Digital restoration and visualization of Nanfeng ancient city-focusing on cultural mining

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Abstract. Taking Nanfeng ancient city as an example, based on mining local culture, digital reconstruction of the ancient city is realized by using digital technologies such as remote sensing mapping, 3D modelling, geographic information and virtual reality and then a virtual platform for digital protection and exhibition of the ancient city is constructed. Firstly, the research sorted out the cultural connotation of the ancient city space from the three spatial levels including space, block and street pattern and then established the geospatial database. Using the key technologies of oblique photogrammetry, laser point cloud, 3D modelling and panoramic technology to restore and visualize the ancient city and then developing the virtual digital display platform which integrated the functions of digital model integration, route recommendation and customization, panoramic roaming and interaction. Finally, the platform was built. The idea and practice of combining cultural mining with digital construction can help to realize the protection and wide spread of Nanfeng ancient city culture and promote the sustainable inheritance of ancient city culture.

1. Introduction
Urban historical and cultural relics are not only the accumulation of the wisdom of the predecessors in production and life, but also an important symbol of highlighting urban connotation and highlighting regional characteristics. Due to the rapid development of urbanization, the natural landscape environment has been polluted, the historical and cultural landscape has been replaced, the urban spatial pattern has been destroyed, the city's regional features have gradually blurred[1] and the traditional style has gradually disappeared[2], making it difficult for the local context of the city to continue. Xi Jinping, General Secretary of the CPC Central Committee, Chinese President emphasized during an inspection tour in Shanghai in 2019: "We should properly handle the relationship between protection and development, and pay attention to the continuation of the historical context of the city"[3]. In 2015, the "Guidelines for the Protection of Cultural Relics and Historic Sites in China" issued by the State encourages the use of digital methods to display the missing cultural relics and historic sites. "12th Five-Year plan" proposed the use of modern information technology to build the national cultural relics resources database, cultural relics preventive protection information platform, and promote the digital museum project[4]. Using digital technology to display the traditional features of the ancient city and inherit the local cultural heritage has become the main trend of ancient city protection, which has been widely concerned by governments and social organizations at all levels.

In recent years, with the rapid development of 3D surveying and mapping, information management
and virtual reality technology, more and more researches have been conducted on the use of digital technology to realize the protection of historical and cultural heritage and historical and cultural cities. In 1994, the United States launched the "American Memory" project[5] and successively launched "Digital Michelangelo"[6], "Rome Regeneration"[7-8], and "Florida Memory"[9]. In 2007, Japan developed the Virtual Kyoto project[10], creating 3D virtual models of Kyoto in Japan in different periods, showing the evolution of the urban landscape of Kyoto. In 2009, Maya3D, the international interdisciplinary project, took the ancient city of Kopan Maya as the research object and used 3D GIS technology to establish a 3D visualization network information system, QueryArch3D[11]. My country's use of digital technology to protect cultural heritage can be traced back to the 1980s and 1990s, and has successively completed many famous digital projects such as Digital Palace Museum[12], Virtual Dunhuang[13], Virtual Yuanming Garden[14]. On the digitization of ancient cities and other traditional settlements, Tang Man et al. used Maya modeling software to complete the digital restoration and reconstruction of the ancient city of Nanyang with the help of the historical maps[15]. Wan Fei et al. used 3D laser technology and virtual reality technology to reconstruct the Historical Architecture of Ancient Post Road in South Guangdong[16]. Judging from existing research, mature digital technologies such as 3D modeling, VR and AR have been widely used in the protection of cultural monuments and ancient cities, providing important support for the recording and preservation of spatial data of ancient cities, the showing and dissemination of local culture. However, in the process of digitization of the ancient city, there is a lack of research on how to deeply excavate and highlight the local context of the ancient city which has an irreversible impact on the protection of cultural heritage and the continuation of local context.

Taking Nanfeng ancient city as an example, based on the collection of local historical documents and field survey and mapping, this study deeply mined the historical information and local culture, builds the cultural geospatial database and constructed a virtual display platform with cultural connotation and interaction by using digital collection, storage, virtual restoration and roaming to promote the protection and inheritance of the local culture.

2. Case Area

Nanfeng County is located in the south of Fuzhou City, Jiangxi Province, on the alluvial plain of the Fuhe River Basin. It is adjacent to Lichuan and Jianning in the east, Yihuang and Ningdu in the west, Guangchang in the south, and Nancheng in the north (figure 1). Nanfeng County is located between Wuyi Mountain and Yu Mountain. Xu River passes through it, forming a pattern of "two mountains and one water". For a long period, Nanfeng has nurtured the millennium ancient city-- Nanfeng ancient city, the millennium tribute-- Nanfeng tangerine, the millennium intangible cultural heritage-- Nanfeng Nuo dance, the millennium talented person-- Zeng Gong, the millennium ancient kiln-- Baishe kiln. This "five-millennium culture" has become the most famous cultural card of Nanfeng, Nanfeng is also known as "the world orange capital, China's Nuo Township, leisure Nanfeng, Zeng Gong's hometown ". 
The ancient city of Nanfeng is located in Qincheng Town in the east of Nanfeng County. It began in the Three Kingdoms, addressed in the Tang Dynasty, built in the Song Dynasty, upgraded to the Yuan Dynasty, finalized in the Ming Dynasty, and flourished to the Qing Dynasty[17]. The ancient city has remained unchanged for more than a thousand years since it was addressed in the Tang Dynasty. It is a representative county-level historical city in the Fuhe River Basin and even in Jiangxi Province. The city has retained a complete historical pattern, with numerous and concentrated historical and cultural relics, clear street texture and prominent regional cultural characteristics of Linchuan. In 2018, it was selected as a provincial historical and cultural city in Jiangxi Province.

3. Historical and cultural excavation of the ancient city

3.1. Spatial pattern

Studying the formation process of ancient city patterns is an important means to restore historical features, display historical background and explore ancient city culture[18]. In the annals of Nanfeng County during the reign of Tongzhi wrote: "Nanfeng, straddling mountains and pillow valleys, facing the river on three sides, high and clear, grand and deep, for a long time to build governance"[19]. The ancient city is close to Junfeng mountain in the West and surrounded by Xujiang River from west to east, which makes Nanfeng form a landscape pattern of "mountain surrounding water". The ancient city is surrounded by water on three sides, and the terrain in the west is high, which is conducive to military defense. It is a natural defense system. In the late Song Dynasty, residents built earthen cities and opened five gates to resist roving bandits, gradually forming an artificial defense system. In Ming Dynasty, in order to consolidate the city, Nanfeng ancient city expanded the stone city and opened four gates. In order to strengthen the defense, the urn door was built. In order to divide water, the upper and lower water gates were built. So far, the scale of Nanfeng ancient city has been formed and has not changed. The city wall is built along the Xujiang River, and the ancient city presents a typical "water-holding city" morphology. The northwest is wide and round, and the southeast is straight, resembling a Guqin, so it is also called "Qin City". The site selection and construction of the ancient city conform to the terrain and the boundary form is free, fully following the construction concept of traditional Chinese
cities in accordance with local conditions. Today, the ancient city continues the pattern of the Ming and Qing Dynasties. The street structure, architectural layout, underground ditches and other city sites are clear and well preserved, which can provide an important basis for the virtual restoration of Nanfeng ancient city. Based on this, this research used remote sensing, oblique photography and other technologies to realize the collection of basic 3D geographic information of Nanfeng ancient city and established the basic framework of Nanfeng ancient city restoration.

3.2. Cultural District

The historical and cultural blocks not only witness the development of the town, but also carry the common memory of the residents, with a strong regional character. The formation of "cross road" in the late Southern Song Dynasty divided the ancient city into four corners and nine squares, supporting the basic cultural framework of the ancient city. Since its evolution, the ancient city of Nanfeng has left four core historical and cultural blocks (figure 2). Among them, Xujiang East Road historical and cultural block is a prosperous wharf economic zone in the past dynasties, and many modern commercial and financial institutions were also located here. It is a typical representative of Nanfeng civil culture, and now there are many shops built in the Republic of China. Xujiang West Road historical and cultural block integrates functional spaces such as religious sacrifices and official culture. It is an important carrier for studying the architectural history of Ming, Qing and the Republic of China. The well-preserved Shouchang Temple, Qiuyu Masters and Peng's Courtyard are the Jiangxi provincial cultural relic protection units. Wangxianqiao historical and cultural block is a typical religious concentrated area, where various religious and cultural buildings coexist and develop, reflecting the cultural characteristics of "tolerance, diversity and openness". Wenchang palace and Catholic Church are still alive at present. Panguifang historical and cultural block, which has always advocated culture and education, has produced a large number of imperial examination talents from the Tang and Song dynasties. Many cultural buildings have been left behind. The existing various archways and inscriptions reveal a strong culture of kegong and official culture.

The four historical and cultural blocks show four vivid historical contexts, reconstruct the overall historical and cultural features of Nanfeng ancient city, with distinctive characteristics and rich cultural connotation. In 2018, they were all rated as historical and cultural blocks in Jiangxi Province. Therefore, the digital protection of Nanfeng ancient city needs to represent the civil life, religious rituals, folk customs and other characteristics of culture through a three-dimensional perspective. Based on using Sketchup software to realize the virtual restoration of the ancient city, this study integrated panoramic development technology to obtain the digital landscape of local culture, and provided a personalized virtual roaming route, to show the diversified local culture of Nanfeng more truly.

Figure 2. Historical and cultural blocks map
3.3. Street name

The streets and lanes of Nanfeng ancient city are composed of main streets and secondary lanes, which are strictly regulated. There is a local saying that "nine wells and eighteen lanes lead to the streets". Nanfeng County government completed the last migration in the Tang Dynasty. At the same time as the city outline construction, the street pattern gradually improved and became clear. Figure 3 shows the generation of streets in each dynasty. In the Tang Dynasty, streets and lanes began to be built. The basic pattern of "Cross Road" was formed in Song Dynasty. The scale of streets and lanes was further expanded in the Ming Dynasty. The number of branch lanes increased in the Qing Dynasty and the main roads of "Cross Road" were expanded during the Republic of China. Today, the streets and lanes continue the trend and spatial scale of the Ming and Qing Dynasties, and are well preserved.

![Figure 3. Evolution of streets and alleys](image)

The streets and lanes of Nanfeng Ancient City have local characteristics (table 1). The names of most streets and lanes are determined by the surnames of the residents of the streets, such as Xiaojiaxiang, Gaojiaxiang and Yangjiaxiang. Through these toponymic data, we can inquire about the people, time and place of the building, infer the original age of the building, and take this as an important supplement to restore the ancient city and comb the map of the relationship between historical figures and events. Secondly, the names of the streets and lanes of the ancient city also represent the characteristics of the streets or the atmosphere of the city. For example, Zhizhong lane and Jiaojiao lane are determined by the shape of lanes, while Douzi lane and Huaxin Lane vividly express the atmosphere of the market named by the common people. In addition, the names of the streets and lanes of the ancient city also express the ruling class's expectations of political morality, such as Gaofeng lane and daytime brocade lane. They praise the good qualities of noble character and sterling integrity and also commemorate the stories of local historical celebrities. This research uses digital models to integrate spatial elements, deduce the stories behind the streets, interpret historical and cultural information, to inherit Nanfeng millennium place name culture.

| Place Name Type          | Quantity | Proportion (%) | Example       |
|-------------------------|----------|----------------|---------------|
| Local characteristics   | 8        | 10.8           | Zhuanjiao Lane|
| Geographical position   | 8        | 10.8           | Heliang Gate  |
| Building facilities     | 8        | 10.8           | Gao's Well    |
| Imperial examinations   | 2        | 2.7            | Kegong Lane   |
4. Platform design and development

4.1. Demand analysis
The platform combines digital technology with historical culture closely, and is committed to making tourists, scholars and other audiences more fully understand the special spatial pattern, rich cultural environment and unique historical context of Nanfeng ancient city. It provides more intuitive visual and auditory feelings, increases the sense of experience and immersion, and expands the research methods of the historical geography of the historical and cultural cities. It also provides support for the construction and renewal of cultural relics, cultural excavation and publicity of ancient cities.

4.2. Overall architecture
The overall design of the platform includes four layers: support layer, data layer, service layer and function layer, as shown in figure 4. The support layer is composed of software and hardware. The basic digital data of Nanfeng ancient city is obtained based on hardware equipment, and the data preprocessing, panoramic generation and model construction are realized by software. The data layer includes text, photo, panoramic data, 3D model and other basic data. The service layer can access various data services published through interfaces. The functional layer implements multiple functions such as roaming in the ancient city and route customization by calling services.

![Virtual Nanfeng Ancient City](image)

Figure 4. The general architecture of the platform
4.3. Key technologies

4.3.1. Oblique photogrammetry
The SHARE-200S oblique camera is used to collect images from one vertical and four tilt angles. After a series of calculations such as geometric correction, point cloud data is obtained. Through thinning, a continuous irregular triangulation network (TIN) is constructed. Combined with the high-precision images taken by Unmanned aerial vehicle (UAV), a high-resolution 3D oblique photography model based on real image texture is generated[20]. The production and release process of the oblique photographic model is shown in figure 5. According to the existing city gates, walls and streets of the ancient city, the speculative restoration is carried out, and then the outline of the ancient city pool is gradually determined according to the literature records, residents' descriptions and experts' research, so as to determine the ancient city with an area of nearly 5500 square meters, and establish a high-precision large scene three-dimensional model with a spatial resolution of 3cm to support the macro scale observation of Nanfeng ancient city.

4.3.2. 3D modeling based on laser point cloud scanning
3D laser scanning can measure without touching objects, with high accuracy and high speed[21]. It can complement oblique photogrammetry and truly reflect the texture information of ancient buildings. After a thorough investigation of Nanfeng's historic sites, it was decided to select the provincial cultural preservation units and religious buildings in Nanfeng Ancient City for 3D laser scanning, including the west gate, south gate, ancient city wall, Qiuyu masters, Peng's courtyard, the upper and lower water gates, Ksitigarbha bodhisattva temple have obtained the fine architectural model of the ancient city, which provides measurable, analyzable and integrable data support for the 3D virtual display and refined management of the ancient city[22]. The workflow is shown in figure 6.
4.3.3. Ancient city restoration based on Sketchup

Sketchup is a software tool for quick start and rapid construction of 3D models, which meets the needs of ancient city restoration. Based on relevant historical materials and field survey data, the virtual restoration of the original appearance of the ancient city is carried out by using the software. The flow is shown in figure 7. According to this process, the ancient city wall is modeled, and the functional building group (Academy and County Department) and ordinary residential buildings are also reconstructed. Then, the model is loaded into 3dsmax for baking, and the unit 3D is used to construct a large-scale geographical scene of Nanfeng ancient city, restore the typical scene of the block, continue to write the street name story, reproduce the prosperous east gate wharf, Quqian academy full of sound of reading, Shouchang temple with many worshippers, Peng’s courtyard with carved beams and painted rafters, showing different types of cultural charm and continue the local culture.
4.3.4. Panorama development
Panoramic photos show the scene image information in all directions, which is real and fast, and the effect is better when combined with VR equipment. The panoramic production and development process is shown in figure 8. In addition to photographing more than 40 historical scenes such as buildings and streets, the Nanfeng Museum and Nuo Mask Exhibition Hall are also used for panoramic data collection to form two online panoramic exhibition halls.

Figure 8. Panoramic production and development process

4.4. Main function

4.4.1. Digital ancient city model integration
The emergence of digital models has created conditions for the expression of spatial information in the historical environment of the ancient city[23]. The key objects of digital restoration of Nanfeng ancient city are unique spatial pattern, diversified historical blocks and ancient street names. For this reason, using oblique photography, digital restoration and laser scanning technology to make various models. figure 9(a) shows the real high-definition geographic scene, which is an important basic data for spatial analysis and urban planning. figure 9(b) presents the characteristics of the architectural heritage of the historic district from multiple angles with high precision. figure 9(c) restores the old spatial structure of the ancient city, showing the cross road and the framework of the Pisces frame.

Figure 9. Model display

4.4.2. Route recommendation and customization
The traditional form of ancient buildings in the Ming and Qing Dynasties, the city ruins that witnessed
history and the rich local folk customs are Nanfeng’s precious cultural tourism resources. Integrating the tourism resources of the four historical and cultural districts from the three perspectives of point, line and surface, gradually planning the routes of specialty food, ancient buildings and religious culture, and drawing the cultural and tourism map (figure 10). Users can customize the tour route in the system model according to their preferences.

Figure 10. Travel route recommendation

4.4.3. Panoramic roaming and interaction

The system integrates panoramic photos of more than forty important architectural heritages, providing multiple perspectives, such as fish-eye perspective, stereo perspective, architectural perspective, asteroid perspective and other diversified display scenes. As shown in Figure 11, with the help of a virtual helmet, virtual glasses or smart gloves, users can simulate the "push, pull, and pan" of the camera to view the buildings at any angle by means of touch, dialogue and somatosensory[24], switch the jump scene, enter the internal space to view the building details and the street history. The system also adds audio content such as character stories, architectural meanings that users can experience the historical environment immersively.

5. Conclusion

The construction of a virtual ancient city platform based on ancient city culture realizes the reproduction of the ancient city’s historical features and the interaction between human and urban space, integrating multi-angle high-precision dynamic models, changing the way the public participates in the experience of Nanfeng's ancient city culture and realizes the best visualization of the local cultural exhibition of the ancient city. Based on this platform, it can assist in mining the temporal and spatial evolution process and landscape information characteristics of the ancient city, and can also carry out the protection and planning of historical and cultural blocks, expanding the depth of the application of the virtual platform of Nanfeng ancient city, providing decision-making basis for the protection and renewal of the ancient city, and providing a reference for the protection research of other ancient cities.

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