, Chinese classical gardens mostly adopt the way of dynamic observation or combination of dynamic and static. Walking among these
garden is like walking among the poems and paintings compiled by ancient people. The core of Jiangnan Garden is a maze. Step by step, man and nature coexist harmoniously.

The traditional classical garden has its unique spatial sequence, and the landscape gradually unfolds in the way of beginning, development, turning point, climax and ending. Only by following its original tour route can we really feel the true interest of the garden, so the authenticity of the tour route is also an indispensable part of the authenticity of the classical garden.

The most important thing in Chinese gardens is that ‘though it is made by people, it was from heaven’. The ‘artistic conception’ in the artistic creation of Chinese garden is exactly the same as the ancient Chinese philosophical thoughts and spirit, combining the philosophical thoughts of Confucianism, Buddhism and Taoism. Under the influence of this idea, landscape design began to consciously integrate architecture, landscape, plants, etc., in the limited space, according to the shape of the situation, to create a harmonious with the natural environment- the ‘unity of nature and man’ of the garden.

The value of natural beauty is rendered by the appreciation of man. The Chinese style garden is a unique creation of people’s attachment to nature, pursuit of harmonious coexistence with nature, and beautification of their living environment.

Nowadays, it has become the pursuit direction of modern architecture to absorb traditional garden landscape art, and create and design garden space with both modern sense and traditional culture essence.

### 1.4.2. The Easiness to Disappear of Chinese Gardens

The existing classical gardens are basically the Qing Dynasty, or even after the liberation of the slowly transformed. It is a great pity that we can seldom see a garden of the original taste in the Ming Dynasty, or even the Song Dynasty, let alone the Tang Dynasty.

Even many Qing Dynasty gardens disappeared, such as Jiezi Garden and Sui Garden, and now no longer exist, leaving only the paintings (Figure 6) Located in Qinhua District, Nanjing City. Jiezi Garden was once a very famous garden. Sui Garden is located in Wuta Mountain, Nanjing City, which is one of the three famous gardens in Qing Dynasty. During the war, all treasure of the garden was carried away and the whole garden became a farm(Figure 7).

Compared with Bridges, buildings, pagodas and the Great Wall, gardens are the easiest to disappear. Only after the garden was written down could we know of its existence. In addition, methods such as painting and woodcarving were developed in order to preserve the garden.
In the Ming Dynasty, a painter named Song Maojin painted a Picture Album of Jichang Garden (Figure 8) (more in Appendix). Due to the war and other reasons, this album was spread overseas, no one found for a long time.

In 2017, an overseas Chinese donated the album to China, and it is now kept in the Shanghai Museum, China, in which 50 scenes of Jichang Garden in Ming Dynasty are listed, which makes it possible to restore Jichang Garden of Ming Dynasty.
1.5. Research methods

The author made full use of the information in the 50 pictures and the plane form of the existing Jichang Garden, and made full reference to contemporary gardens, so as to ensure the accurate understanding and grasp of the development course of Jichang Garden. Then the author determined the plane shape of The Ming Dynasty Jichang Garden and drew a 3-D sketch model. (See Chapter 2-3 for details)
2. INTRODUCTION OF JICHANG GARDEN AND DISCUSSION ON ITS AUTHENTICITY

Jichang Garden, also known as Qin Garden, is a Classical Chinese garden located in Wuxi city, Jiangsu Province, China (Figure 9). It is a master of the private gardens in The south of the Yangtze River, which is very representative for the study of the gardens in the South of the Yangtze River.

The garden is surrounded by trees, small Bridges and flowing water. In short, the mountain scenery is also borrowed to become the landscape of the garden. It is one of the representative gardens in the south of the Yangtze River and listed by the State Council of China as one of the third batch of national key cultural relics protection units. (Figure 10)

Jichang Garden is located between Huishan and Xishan in Wuxi City, Jiangsu Province, China (Figure 9). It is located at the foot of two mountains, so it has very good conditions for borrowing scenery.

Jichang Garden covers an area of 14.85 Mu - 9.9 \( \times 10^3 \) m\(^2\), long from north to south and narrow from east to west. Mu is a Chinese classifier for fields, 1 mu is equal to 666.667 m\(^2\). The landscape layout takes the mountain pool as the center and integrates with nature. The big trees in the garden are towering; the bamboo shadow is whirling the desolate clearance, which is simple and quiet. It has a unique style in jiangnan gardens with its ingenious scenery borrowing, superb stone stacking, exquisite water management and elegant architecture.

![Figure 9 Location of Jichang Garden](image-url)
2.1. Owner of Jichang Garden

There are many gardens in China that change owners all day long. For example, humble Administrator’s Garden once had seven different owners.

Up to now, the owner of Jichang Garden never changes in the past 500 years and it always belongs to the Qin Huishan family, who are the descendants of Qin Shaoyou (1049 AD -1100 AD), a poet in the Northern Song Dynasty. Figure 11 is the evolution of the writing of character – Qin.

![Figure 10 Picture of Jichang Garden](image)

2.2. The History of Jichang

2.2.1. Construction of Jichang Garden

Zhan Qian Yuan is also known as ‘Qin Yuan’.

In the Reign of Ming Dynasty (1506A.D. - 1521A.D.), Qin Jin, who had been the minister of war in Nanjing, purchased the monks’ residence in Huishan Temple. He expanded it on the base of the former monks’ residence. He built a villa and turned it into a garden named Feng Gu Xing Wu.

After the death of Qin Jin, the garden belonged to his nephew Qin Han and his son Qin Liang, a political envoy of Jiangxi province. After the death of Qin Liang, the garden belonged to his nephew - The right deputy of the imperial court, Huguang governor Qin Yan.
In the nineteenth year of Wanli (1591 A.D.), Qin Yan was dismissed due to some political struggle. Then he returned to Wuxi, rebuilt the garden house, wrote a poem for each scene during which he sent a feeling of depression to the landscape. Finally, he took Wang Xizhi’s poem and renamed the garden – Jichang Garden, which means ‘Get the peace of life in the landscape’.

2.2.2. Fame of Jichang

From the twenty-third year of the Reign of Emperor Kangxi (1684 AD) to the one hundred year of emperor Qianlong (1784 AD), the two emperors made twelve cruises to the South of the Yangtze River, and each time they made a trip there, leaving behind many poems, plaques and couplets.

The Emperor Qianlong (1711 - 1799) believed that there were many places of interest in the South of the Yangtze River, of which only The Qin Garden at Huishan was the oldest. He loved its quiet and unique, so he drew a layout of the Qin Garden and brought it back to Beijing. Later, he built a replica of the five jiangnan gardens in Beijing that he thought were the best. Four of the gardens have long since been abandoned, and only the Huishan Garden, modeled after the Qin Garden, is still intact in the Summer Palace. In 1811, Huishan Garden was renamed as ‘Xiequ Garden’ (Figure 12).

Figure 12 Photo of Xiequ Garden

The Garden also preserves Kangxi’s ‘mountain color stream light’ and Qianlong’s ‘Jade and golden Pine’ (Jade and Golden Pine refers to steam and rockery) Yu Shu stone board each side.

2.2.3. State Repair after Donation

In the middle of the 20th century, the People’s Republic of China was founded. After a century of wars, Qin Lianggong, a descendant of the Qin family, dedicated the garden to the state in 1952. The People’s government of Wuxi carried out renovation and protection and gradually restored the ancient garden. Jichang Garden is a famous classical garden in the south of The Yangtze River in China. On January 13, 1988, the State Council declared it a national key cultural relic site under state protection.

From 1999 to 2000, with the approval of the State Administration of Cultural Heritage, Xihui Scenic Area restored the southeast part of Jichang Garden, which had been destroyed during the Taiping Heavenly Kingdom war. It restored lingxu Pavilion, Xianyue Pavilion, Xiyun Hall and other buildings.
successively, restoring the garden landscape in its prime time and making the whole ancient garden full of elegance and vitality. Jichang Garden belongs to villa-type garden at the foothills.

2.3. Authenticity in Garden Restoration

Chinese classical gardens have made brilliant historical achievements and written a significant page in the history of the development of world gardens. They are the precious cultural heritage and spiritual wealth of all mankind. But at the same time, affected by natural and man-made factors, classical gardens everywhere have been damaged to a certain extent. In order to protect and study classical gardens, it is necessary to repair them.

Fortunately, the discipline of landscape architecture has developed greatly in recent years, and more and more attention has been paid to the restoration and protection of Chinese classical gardens. But then comes the question of the authenticity of classical garden restoration. As a world-famous Chinese classical garden, the Old Summer Palace has been extensively repaired and studied, and there are many controversies and discussions about it. The discussion on the protection of its authenticity will help to answer this question.

According to the national conditions and cultural background, all countries in the world establish their own standards for landscape restoration. There has been a certain degree of international consensus on the question of authenticity, which holds that the original components of the building should be retained, the historical traces preserved, and the restored part should be distinctly different from the original part. Obviously, these guidelines are set for western stone historical buildings.

These guidelines have been challenged in terms of gardens, especially classical Chinese gardens. The greatest feature of a garden is that it is alive and the garden itself exists as a process of constant change. Plants in gardens obey their own natural laws, with the passage of time will have four seasons change, birth, old age, sickness and death; Due to the decay of the building’s wooden structure, continuous renovation and reconstruction inevitably become part of the landscape change process. As plants grow and wooden structures decay, classical gardens do not last for a long time, which means that it is impossible to deal with the authenticity of classical Chinese gardens simply from the perspective of the authenticity of western historical buildings.

2.3.1. Exploration of the Authenticity of Chinese Classical Gardens

To the above questions, the Zhuozheng Garden (Figure 13) and the Yu Garden (Figure 14) in Suzhou have carried on the beneficial exploration.

The Zhuozheng Garden was badly damaged and the east part was completely destroyed. In the 1980s, according to literature, calligraphy and painting, the style of Zhuozheng Garden in Qing Dynasty was restored as much as possible, and the East Garden was restored. Although the east part is completely restored by modern people, it can be said that there is no authenticity at all, but if the three parts of the garden are viewed as a whole, the reconstruction of the East Garden is indispensable to the integrity of the Humble Administrator’s Garden.
The Yu Garden was first built in the Qing Dynasty and overhauled in 2008. In terms of architectural restoration, it insists on the use of raw materials and original techniques, and uses traditional methods to restore the wooden structure, which corrects the clumsy aspects of previous restoration. Among them, the reconstruction of the main gate specifically refers to other garden gates of the same time in Suzhou, and tries to reflect its authenticity as much as possible.

In terms of the restoration of plant configuration, the dead trees should be cleared, the trees with the same or similar variety, height and shape should be selected for replanting, and the existing plants that do not conform to the historical landscape of the garden should be replaced year by year. At the same time, the original architecture and landscape pattern are restored to achieve the authenticity of the tour route.
2.3.2. Principle of Authenticity of Chinese Classical Gardens

To understand the authenticity of Chinese classical gardens, it is necessary to place them in the context of Chinese traditional culture.

In the History of Chinese Architecture, Liang Sichen (1901 - 1972) states that ancient Chinese architecture has the ‘concept of not seeking for the original and enduring the original’ and does not pay attention to the preservation of the original. Styles and styles change with The Times only pay attention to the original site and the date of construction, and the pursuit of authenticity is limited to this.

This was obviously contrary to the international consensus on the principle of authenticity, so Liang Sicheng advocated the idea of ‘repairing the old as the old’, arguing that the focus of authenticity was to preserve the authenticity of raw materials.

According to the discussion and exploration of authenticity in China, the authenticity of Chinese classical gardens should conform to the following four principles at least.

First of all, the original features and forms of landscape, architecture and plant configuration in history should be maintained on the basis of the complete scope of the garden.

Secondly, on the premise of a clear understanding of the original appearance, it should be allowed to repair and restore parts that have been damaged or do not conform to the historical original appearance. The original building materials should not be deliberately sought for preservation, and the historical materials and techniques should be used in the restoration as far as possible.

Thirdly, the process, technology and material selection of garden construction and repair are also part of the original nature of the garden, which should be preserved and inherited.

Finally, when replacing the diseased and dead trees, the trees with the same species and similar shape as the original trees should be selected to maintain the authenticity of the plant landscape.

2.3.3. Authenticity of Existing Restoration of Jichang Garden

Based on the discussion of the principle of the authenticity of Chinese classical gardens and the practical experience of the protection of the authenticity, the authenticity of Jichuan Garden can be discussed from the following six perspectives.

2.3.3.1. Authenticity of Completeness

The authenticity of integrity is the basis for maintaining the authenticity of other contents in the garden.

The Garden was directly handed over to the state by the descendants of The Qin family, and was not damaged beyond its disrepair. Therefore, its integrity basically conforms to the original historical appearance and achieves the authenticity of its integrity.
2.3.3.2. Authenticity of Architecture and landscape

In the restoration organized by the state, experts referred to all kinds of materials and Picture Albums, and basically achieved the complete restoration of Qing architecture and landscape.

At that time, *Picture Album of Jichang Garden* was not found, so it was not in the reference of experts at that time. Today, it is impossible to recreate the Ming style. The only way to see the restoration of The Ming Dynasty is to rely on HBIM technology, which is also the significance of this paper.

2.3.3.3. Authenticity of Tour Route

Different from the fixed viewpoint of most western classical gardens, Chinese classical gardens mostly adopt the way of dynamic observation or combination of dynamic and static.

The traditional classical garden has its unique spatial sequence, and the landscape gradually unfolds in the way of beginning, development, turning point, climax and ending. Only by following its original tour route can we really feel the true interest of the garden, so the authenticity of the tour route is also an indispensable part of the authenticity of the classical garden.

Today’s main entrance and main tour route are in line with the Qing Dynasty’s Jichang Garden.

2.3.3.4. Authenticity of Cultural Artistic Conception

Chinese classical gardens emphasize the artistic conception and cultural experience in the process of sightseeing, which is more than other gardens in the world, and has become the most characteristic part, so it should also become a part of the authenticity of the garden.

In classical gardens, symbols and dot-questions are commonly used to create artistic conception. Plaques, couplets and scenic spots used to illuminate artistic conception are all well preserved.

2.4. Summary of this Chapter

The important significance of protecting Chinese ancient gardens lies in the fact that ‘studying the present must study the past, without which the present cannot be achieved’.

The protection and study of Chinese classical gardens is not only about preserving and studying history, but more importantly, it can help today’s garden designers to solve problems they may encounter today and in the future.

Although the definition of the original true there is some controversy, but the original true establish a criterion for landscape protection, it is no doubt, the original true meaning is that it reflects the characteristics of time and space, the real situation at that time and will reflect the law of development of Chinese classical garden history, and that for today’s academic research and development of landscape architecture discipline is very important.
3. MODEL ESTABLISHMENT AND EVALUATION

3.1. Analysis on *Picture Album of Jichang Garden*

3.1.1. Differences between the Current Situation and Ancient Picture Books

The author has made a careful comparison between the 50 paintings in The Picture Album of Jichang and the present Jichang and found that there is a big difference between the Picture Album and today’s Jichang.

Here are three examples. The pavilion in Figure 15(a) was in the middle of the lake. It was originally an S-shaped corridor, but now it’s on the east side of the lake. The scenic spots in Figure 15(b) are no longer available. The water in the steam in Figure 15(c) was very abundant and a bridge was built over the river for people to cross the river. Today visitors are walking along what was once the river.

(a) Pavilion (b) Doorway

(c) Stream

Figure 15 Differences between Current Situation and Ancient Picture Books
3.1.2. Cause Analysis

In the Ming Dynasty, the water of Jichang Garden was brought from Huishan Spring. The spring water in the pool is very good, transparent, sweet and delicious.

Lu Yu in the Tang Dynasty listed Huishan Spring as ‘the Second Spring Under Heaven’ (Figure 16). From then on, people from all over the country, from the emperor to the bureaucrats and the literati, had their carriages and boats pulled to Erquan to drink the water.

From Figure 17, we can see that in the Ming Dynasty Erquan water is very abundant, in Jichang Garden can be made a large waterfall. The culvert pavilion in the middle of the lake is designed for viewing waterfalls.

Figure 16 ‘the Second Spring Under Heaven in the World’ Nowadays

Figure 17 Water Fall in the Picture Album

In the Qing Dynasty, springs in the garden had dried up. In the early Qing Dynasty, When Qin Songling rebuilt Jichang Garden, he dug up the original mountain and led the spring water to the bottom of the valley, making it a flowing mountain stream (Figure 18). At the same time, the Hambi Pavilion was removed.
3.2. Preparation for Modeling

3.2.1. Dragon Light Tower

Xishan is the main mountain of Wuxi, is also the source of Wuxi’s city name. At the beginning of the 16th century, it was believed that the tower would make the people of Wuxi officials, so a tower started to be built in 1574. Fifty or sixty years after the tower was built, no one passed the exam to become an official, so people believe that another tower should be built and a second brick tower was built in the second year of Wanli (1574). Coincidentally, Sun Jigao, a native of Wuxi, won the first place in the examination this year, then the second tower was named ‘Dragon Light Tower’, which means the tower is blessed by the dragon’s light.

Many years later the first tower fell and a pavilion was built on top of the tower. From then on, there was only one tower on Xishan mountain. The tower is 31.29 meters high and was the tallest building in Wuxi before 1949, which has been the symbol of Wuxi a long time ago (Figure 19-20).

Figure 18 Mountain Stream in the Jichang Garden

Figure 19 Google satellite image of Dragon Light Tower
Figure 20 Dragon Light Tower taken from Jichang Garden

*Picture album of Jichang Garden* was made in the Wanli period of the Ming Dynasty. The two towers coexisted when painting, so there were two towers there. Dragon Light Tower is now located in the southwest of Jichang Garden. The author can roughly determine the position of the painting by observing whether there are dragon minaret in the painting Figure 21.

Figure 21 Two Towers in the *Picture Album of Jichang Garden*
3.2.2. Similarities

In the different scenes of The album, the author found many similar parts. For example, the rockery in Figure 22 and the waterfall in Figure 23.

![Figure 22 Same Rockery in Different Pictures](image)

![Figure 23 Same Water Fall in Different Pictures](image)

3.3. Model Establishment

3.3.1. Restoration of Plan of Jichang Garden in Ming Dynasty

According to the existing plan of the Garden (Figure 24), the restoration plan of Ming Dynasty Jichang Garden shown in the Figure 25.

The main technical difficulties encountered when building this model are as follows:

(1) First of all, it is necessary to have a more in-depth understanding of the landscape structure of Jichang Garden, not only to understand the overall landscape structure, but also to understand the detailed structure of each component, such as the mortise-and-tenon shape of each component, etc. However, there are many structural relationships that cannot be directly imagined. Therefore, it is necessary to
consult relevant books or to view representative ancient architectural sites to understand. This modeling has been simplified in terms of some details due to limited time.

(2) The second one is the establishment of component families. The information model of Jichang Garden is built through various component family models. The parameterization of the model is achieved by relying entirely on the family function of the component. There are several difficulties in the process in the production of how to use appropriate modeling tools to build complex shapes and associate them with the main drive parameters. Since most of the components in the model in this paper can use the original parameters and do not need to be debugged into other values when they are reused, parametric modeling is not used in order to save modeling time.

(3) Finally, there is the issue of large files. Including all the landscape systems leads to a very large amount of final files. Generally, the memory of a computer cannot support all the modeling of the roof. How to split and link files is also a relatively complicated process.

![Figure 24 Plan of Contemporary Jichang Garden](image)
3.3.2. Component Creation

The author created the components of architecture (house, pavilion, cloister, bridge), fence, rockery, etc., as shown in the picture 26-30, respectively.

Figure 25 Restoration plan of Jichang Garden in Ming Dynasty

Figure 26 Components of Cloister and Bridge

Figure 27 Components of Fence
Figure 28 Components of House

Figure 29 Components of Pavilion
3.4. Completion of the Model

According to the plan above, the model was completed. Rendering of the Overview is in Figure 31 and part of the rendering is shown in Figure 32. Comparisons between models and albums and model appreciation will be discussed in the next chapter.
Figure 3.4 Rendering Pictures of Details

3.5. Model Evaluation

3.5.1. Comparison between Model and Picture Album

Figure 33-41 lists the comparison of the Picture Album of Jichang Garden and the model built by the author. Some details of the building or the stone could be further detailed but the general composition and shape are almost done.

It can be seen from Figure 33 that the author did not establish a model of distant mountains, but roughly restored the general layout of Jichang Garden. Figure 34 shows a rough restoration of the waterfall and pavilion, but the size of the waterfall is not as large as that in the picture book. This shows how abundant the spring was during the Ming Dynasty. Figure 35 shows the ‘S-shaped’ corridor on the lake. Figure 36 is a rockery between two gateways. Figure 37 is a doorway on the water that can be passed by small boats. Figure 38 shows a house with a pond and a small bridge in front of it. Figure 39 shows the ‘Z-shaped’ bridge deck along the bank leading to the pavilion. Figure 40 shows a hexagonal pavilion and a rockery. Figure 41 shows the lakeside building and its rear promenade.
Figure 33 Comparison of Panoramic View between Model and Picture Album

Figure 34 Comparison of the Water Fall between Model and Picture Album

Figure 35 Comparison of the Long Corridor between Model and Picture Album
Figure 36 Comparison of the Rockery between Model and Picture Album

Figure 37 Comparison of the Doorway between Model and Picture Album

Figure 38 Comparison of a Building and a Pool between Model and Picture Album
Figure 39 Comparison of the Walkway over the Lake between Model and Picture Album

Figure 40 Comparison of a Pavilion between Model and Picture Album

Figure 41 Comparison of a Building between Model and Picture Album

3.5.2. Appreciation of Garden in Ming Dynasty

Garden is a symbol of an era, an artistic style, a place for people to rest and create, or even a work created by an artist.

Chinese gardens can be viewed from the land, foundation, water, architecture, plants and owner.
3.5.2.1. Land

Land selection refers to the site selection of gardens and the investigation of the surrounding environment, with the purpose of finding a suitable place for people to live in and a beautiful environment.

The Jichang Garden in Wuxi is a typical mountain forest with the highest mountain on the west. The forest gardens are the most highly appraised for their integration with nature; On the other hand, gardens in cities will be rated lower because of more flat land.

3.5.2.2. Foundation

From the perspective of the location of rocks and water and the layout of the main building, the two parts of the garden are separated by dark mountains.

The eastern part is for sightseeing, while the western one is for living. The eastern part of the tour is dominated by water, while the buildings are almost all in the residential part of the west, as shown in the picture.

The south of the Yangtze River, where The Garden is located, has a subtropical monsoon climate. In winter, when the northwest wind blows, mountains act as a barrier to keep out the wind and avoid the discomfort of the living environment caused by the cold and dry northwest monsoon. Scientifically and psychologically, this is also in line with the living habits and usage rules.

3.5.2.3. Water

The water in nature transforms in many shapes and forms, and its charm and sound can bring people the enjoyment of beauty and arouse the visitors’ endless reverie. Water is fluid and amorphous, in sharp contrast to the steadiness and fixity of mountains, which expressed the idea of association of activity and inertia.

Water is the soul of Chinese classical gardens, as almost all existing gardens decorate themselves with water in them. Therefore, the amount of water and the way to manage water are a significant element to judge gardens.

There are many private gardens at the foot of Huishan Mountain, all of which take the water from the Second Spring Under Heaven as the essence of the gardens. Jichang Garden has long been famous for its many springs in the sea.

3.5.2.4. Building

The two architectural features of Jichang Garden are: 1. Small, but exquisite and natural. It is better to make the house smaller and merge it with nature. 2. Most buildings are isomorphic. In other words, a pavilion with four sides may become a pavilion. If the pavilion is enlarged, it may become a hall. Their construction and material are almost the same.
3.5.2.5. Plants

To the east of Jichang Garden planted plum trees, plum blossom is a scene in spring; there is a western maple with fiery red leaves in autumn. Suitable for plant habits, conducive to plant growth. In the landscape plants in the specific embodiment of all kinds of plants to achieve a balance in the final spring, summer, autumn and winter state, so that the four seasons have a view.

This not only embodies the Yin and Yang harmony of this ‘unity of nature and man’ thought, but also greatly enriched the landscape of plants in gardens. Spring has magnolia, begonia, peach blossom, while in summer there are lotus, banana, evergreen plants. Autumn has osmanthus, chrysanthemum, color leaf plants. In contrast, in winter there are pine and cypress, plum blossom and so on. This change of seasons and the collocation of different tree species reflect the balance of time and space.

In addition, many people assume that plants in Chinese gardens grow naturally, while plants in western gardens are artificially pruned into fixed geometric shapes, which is actually not the case. Plants in Chinese gardens have also been carefully pruned, but the pruning methods and specimens are not geometric, but built naturally.

3.5.2.6. Owner

All gardens made by literati are collectively called literati gardens. Generally speaking, the character and artistic conception of the literati garden are the best. Other man-made gardens were inferior, especially those of merchants. For example, most yangzhou gardens were built by salt merchants, while most Suzhou and Wuxi gardens were built by literati.

Jichang Garden is a typical garden built by literati, which has not changed its owner for 500 years and is basically well preserved.

3.5.2.7. Summary

With more and more attention being paid to environmental protection, it is a problem worth thinking about how to combine modern architecture with environmental protection. In this Jichang Garden (Figure 29), there are mountains and rivers, flowers and trees, walking and boating, and people live comfortably. It can be said to be a model of harmony between human being and nature.

3.6. SUMMARY OF THIS CHAPTER

In this chapter, the author analyzes the differences between the Picture Album of Jichang Garden and the realistic Jichang Garden and reviews relevant historical records to restore the sketch and 3D model of Jichang Garden in Ming Dynasty. Then, the restored model is compared with the picture album, and the layout of ‘harmonious coexistence of man and nature’ in The Garden of Jichang of Ming Dynasty is appreciated.
4. CONCLUSION AND PROSPECT

4.1. Conclusion

Chinese gardens are a treasure that belongs to people all over the world. The author tries to restore the general layout of The Garden by using the Picture Album of cultural relics rediscovered in 2017, from which we can draw the following two conclusions:

HBIM brings new life to the restoration of ancient buildings, and it is of strong practical significance for China with a long history. It is known that the cost of rebuilding a complete garden is inestimable. The technology can be digitally restored without occupying any space in the real world.

The discovery of ancient paintings has great significance for the restoration of ancient buildings. China has experienced a century of wars, during which countless cultural relics, treasures, pictureps, books disappeared. People all hope in the near future more relevant information will be found to help them regain the wisdom of the ancients.

4.2. Prospect

Due to the time limitation and the difficulty in obtaining data, the model built this time is only to preliminarily determine the overall layout of Ming Dynasty Jichang Garden, without the use of parametric modeling.

Parameterized families will be established in Revit and the details of each building will be further refined to facilitate reuse. It is hoped that the further model can be used for teaching or VR visiting of tourist attractions in the future.
REFERENCES

Journal article


Book


Conference proceedings


**Dissertations**


**Standards**


**Website**


# LIST OF ACRONYMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>BIM</td>
<td>Building Information Modelling</td>
</tr>
<tr>
<td>HBIM</td>
<td>Historical/Heritage Building Information Modelling</td>
</tr>
<tr>
<td>NBIMS</td>
<td>National Building Information Modelling Standard</td>
</tr>
<tr>
<td>NBIMS-US</td>
<td>National BIM Standard-United States</td>
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<tr>
<td>NBS</td>
<td>National Building Specification</td>
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APPENDICES

APPENDIX 1: PICTURE ALBUM OF JICHANG GARDEN

Some of the pictures are black and white and that is because it is difficult to find all the colorful version due to copyright reasons. All of the 50 pictures are listed in Figure 42 - 54.

Figure 42 page 1 of Picture Album of Jichang Garden
Figure 43 page 2-5 of *Picture Album of Jichang Garden*
Figure 44 page 10-13 of *Picture Album of Jichang Garden*
Figure 45 page 14-17 of *Picture Album of Jichang Garden*
Figure 46 page 18-21 of Picture Album of Jichang Garden
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Figure 52 page 42-45 of *Picture Album of Jichang Garden*
Figure 53 page 46-49 of Picture Album of Jichang Garden
Figure 54 page 50 of *Picture Album of Jichang Garden*