

## DIGITAL CONSTRUCTION FOR SPATIAL DOCUMENTATION OF BEIJING OLD CITY

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### ABSTRACT:

Beijing old city has been changed on a large scale and the walls of the old city had been demolished entirely because of population increasing and infrastructure developing. However, historic notes in Beijing old city are objects of architectural or cultural interest since it includes a large number of traditional buildings and monuments dating from various historic periods. These buildings and monuments together with their access and surrounding areas are often a unified construction total, whose spatial design and planning characteristics had been fully recorded and documented by means of some analogy methods, such as the topography map, aerial photo, sand table and city map etc. before 1960s. Nowadays, it is feasibility to make a digital restoration of the old city notes, such the old city walls and Siheyuan are restored by virtual technique using the existed spatial information and documents. Therefore it is necessary to create a spatial system to manage, organize and protect the existed spatial information and further, combine those data with a variety of quality information, such as picture, videos, old maps and city plans and other available data. In this paper the background, a project design of digital construction is implemented to rescue the available spatial data and make their exploitation.

### 1. INTRODUCTION

Before the middle of 1960s last century, Beijing's enceinte had little been changed; the wall of the old city had been kept about 500 years since the Ming Dynasty (A.D.1368-1644) and the Qing Dynasty (A.D.1644-1911). After the middle of 1960s, Beijing old city has been changed on a large scale and the wall of the old city had been dismantled entirely because of population increasing and infrastructure developing. However, an amount of non digital spatial documents of the old city, such as city map, topographic map sheet, aerial photo and city building and sand table, have still been preserved. Therefore, it is an actually significances and feasible on the historical culture heritage protection and urban planning to apply the non digital spatial recordings to construct the digital interface for Beijing old city so far. Figure 1 shows two period city maps, (a) the Ming Dynasty, (b) the Qing Dynasty.

The basic idea of the digital construction involves in researching the collection and procession methods of the multi-sources and multi-type spatial recordings of Beijing old city by colleting the large scale topographic map, ortho-image, and wood city sand table of 1950s, and researching organization, management and display methods of the multi-sources and multi-type spatial documents by designing a technique procedure and creating digital interface for the historical buildings and historical district in Beijing old city. Furthermore, a large number of buildings in the old city block belong to the state and private. Management and control of these properties under historic and present circumstances are very difficult almost impossible since many necessary information for that is not yet recorded. The creation of a spatial information system is expected to dramatically improve the situation and help to solve the problem. Practically the project aims at the reassessment of

the functional use of spatial data and other relative information in the old city, most of them traditional.

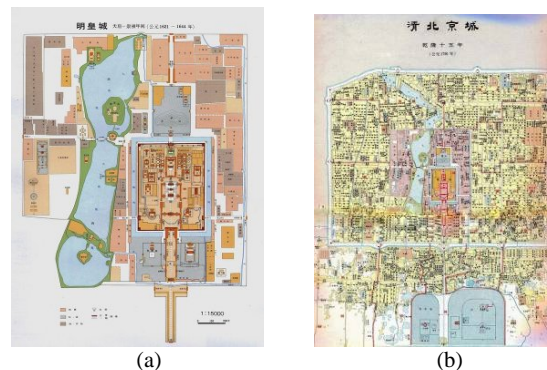


Figure 1. Beijing old city maps, (a) the Ming Dynasty, (b) the Qing Dynasty

A project design of digital construction is implemented to rescue the available spatial data and make their exploitation. The enhancement of the existed spatial information collection and architectural heritage restoration of the old city are the research area undertaken by Beijing Municipal Science & Technology Commission with the technical assistance of the Digital Archives Laboratory of Beijing University of Civil Engineering and Architecture(BUCEA). There are three phases to carry out the project, the first phase is for collecting data and building a spatial information management system; the second phase is for making three dimensional (3D) restoration of architectural heritage and the third phase is for integrating and displaying several of spatial data, 3D module, and multi-media

of the old city. In addition, this paper describes an attempt on the first phase work of the project.

## 2. HISTORICAL NOTES OF THE OLD CITY IN BEIJING

The history of Beijing as a city may be traced back to about 3000 years ago when a small town appeared on the present site of south-western Beijing. It was named Ji and then changed to Yan. At the beginning of the 10th century, it was the second capital of the Liao Dynasty. From then on, the old city had been the capital of the Jin, Yuan, Ming and Qing dynasties until 1911. A long history has left numerous famous historical sites which possess great aesthetic and cultural values. Beijing old city divides as two parts, the Forbidden City belongs to the inner city of the old city (Figure 1) and it locates a centre of the city and is splendid crystallization of ancient Chinese architectural art, but also a lot of traditional buildings surrounding outer city. The old city is an area protected by a special legislation, which rules the construction development and defines very strict building- and land-use regulations to avoid alteration of the existing characteristic architecture and style.

### 2.1 Old City Wall

Chinese cities rarely centre on a castle. Instead, the city's administrative centre is spread over a relatively large area, which may or may not be surrounded by a second set of "inner" walls similar in shape and construction to the main, outer wall. The wall of Beijing's inner city was originally about 24 kilometres in length. The outer wall to the city was 16 meters in width, while the imperial city's wall was about 10 meters wide. The wall enclosing the Forbidden City still stands today, spanning 1,006 meters from south to north, and 786 meters from east to west. Thus the area of the Forbidden City is 72 hectares. The ruler of Ming Dynasty began constructing the wall spanning 40 kilometres in 1419. In the 1950s and 1960s, the majority of the wall was razed to develop the city. A section of the old city wall in Beijing has become an attraction for both travellers and local residents after a delicate renovation project. Figure 2 shows a plan of the walls of Beijing old city and Figure 3 shows two gates and towers photos of the old wall, Yongdingmen and Xizhimen.



Figure 2. Plan of the walls of Beijing old city

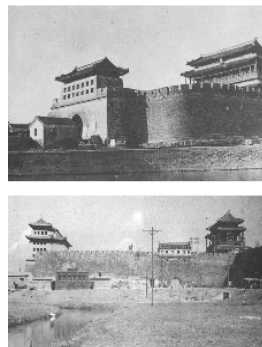


Figure 3. Yongdingmen(top), Xizhimen(bottom)

walls. In Beijing, for example, the proposed demolition of the city walls was at first opposed by experts ranging from architect Liang Sicheng, to Soviet advisor Mosin, on the grounds that the city walls of Beijing were the most sophisticated and well-preserved system of city walls in China. However, in 1958 summiters intervened, and declared that the demolition of the old city wall was a political issue, by 1970 almost all of the city wall had been demolished.

### 2.2 Si He Yuan

A Siheyuan (quadrangles) is a historical type of residence that was commonly found throughout China, most famously in Beijing. The name literally means a courtyard surrounded by four buildings. Fully developed Siheyuan date back as early as the Western Zhou period (1122 BC to 256 BC), and exhibit the most outstanding and fundamental characteristics of Chinese architecture. They exist all across China and are the template for most Chinese architectural styles. Studies put the estimates at about over 30,000 Siheyuan courtyards in Beijing old city.

The four buildings of a Siheyuan are normally positioned along the north-south and east-west axes. The building positioned to the north and facing the south is considered the main house. The buildings adjoining the main house and facing east and west are called side houses. The northern, eastern and western buildings are connected by beautifully decorated pathways. These passages serve as shelters from the sunshine during the day, and provide a cool place to appreciate the view of the courtyard at night. The building that faces north is known as the opposite house. Behind the northern building, there would often be a separate backside building, the only place where two-story buildings are allowed to be constructed for the traditional Siheyuan.



Figure 4. Si He Yuan of Beijing old city



Figure 5. Hu Tong of Beijing old city

The city of Beijing originally was protected by huge walls, and each Beijing home also had a wall built around it. Walled houses were attached, forming a labyrinth old city with narrow paths connecting the maze. The Hutongs they formed were orderly, lined by spacious homes and walled gardens. Farther from the palace, and to its north and south, were the commoners, merchants, artisans, and laborers. Their Siheyuan were far smaller in scale and simpler in design and decoration, and the Hutongs were narrower. It is recorded as the 978 Hutongs listed in Qing Dynasty and swelled to 1,330 by 1949. Figure 4 shows a classical Si He Yuan of Beijing old city and Figure 5 shows a typical Hu Tong of Beijing old city.

Modern Beijing's population boom has made housing one of city's biggest challenges. Siheyuan today are typically used as housing complexes, hosting multiple families, with courtyards being developed to provide extra living space. The living conditions in many Siheyuan are considered squalid. In the 1990s, systematic demolition of old urban buildings took place in Beijing under rapid economic development. Siheyuan are

After the founding of the People's Republic of China, a political dimension was added to the economic problem posed by city

being torn down to address, and the hutong area is rapidly disappearing, replaced by modern apartments and stores.

### 2.3 Protected Area

The Plan to Protect the Historical and Cultural Heritage of Beijing will be fully implemented. Special attention will be given to the protection of the royal city and the historical buildings situated along the ancient city axis and within the 25 historical and cultural protection areas, the protected major historical and cultural sites, the ancient urban water systems and the layout of the ancient city. The first group of Old City Conservation zones (25 zones with a total area of 1038 hectares) has been protected strictly in accordance with the Protection Plan approved by Beijing City in 2002. The



Figure 6. Plan of protection area in Beijing old city



Figure 7. Renovation of the Siheyuan(top) and the Tower wall (bottom) of Beijing old city

protection of the second group of Old City Conservation zones (5 zones occupying 249 hectares) concentrated efforts made between 2002 and 2008 recovered or restored Beijing's cultural relics in places named "two lines, five areas and six sites". The "two lines" refer to the Middle Axis Avenue and the Chaobu Road. The "Five Areas" refer to the Shishahai scenery area, the Imperial College ancient architecture area, the Azure Stone Workshop commercial area, the Forbidden City scenery area and the Bell Tower and Drum Tower ancient street area in the old city. With all these, Beijing old city will achieve a balanced distribution and distinct presentation of its famous history and traditional culture(Figure 6). Nowadays, according to the Beijing Municipal Administration of Cultural Heritage, there are over 3,000 "well-preserved" courtyards remaining in Beijing, and over 539 are in Cultural and Historical Conservation Areas (Figure 7).

### 3. THE PROJECT UNDERWAY

A project design of digital construction is implemented to rescue the available spatial data and make their exploitation. Finally, with the rapid development of computer graphics, distributed-computing and Internet, it is possible to achieve Internet-based virtual old city restoration. There are three phases to carry out the project, in present, the first phase is working to collect data and building a spatial information management system and the second phase is working to make

3D restoration of some architectural heritage. The main technological procedure and their benefits are discussed as below.

### 3.1 Data Preparation

The first phase of the project is the compilation of a digital framework for the whole area of the old city. This includes: the detailed recording of the 1950s situation, the creation of different layers of geometric information, each one of them contains the situation at various time periods, using all available information, e.g., topographic maps at a scale of 1:1000 and 2000, any other geometric data at appropriate scales, such as a sand table of Beijing old city at a scale of 1:1000, made use of wood in 1950s, existing aerial photos at a scale of 1:2000, street maps compiled in 1950s, urban plot maps, plans of specific monuments, etc. The utilization of the available large scale aerial photos plays an important role for the creation of integrated surveys, which represent the development of the old city in the area through time. Figure 8,9,10,11,12 show two topographic maps, ortho-image, mosaic aerial photo, sand table and street map of Beijing old city in 1950s respectively.

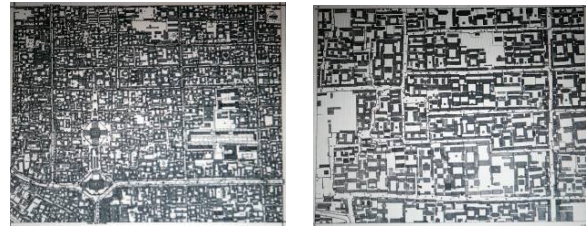


Figure 8. Topological maps surveyed in 1950s, (a) 1: 2000, (b) 1:1000



Figure 9. Ortho-image of Beijing old city in 1959



Figure 10. Mosaic aerial photo of Beijing old city in 1949



(a)



(b)

Figure 11. Sand table of Beijing old city, 1:1000, made use of wood in 1950s. (a) Courtyard housing, (b) Forbidden City

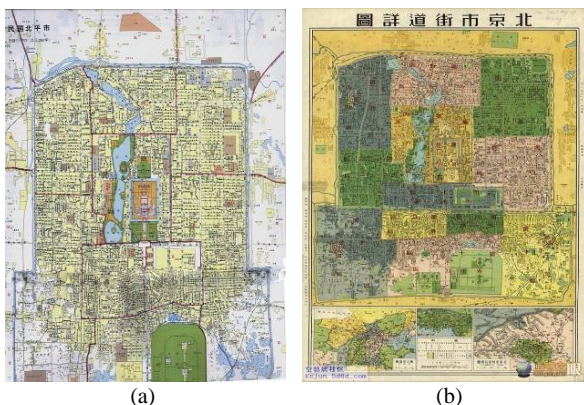


Figure 12. Street maps of Beijing old city compiled (a) in 1940s, (b) in 1950s

From those, combination of various data is used in order to provide a powerful tool for recording and monitoring the development in Beijing old city certain time. Further, a structured light scanning processing of that sand table and photogrammetric processing of that aerial photo will produce 3D geometric information about the architectures in the old city. This will include the city walls and their evolutions, the various traditional buildings with information about their heights and volumes. This document will be the basis for all subsequent actions towards part of the final goal of the project too.

### 3.2 Data Processing

Technological route of data processing is described as follow as below:

(1) Collecting multi-source and multi-type data: Scanning and digitizing topological maps of 1: 1000; scanning air photos of 1:2000; scanning the sand table of 1:000 using a structured light system to acquire 3D point cloud of the city walls and some historical architectures, and scanning some existing historical buildings using a terrestrial laser scanner(TLS) to acquire 3D point cloud of the architecture in large scene(Figure 13). Adopting different technique to acquire different type of historic spatial data, and meanwhile, take them to contract and correct for each other.

(2) Processing data: Transforming the scanning coordination of these data to unified Beijing local coordination system based on the topographic map in 1:1000, and then, making the geometry correction and joint respectively. The vector represents are archived with extracting 3D models from the point cloud data scanning the buildings(Figure 14) and scanning the sand table. Jointed and edited vector models will be enclosed the unified local coordinate system.



Figure13 TLS and Scanning

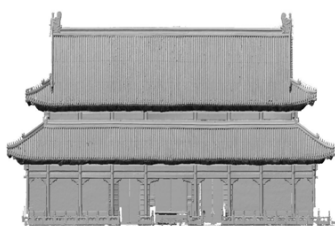


Figure 14. Simplified Triangle on the site Models of the Taihe Gate

(3) Organizing and managing data: A basic framework is organized using the topological map of 1: 1000 of 1950s, other data are embedded in the basic framework, including the vector models which scanning from the old city model. The 3D data and models are organized with multi-layer and tree structure to implement an effective visualization and management for large scene and details of the objects.

### 3.3 Spatial Information Management System

Basic spatial data frame and spatial data database, the qualitative (attributes) and their geometric characteristic, multimedia of Beijing old city are constructed using GIS software,database and integrated developing method to store, record, manage and utilize them. An interface and index of these digital documents are developed to search and display the historical spatial information and other related data of the old city using integrated technology. The linkage windows of two dimensional (2D) and 3D data in the interface are designed to display this main city walls and important histoic buidlings. The system's architecture allows the integration of additional geometric or other type of information, such as "time window" can be opened to show the spatial documents which are in different historical term of Beijing. Figure 15 shows a preliminary interface of the spatial information management system.

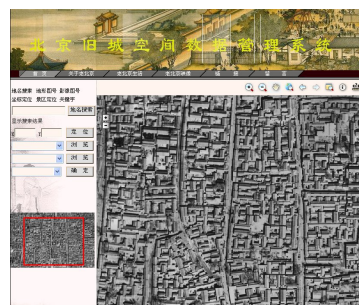


Figure 15. Preliminary interface of the spatial information management system

### 3.4 Animation and Visualization

The completion of this project will be achieved through the final phase, in which animations and virtual walk-through paths along selected routes are going to be produced. These works will be done after the finalization of the third phases of the project and it is scheduled that they will refer to the old city walls and part of the protected area mentioned above.

An application of 3D animations will be developed; all buildings will be presented in real time and the buildings of special interest will be represented in detail. In this task terrestrial images will be draped on the 3D models produced in previous phases. The level of detail on the 3D models will be such that would enable the users to perform their own actions. Finally, with the rapid development of computer graphics, distributed-computing and Internet, it is possible to achieve Internet-based virtual old city restoration.

## 4. CONCLUDING

During the recent years there was a significant development of the techniques and the methods used for the digital geometric documentation of Beijing old city and historical monuments; in

parallel, collection data techniques of the structured light instrument and terrestrial laser scanner, software for the management of spatial information, 3D data, virtual environments and the Internet is developed. These technique tools pushed the development of the restoration of the old city, and especially the detailed models of the historical city notes which were dismantled in various historic heritage cities using a lot of existing spatial documents.

Beijing Municipal Science & Technology Commission realized that the protection of that spatial information for Beijing old city is necessary, and the creation of such a spatial information management system; in cooperation with the Beijing University of Civil Engineering and Architecture, the design of a specific project is made and the execution of the first phases is implemented. During its application procedure, the results and the products of the created spatial information management system will be analyzed and criticized, together with the difficulties and the problems for the development of the system. This will lead to corrections and adjustments of the whole process for the integrated implementation in the whole area. Finally, some recommendations about the further improvements and the possible perspectives of the system will be given, for a possible use by Beijing public services and organizations as well as library of BUCEA.

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