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RESEARCH ON HBIM AND LEVEL OF INFORMATION FOR THE LIFE CYCLE OF TRADITIONAL CHINESE BUILT HERITAGE IN TAIWAN

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ABSTRACT:
As a witness of history, built heritage has many values that is very important to human being. Therefore, how to conserve this valuable information becomes a common issue for cultural heritage conservation in the world. Many researches about conserving the information of within built heritages were done and more issues were raised. The difference between built heritage and new building is that built heritage is not from 0 but it is already exist. This difference cause a big different for modelling process of built heritage in BIM environment. For this reason, the information of the 3D model of built heritage is added to the model after the it was created. So, what information should be conserve and what information should be provided to which user is worth of discussion. This research aims to propose a data structure, which fulfils the requirement of user, and respect the standard of important international chart of conservation. The method is to define a basic data structure of built heritage components and evaluate it layer by layer. The result shows that HBIM for built heritage, by linking information, can store more important information and take the LoI of life cycle into consideration simultaneously. The prototypical schema of this study may possibly be an upper layer concept for later researches in both Western and Eastern built heritage.

1. INTRODUCTION

Built heritage is an outcome of ancient human being for their survival and their requirement. It is a construction that handed-down during the development of human history as well. It is not only an evidence of history, but also a path of cultural development. The conservation works of built heritage are a universal value nowadays. Digital archiving technology for conserving built heritage is an important subject in the 21st centuries. Internationals are aiming at supporting the conservation works through digital archiving technology and the integration of different government agencies. For example, the FP1-FP7 and Horizon 2020 projects of the European Union include many topics on digital cultural heritage. The main issues of these topics include basic definitions of digital cultural heritage such as ontology and semantics. Therefore, the important international trend is the different schemas of digital archiving and building 3D model. In Taiwan, the Ministry of Culture continues to converge the concept and technology of conservation in response to international conventions. In 2016, the new national cultural heritage database was officially launched and continuing updating with the international trends (NCHDB, 2018).

The innovation and development of Information Communication Technology (ICT) in support of the Architecture, Engineering industry, Construction and Operations (AECO) is characterized by the growing use of BIM (Succar, 2009). Many researches on applying BIM in built heritage conservation works were published and is still ongoing. The benefits of BIM make it a very suitable solution for modelling and managing information relating to existing buildings like built heritages. A BIM for an existing or built heritages can be used as a documentation and management tool for conservation work, retrofitting, renovations and building analysis (Dore & Murphy, 2017). The digitized management of historic buildings, infrastructure and complex systems bases its foundation on theoretical and operational processes in continuous development (Banfi, 2016). Therefore, digital archiving of built heritage through BIM concept (so called HBIM) is an international trend already.

2. LITERATURE REVIEW

HBIM is an effective information integration platform for archiving built heritage digitally (Fai and Rafeiro, 2014). The number of researches about HBIM is increasing rapidly in recent years. In addition to the efficient integration to various information of cultural heritage, HBIM can also be the exchange platform for the cultural heritage conservation and other existing spatial information (Kuo et al., 2018). It is a very meaningful tool for the management of built heritage in the digital age. Both the geometry and the information are important for a built heritage in the perspective of conservation (Banfi, 2017). The recorded information can be essential to plan or manage a recovery plan and a maintenance program (Pauwels et al., 2013) and exchanged between project stakeholders (Bonduel et al., 2018). It indicates that information is an indispensable element for HBIM and complete conservation is required as well. However, most of the HBIM researches are dealing with the geometry of the model such as its accuracy, precision and size (Lu et al., 2018). This research aims to strengthen the perspective of information part of built heritage through defining an ontology model. In order to satisfy different requirements of Level of Information (LoI) in every stage of the life cycle of built heritage, the information of built heritage not only includes the basic data but also the data about restoration. The study case of this research is the traditional Chinese built heritage in Taiwan.

3. METHOD

3.1 Data structure of components

The proposed method (Figure 1.) starts from the perspective of the components of built heritage, following by the investigation of the important properties of the components through international charters, Taiwanese restoration craftsman and Taiwanese Cultural Heritage Preservation Act, the international charters including "*The Athens Charter for the Restoration of Historic Monuments*", "*The Venice Charter for the Conservation and Restoration of Monuments and Sites*", "*The Nara Document on Authenticity*" and "*Operational Guidelines for the Implementation of the World Heritage Convention*". Especially in the operational guideline, the indexes of Authenticity are clearly defined in no.82 as shown in Table 1. This research respected the indexes for the important properties and took the indexes as the basic concept to integrate with other literature review results. Apart from these important international charters, there are many researches on HBIM which are also considered. For example, Banfi et al. (2017) proposed that linking the information to the parametric models was the main added value of the models in order to define their utility. From these sources, a data structure for building components was defined and become a standard for the next step in the research as shown in Table 2. In order to fulfil the requirement of end users, this research also interviewed several stakeholders included from carpenters to government officials while defining Table 2. Their advices and suggestions are more tend to actual repairing work and documentation that is very worth reference. Those stakeholders also evaluated the final data structure for making sure the content is corresponding to their concept and request.

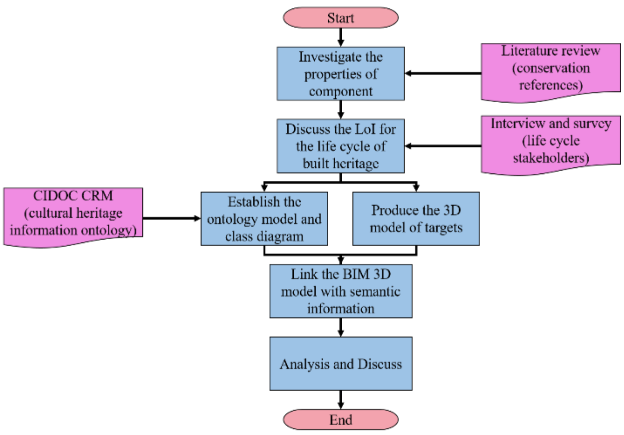

Figure 1. The research flow chart

Table 1. The eight indexes of Authenticity defined in Operational Guidelines for the Implementation of the World Heritage Convention

1.	Form and Design	2.	Materials and Substance
3.	Use and function	4.	Traditions, Techniques and Management systems
5.	Location and Setting	6.	Language and other forms of intangible heritage
7.	Spirit and Feeling	8.	Other internal and external factors

Table 2. The data structure of the built heritage component

General Information		Restoration Information	
Property	**Definition**	**Property**	**Definition**
ID	A specific ID for the documented component	**ID**	A specific ID for the restoration documentation
Time	Time span of the component	**Time**	Time span of the restoration
Name	The proper name (after resolution) of the component	**Condition assessment**	The condition of every stage from before to after the restoration
Geometry	Information of the geometry of component	**Construction method**	The construction method or process of the restoration
Dimension	General description of the documented dimension information	**Tool**	The tools that were used during the restoration
Description	All kinds of descriptions about the component	**Material**	For separating the new and old part of the component, it needs to be recorded again
Material	The materials which constitute the component	**Craftsman**	The ID or name of the craftsman
Related information	Any related info/data of the component	**Related information**	Any related info/data of the restoration

3.2 Life cycle of built heritage

Afterwards, discussing the LoI for the life cycle of built heritage to provide the accurate information for different users. The scholars (Yang et al., 2018) have recently adopted the concept of the life cycle of traditional Chinese built heritage in Taiwan. Based on the previous concept, this research sorted and inducted main user's requirement in every stage of the life cycle of Chinese built heritage for collecting the information to define the LoI and establish the ontology model of Chinese built heritage components and restoration information. The main users included government officials, IT department staff, craftsmen, history preservers, architecture academics and so on. A table of LoI for the life cycle was determined, and the required information was recorded within the fields as shown in Table 3.

Table 3. LoI of traditional Chinese built heritage life cycle

Life cycle of built heritage		Corresponding table
Phase 1	General investigation Deliberation Designation	1.Built heritage general information table
Phase 2	Rehabilitation Reuse	2.Rehabilitation and reuse project table 3.Planning and designing table 4.Construction table 5.Construction supervision table 6.Work report table 7.Contingency Plans table 8.Dissection investigation table 9.Design modification table
Phase 3	Management Maintenance	10.Management and maintenance table 11.Major disaster emergency incident management table

3.3 Ontology Model

Thirdly, it had to define an object-oriented class diagram and ontology from the scale of the component to clarify these concepts and increase the interoperability of information. The design of the ontology is based on the CIDOC CRM ontology model in order to make the ontology have a robust data exchange standard (CIDOC CRM, 2018). Apart from the exchange standard, the definition of every component in traditional Chinese built heritage is determined by various architects, craftsmen and stakeholders through expert consultation meetings. The correctness of the corresponding between ontology and component are increased by the aforesaid definition (Acierno et al., 2017). Two traditional Chinese built heritages, the Tsai Lineage Temple and the Huangxi Academy (Figure 2 & 3) were chosen to be studied for the definition of components. Each component within these two buildings was documented in few tables. This research defined three ontologies for the component, and the models were drawn as Figure 4.

Figure 2. The Tsai Lineage Temple

Figure 3. The Huangxi Academy

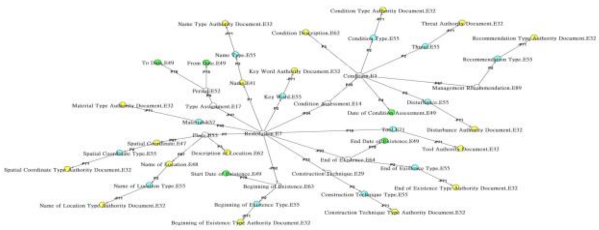

Figure 4. Ontology of restoration information

3.4 3D BIM models of study cases

The first stage of creating 3D model is to do laser scanning of whole building. This research used the FARO laser scanner the type is Faro Focus3D x130. Sphere targets are included into the scanning for better registration. After obtaining 3D point clouds of both study cases, some general post-processing of optimizing the result of point cloud. The final point cloud was imported into AutoCAD software for depicting the longitudinal section and latitudinal section of the built heritage (Figure 5). This step might need some surveying data of the component of built heritage since the scanning can only record open place but not for the place which is blocked or too small for placing the scanner. The longitudinal section and latitudinal section of built heritage were then be imported to Autodesk Revit for producing 3D model. In this step, the built-in families of Revit is nearly impossible for the need of built heritage component. Therefore, it is necessary to create families for every complex component by using two methods. One is to create the component by Geomagic software, this software can produce 3D mesh and then import into Revit. It is a better method for creating model of component that has very complex surface or decoration. Another method is to create the model by using the default functions within Revit. This method is suitable for the component which has rather simple surface and decoration (Figure 6.). In the end, the 3D models of two study cases were built with new families of building components.

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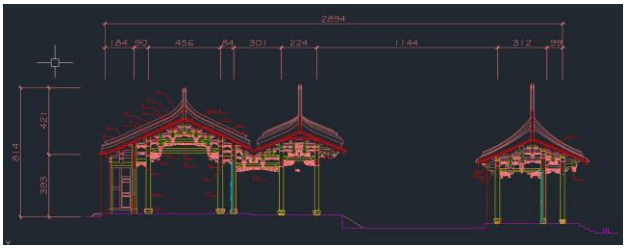

Figure 5. Longitudinal section of study case

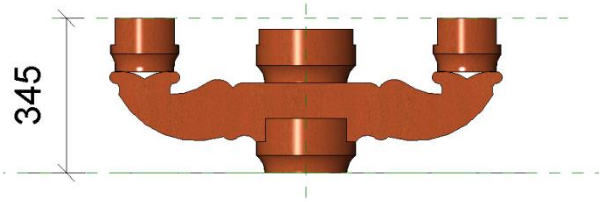

Figure 6. Example of a building component of the Huangxi academy.

3.5 Combing models and information

In the previous step, 3D models of Chinese built heritage components (Figure 7.) is created for visualization and can be linked to the component information according to ontologies (Figure 8.). In order to link the component model to the information it has, we recorded every Revit ID of every component in our database. To accomplish this, we chose to export IFC file from Revit so the ID of every component can be find within the IFC file. For 3D model viewer and database (the database was built according to ontology model), we designed a web based page for conducting these functions. The website can connect to both model and database for different information by searching their Revit ID in the storage of model and the database.

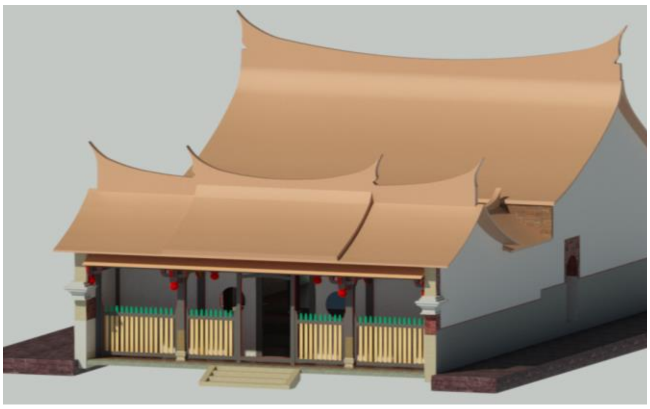

Figure 7. 3D model of Tsai Lineage Temple

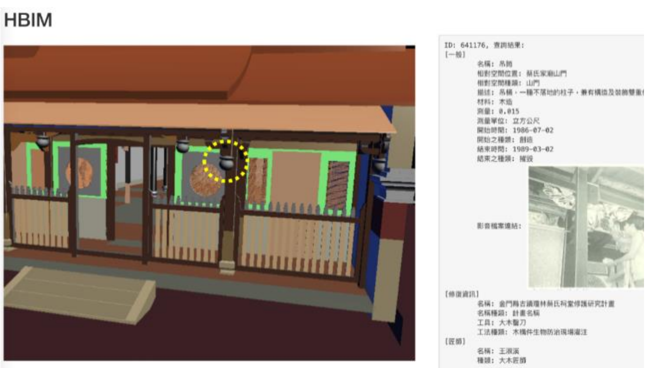

Figure 8. 3D model and its properties

4. RESULT & CONCLUSION

The result shows that HBIM for built heritage, by linking information, can store more important information and take the LoI of life cycle into consideration simultaneously. Information is based on an ontology concept for the sake of reliable and credible. Ontology also increases the interoperability of the information since it is defined through the concept of CIDOC CRM — the international exchange standard for cultural heritage. Although there is no large-scope of the investigation to the users' requirements, this research can be a prototype of establishing an information richness HBIM schema. As for the users' requirements, it should be gradually accumulated by the follow-up investigations and studies in this field.

In the process of defining important properties, we noticed that the demand of a restoration data structure of components is similar between Western and Eastern built heritage. The prototypical schema of this study may possibly be an upper layer concept for later researches in both Western and Eastern built heritage. It is worth to investigate the similarities and differences of schemata between various built heritage.

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