Integrating GIS, BIM and social/cultural phenomena data: an experimental database for the Wuxi Shrines Cultural Landscape heritage

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Abstract: The Cultural Landscape of Shrines Around Huishan Mountain of Wuxi (Taihu Lake) integrates architecture, gardens, natural settings as well as the attached abundant historical, cultural and social backgrounds and continuous community life. This paper presents the framework of a geographical information system (GIS) database using CityGML to organize heritage information. Physical properties including courtyards, buildings, inner landscape features, environmental settings and other relevant landscapes or urban features are depicted through 3D objects. While intangible social/cultural phenomena are recorded with temporal scale and multimedia description as attributes of spatial elements. For the physical parts, details of physical constructions are organized in a separate building information management (BIM) system and import the records into the main GIS database through data transfer tools. Other than simply recording physical and social/cultural phenomena of the cultural landscape heritage, the propose database will also support the future cultural landscape investigation and management in broader contexts.

Key words: Cultural Landscape, GIS, history, community, CityGML

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1 INTRODUCTION

The Cultural Landscape of Shrines Around Huishan Mountain of Wuxi (Taihu Lake) integrates natural landscapes with more than 100 shrines dated from the middle age of China. It was built in a complex context constructed by hills, river networks, lakes, farmlands, urban areas (Fig. 1), and one of the significant regional landscape element as well as national-range

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cultural route, the Grand Canal. The cultural landscape had been nominated to the newest revision of the World Heritage Tentative List of China. The application had been evaluated by the professional committee and the result shall be announced soon.

Fig. 1 The hillside connects to the shrines near the center of the core area of the landscape cultural (UAV aerial photo courtesy of Prof. LI Zhe)

The proposed protection boundary of the cultural landscape area is up to 57.4 hectares and the buffer zone is 2138.4 hectares (Cultural and Natural Heritage Research Institute of Nanjing University, 2012). The physical landscape is composed by the entire Huishan Mountain, east side of Xishan Mountain, and the historical town of three main historical streets which includes one river street (Fig. 2). Property of the comprehensive cultural landscape integrates architecture, gardens, natural settings as well as the attached cultural backgrounds of the constructions and landscapes, such as history and traditions of families or clans, stories and myths of scholars, celebrities, heroes and immortals, ritual or traditional activities, educational programmes, religions, tea and wine culture, music, and so on.

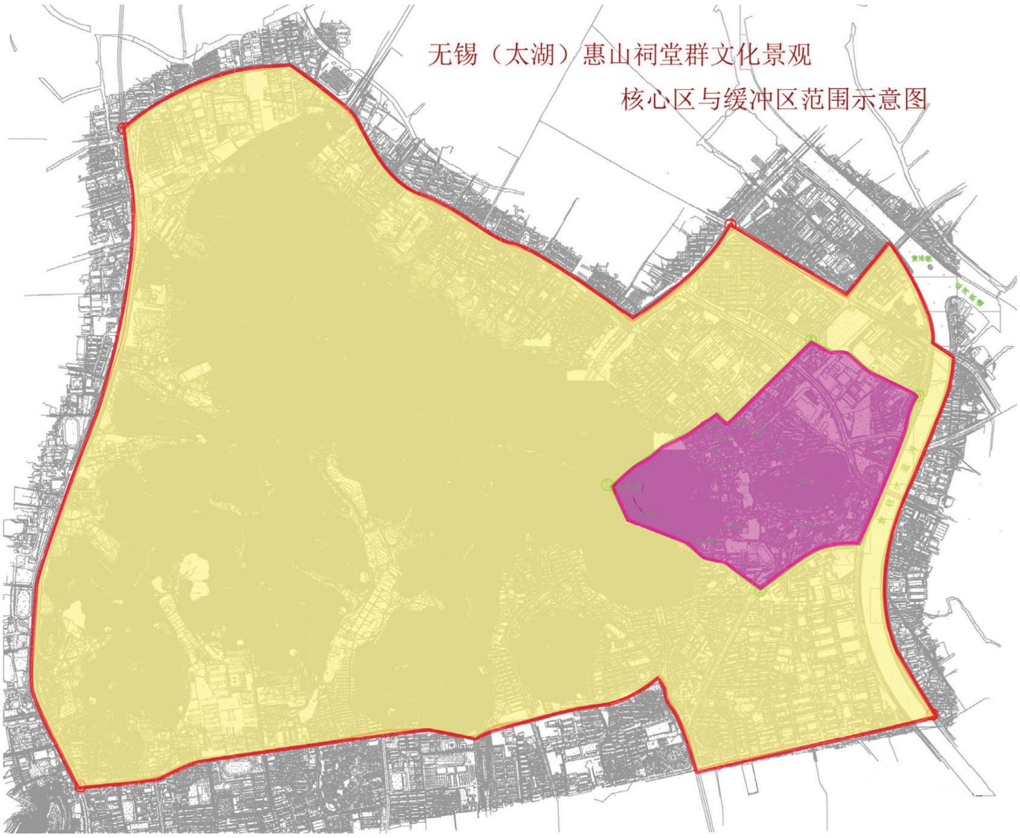

Fig. 2 Planned boundary of the cultural landscape area (in purple) and the buffer zone (in yellow) (from Cultural and Natural Heritage Research Institute of Nanjing University (2012), p.10)

In order to prepare the World Heritage Site application in the near future, the local government is launching a five-year research program including site surveying, historic, social and architectural analyses, conservation planning, and heritage management. The authors' research team is in-charging the fundamental data acquisition and preparing primary outstanding universal value (OUV) assessment for the heritages. In order to organize the collected data for better supporting to the OUV evaluation and other further heritage research, planning and management, the research team is proposing a database based on geographic information system (GIS).

2 METHODOLOGY

The proposed database intends to use GIS organizing physical and intangible heritage data, and integrate an extra building information management (BIM) system for detailed construction data management. All heritage information, including physical and intangible properties is basically recorded either as or affiliating to 3D spatial objects. For the physical parts, surveying and recording data and details of physical constructions will be organized in BIM for study and management convenience. Methodology of constructing the proposed database includes data acquisition, database architecture, temporal and of intangible records, and BIM integration.

2.1 Data Acquisition

Since the heritage site of the cultural landscape is too large and composed by multiple kinds of properties, detailed site surveying and data acquisition is planned to last for 3 to 4 years, especially the on-site surveying and monitoring works. Data proposed to be collected includes historical records, maps, physical architectural recording, and social surveying indicated in Table 1.

Table 1 Heritage data to be collected

Name	Contents	Temporal Scale	Source	Digital / Spatial Format	Dimensions
City maps	Recent topography and land use maps of the city	About recent 10 years	City government bureaus	Vector and geo-referenced	2D or 2.5D
Historical maps	Topographical or land use maps in either cartography or mental drawings	From several hundreds years before to modern time	City government, national surveying archives, overseas historical archives (Japan & US), local historical archives, family archives, etc.	None Need to be digitized and rectified	2D
Aerial photos	Aerial and satellite photos	From WW2 to current	City government and Surveying Bureau, overseas archives (US & Japan), commercial satellite image distribution services, etc.	Partly digitized and rectified	2D
Historical images	Historical photos or images besides aerial photography	From several hundreds years before to modern time	City government, local historical archives, family archives, etc.	None Spatial reference may be add after investigation	--
Architecture survey and recording	Details of every building and landscape architecture feature	Have historical records. Future investigation needed	Site surveying, measurement and recording	Vector and partly geo-referenced	2.5D & 3D
Governmental archives	History of property changes, ownership, economical data, biography, government statistics, etc.	After PRC	Government bureaus, publications, libraries	--	--
Family archives	Comprehensive history of heritages and contexts	Hundreds to more than a thousand years	Personal or community collections, publications, libraries	--	--
Other local historical archives	Records from former county annual, government archives and other resources	From several hundreds years before to ROC	Libraries, local archive collections, publications	--	--
Landscape resource records	Data of environment, ecology, climate, etc.	From 1950s, but details may only available in	Environmental Protection Bureau, Forestry Bureau, Hydrology Bureau,	Partly digital and geo-referenced.	2D & 3D

		recent 10~20 years	Agriculture Bureau, etc.	Others can be digitized.	
Environmental surveying and monitoring	Climate, pollution, erosion, etc.	The coming future	New installation on site	Digital and geo-referenced	2D & 3D

The architectural survey and recording organized by the Key Scientific Research Base of Historic Building Survey and Recording of State Administration of Cultural Heritage and School of Architecture of Tianjin University, in which the research team affiliated, has been initiated this summer. The site surveying began with two sites listed as Major Historical and Cultural Site Protected at the National Level, the Jichang Garden and the Shrine of the Dutiful Son of Hua Family. Site works introduced traditional manual measurement on building constructions, positioning through total station and GPS, as well as high-tech approaches such as photogrammetry by unmanned aerial vehicle (UAV) and ground-based laser scanning for data collection and virtual measuring in 3D digital models. The first round of data release, which includes more than 200 sheets of digital 2D architecture drawings in scales from 1:50 to 1:20 (a few detail drawings in 1:5 to 1:1), is planned to be on late October. Then the next step will be 3D modeling and BIM construction for several key heritage properties of these two courtyards, for example, the Main Hall of the Shrine constructed in 1485 A.D., which has very unique structure characteristics and typical construction style of Ming Dynasty. Detailed architectural measurement for the rest properties of the heritage site, overall site plan, as well as landscape and ecological surveying of the whole cultural landscape will be conducted in the following years.

2.2 Database Architecture

The proposed main database will be based on City Geography Markup Language (CityGML) approach and use 3D objects in lower levels of detail (LOD) in GIS system as basic unit of abstracted heritage properties. Higher LOD models will be imported from BIM data. Organization of physical heritage properties and LOD level can be found in more detail in section 3.1.

2.3 Attribute Date for Temporal and Social/Cultural Expressions

Since the proposed database is designed for heritage records, it has to take temporal and intangible phenomena into great consideration. To take advantage of the XML-based CityGML encoding approach in this GIS system, attribute table will be used to determine non-spatial features associated to the models. History and social/cultural phenomena will be recorded separately and indexed to the heritage properties or historical buildings of LOD 0 to 2 in order to achieve efficient management. Attributes of property’s historical development will be recorded in a metadata format illustrated in Fig. 3 to show the major events throughout the property’s construction history. Social and cultural background of spatial properties will be organized in similar structure, but arranged by activities instead of events.

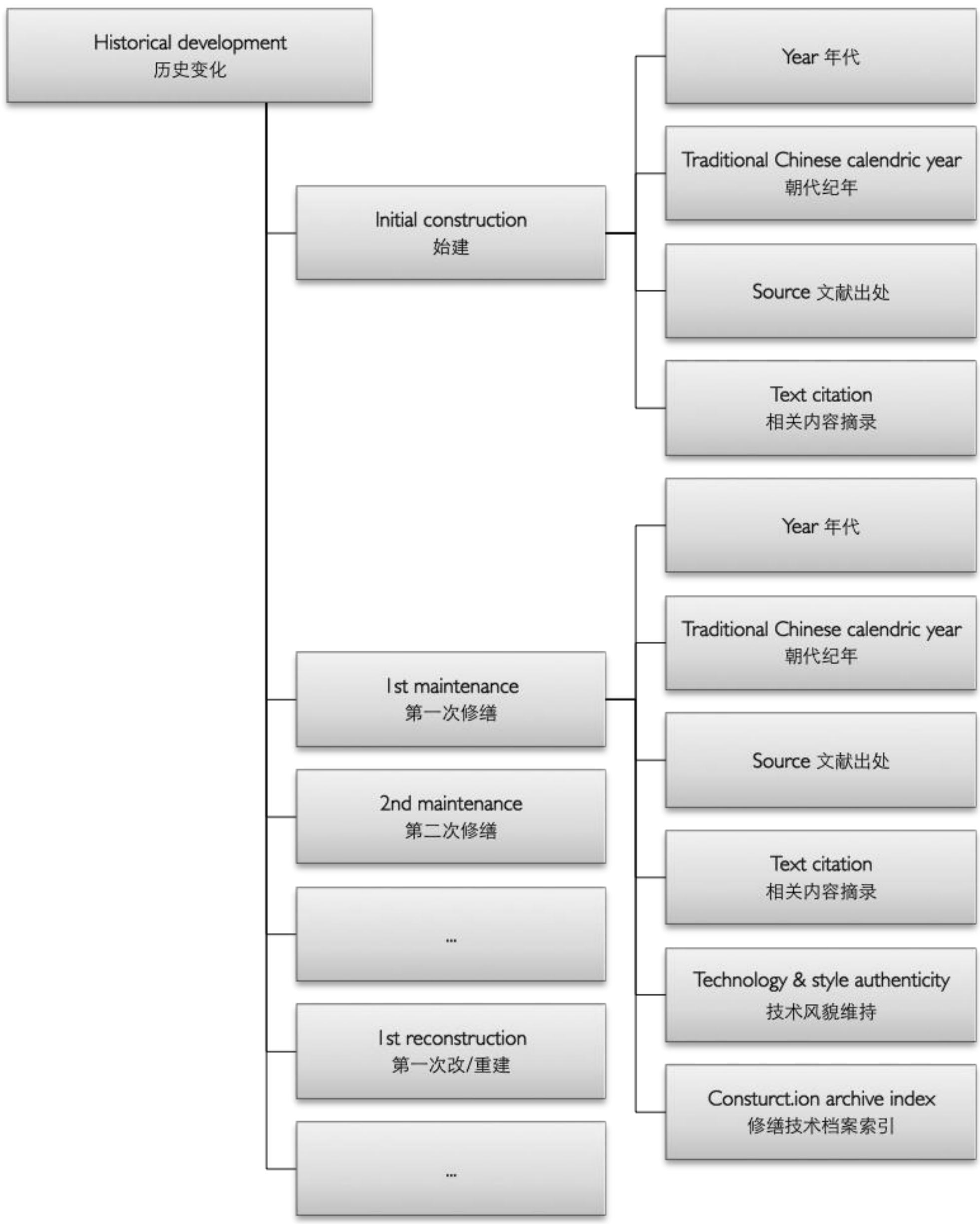

Fig. 3 Metadata structure of the historical development temporal data of a typical historical building

2.4 BIM Integration

Although smooth integration of BIM and GIS is still under development (Laat and Berlo, 2011), but CityGML does has advantages for importing BIM data in industry foundation classes (IFC) format (Istkdag and Zlatanova, 2009; Laat and Berlo, 2011). The research team follows our former experience (Wu et al, 2011) to proposed a BIM for comprehensive heritage preservation including surveying, data recording, research, management and visualization operated on AutoCAD Revit software platform. For integrating with the main database, the BIM data will be imported directly to CityGML models or transferred through IFC and then convert to CityGML. Among the imported data, construction details from the separate BIM system are mainly illustrated in LOD3 and a few in LOD4, while GIS is generally dealing CityGML models in LOD 0 to 2, mostly in LOD 0 to 1 (see Fig. 4).

3 THE DATABASE

Main content of the proposed database will integrate GIS and BIM to organized 3D buildings, urban and landscapes with attributed social and cultural phenomena, in order to recording the cultural landscape heritage comprehensively and profoundly for heritage management and further applications.

3.1 Structure of Physical Property Organization

As mentioned in the section 2.2, physical properties, including courtyards, buildings, inner landscape features, environmental settings and other relevant landscapes or urban features, are basic 3D spatial units of the proposed system. According to the LOD format of CityGML models, objects standing for heritage properties will be organized hierarchically to reflect different levels of building and landscape, and then modeled in different LOD. These spatial elements are organization by categories and other attributes as the format illustrated in Fig. 4.

- LOD0: Besides traditional LOD0 categories like the natural landscapes, environmental settings, and so on, heritage property unit defined by an enclosed spatial boundary, such as courtyard, garden, or group of buildings, will be depicted in this level. Format of these units will be polygons draped on the DEM.
- LOD1: The minimum property unit will be limited to individual building constructed in LOD1 scale in this project.
- LOD2: A few significant buildings, all trees and environment features, and other landscape architecture elements will be depicted in LOD2 since it is necessary to be recorded and illustrated in detail. Special styles and shapes of buildings, and textures of landscapes features will be recorded in LOD2 models. Accuracy of

details of LOD2 models may even finer than the typical suggested 2/2 meters by the CityGML standard (OGC, 2007).

- LOD3 and LOD4: More detailed elements, such as structural elements of ancient wooden buildings, will be managed in BIM and transferred into LOD3 or LOD4 levels.

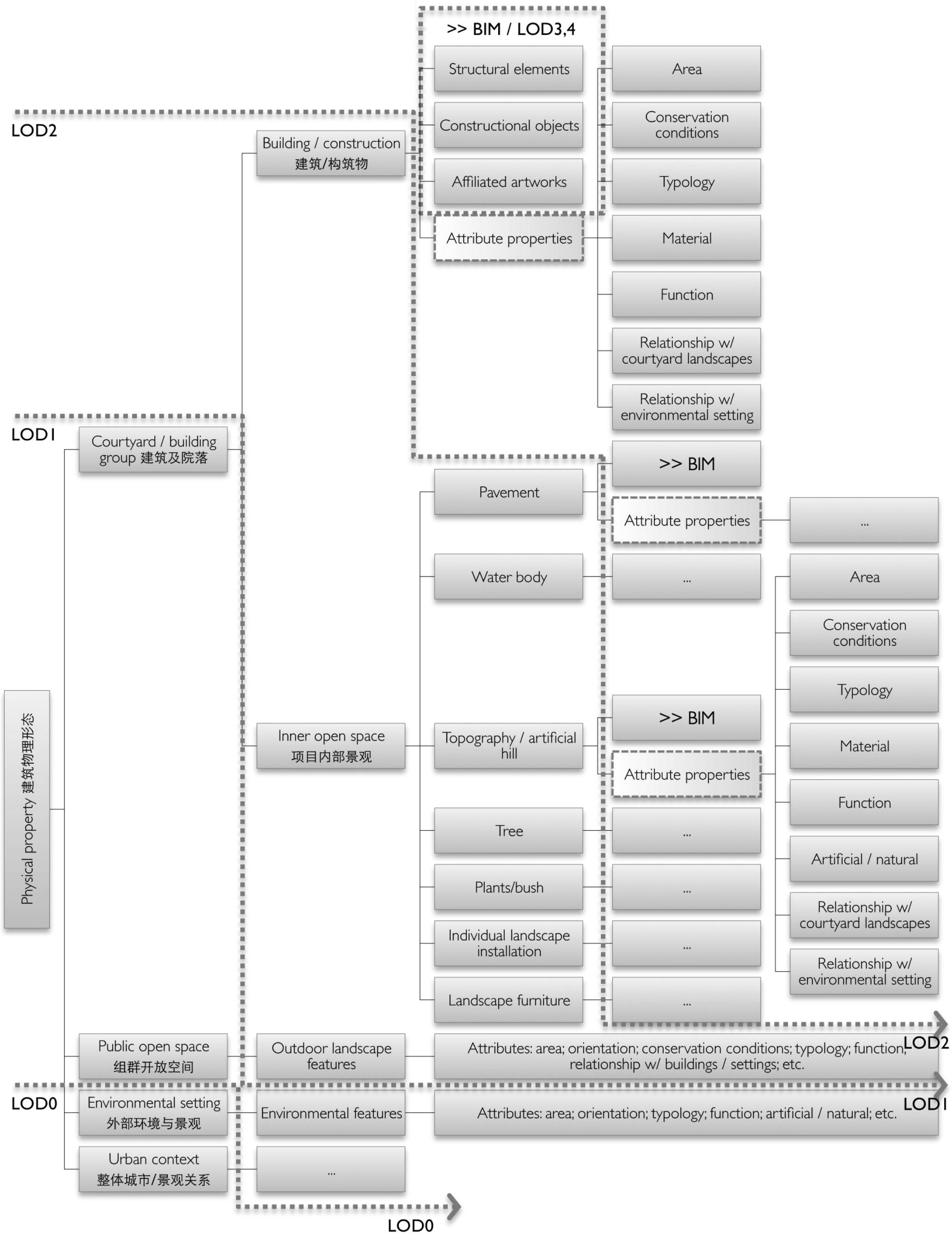

Fig. 4 Metadata structure and LOD of the physical property data organization

3.2 Attribute Data of Intangible Phenomena

Intangible phenomena like social and cultural background are very important characteristics of this cultural landscape heritage. Method of depicting these phenomena, as mentioned in the above sections, is introducing attribute table to describe activities affiliated to the 3D spatial features. The major attributes associated to the properties' physical existence are categories, descriptions, temporal changes, environmental behaviors, continuity and sustainability, multimedia records, etc. of the following types of activities or phenomena:

- Property ownership shift, including time and ownership, especially during the most recent renovation of the Huishan Historical Town.
- Functionalities of the heritage properties, either individual building or any shrine or building group. The database will record its initial functions, such as memorial of ancestors or certain celebrity, and the following changes in functions. For example, some shrine was confiscated by the government after PRC and switched to public facilities, but has been recovered to its original shrine function in recent renovation in 2000s.
- Ritual or cultural activities affiliated to physical properties. In some cases, using of spaces in those activities, such as route of procession, will be depicted into line or point features in GIS.
- Property as social/cultural contexts. Some heritage property also serves as a physical base of the social/cultural phenomenon beyond its original functions. For example, the World Second Best Spring in this cultural landscape is not only a simple landscape features itself, but also works as a cultural icon of a significant local historical event, the visits of Emperor Qianlong, as well as one of the most famous Chinese folk musical work, *the Moon Reflected on the Er-quan Spring* and its musician, the local cultural celebrity A'bing.

4 DATABASE APPLICATION

The proposed database is design for basic data collection and management. It will also directly serve as the analytical base of in-depth and multidisciplinary studies on the cultural landscape OUV. Studies on building and structure levels will depend on the BIM data. While the historical interpretation and spatial phenomena will be investigated base on the spatial and attribute data. In addition, since the potential of 3D supporting by CityGML format, visualization will be emphasized on the further add-on functionalities which has been planned to be realized through separate modular. A virtual geographic environment (VGE) will be the next development base on the proposed database. The virtual 3D digital heritage environment can serve heritage and tourism management, monitoring and protection through its innovative comprehensive information platform. The same platform can also assist the community on data query, self or voluntarily information development, public participation on heritage protection and urban planning, or even establishing a virtual community for the families affiliated to the shrines and the original residents in the cultural landscape.

Significances of propose database and GIS-based system will be shown on the following three aspects. Firstly, through this database, the cultural heritage can be investigated in broader contexts. This is critical for this specific cultural landscape case since it is a typical historical urban and social-economical development example in Yangzi River Delta as well as a significant knot along the Grand Canal. Secondly, the social and cultural phenomena associated to the cultural landscape make it a “place” for the community who are sustaining the cultural landscape along the history. Not only will the static phenomena be revealed and illustrated in a clear format, but also through a well-organized database and other digital tools, the heritage can be revitalized into community life, such as facilitating a 3D virtual community, promoting public participation during conservation planning, etc.. In addition, the propose database on CityGML is preparing information to cooperate with future digital information engineering in broader range, such as digital city construction of Wuxi, and digital heritage preservation for the Grand Canal.

5 CONCLUSION AND DISCUSSION

Since this heritage project is still under preparation stage and not yet actually start, its database design is only in a proposal level. In this paper, we can only present the basic idea of the database architecture and data characteristics. However, by the efforts of the research team in the following years, the propose system shall become an important experiment on digital cultural heritages.

Integrating spatial element with BIM and social/cultural data are two key strategies of the database. CityGML does provide more feasibility on 3D GIS and BIM integration. Its potential in 3D visualization is also more suitable for enhancing the capability of heritage protection. However, comparing to traditional GIS database, to achieve CityGML requires much more resources and efforts in database construction. Furthermore, coupling CityGML with existing urban CAD or GIS data, or digital city system may have difficulties. On the other hand, for the World Heritage management and protection planning, 2D polygon representing a heritage scope is a traditional format. 2D to 3D data transition technology and methodology of using CityGML in heritage database will be further investigated.

Moreover, the associated intangible social and cultural phenomena, which make the cultural heritage still alive, are very precious for the cultural landscape’s OUV. Not only will the static records be input as attribute data, but also the propose database and spatial information platform shall support dynamic and interactive data management and presentation. This flexibility will be the major concern of our further research. Currently some of the social/cultural phenomena are able to be concluded into 3D spatial feature, as described on section 3.2, not just only attribute characteristics. These data may conflicts with the 3D objects describing the properties. Detailed methodology for differentiating the spatial elements has to be explored.

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REFERENCES

Cultural and Natural Heritage Research Institute of Nanjing University (南京大学文化与自然遗产研究所) 2012. 无锡（太湖）惠山祠堂群文化景观（《中国世界文化遗产预备名单》申报文本). 无锡: 无锡市人民政府.

Isikdag U, and Zlatanova S. 2009. Towards Defining a Framework for Automatic Generation of Buildings in CityGML Using Building Information Models. In Lee J, Zlatanova S, Cartwright W, Gartner G, Meng L, and Peterson M P (eds). 3D Geo-Information Sciences. Berlin and Heidelberg: Springer: 79–96.

Laat R, and Berlo L. 2011. Integration of BIM and GIS: the development of the CityGML GeoBIM extension. In Kolbe T S, König G, Nagel C, Cartwright W, Gartner G, Meng L, and Peterson M P (eds). Advances in 3D Geo-Information Sciences. Berlin and Heidelberg: Springer: 211–225.

Open Geospatial Consortium, Inc. (OGC). 2007. Candidate OpenGIS® CityGML Implementation Specification. OGC 07-062. Open Geospatial Consortium Inc. http://portal.opengeospatial.org/files/?artifact_id=22120&passcode=hfbq2pa6eprrnh9jbyzp.

Wu C, Wu S, Liu F, He X, and Gu J. 2011. Application of BIM on Angkor Monuments: a case study on documentation and research of the South Outer Gopura in Ta Keo Temple, Angkor Monuments. East Asian Architectural Culture International Conference (EAAC 2011). Singapore: National University of Singapore.