CULTURAL HERITAGE PRESERVATION USING NEW MEDIA METHODS: YINGXIAN WOODEN PAGODA, CHINA

CONSERVACIÓN DEL PATRIMONIO CULTURAL UTILIZANDO NUEVOS MÉTODOS DE COMUNICACIÓN: LA PAGODA DE MADERA DE YINGXIAN, CHINA

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Highlights:

- Examination, documentation, research and education of architectural heritage sites using new media methods.

- Integration of old archives and digital/computational software to represent the outstanding value of the oldest and tallest wooden skyscraper in the world.

- Use of 2D/3D modelling and virtual reality photography developing information to increase awareness on cultural heritage sites suffering wood deterioration.

Abstract:

Architectural landmarks that represent a culture's identity are also sanctuaries for cultural heritage preservation. The tallest and oldest wooden multi-storey structure in the world, the Yingxian Wooden Pagoda of China is tilting at an ongoing rate that requires an urgency to find solutions to revert the damage. To preserve the evolving humanistic and artistic understandings of ancient Chinese architecture, and to cultivate the scientific reasoning behind ancient Chinese carpentry, new media allows digital and computational assistance to support human users who once relied on manually analysing data and information from cultural sites and artefacts. Using old evidence gathered from previous research, and old methods of documentation that required a strong understanding of the information performed by the researcher, these forms of records can be described as static and antiquated, while only able to offer information as it presents itself. New media gives the Yingxian Wooden Pagoda the latest digital assistance in finding discoveries that were not possible in previous old method research. The aid from computational software and tools expands the evidence once hidden in cultural heritage sites. This article will exemplify new media tools, such as animation via 3D/2D modelling, 3D scanning and virtual reality photography, to examine material evidence on the Yingxian Wooden Pagoda, and the role new media can assist in its fight to sustain its originality since 1056.

Keywords: 3D modelling, 3D scanning, 2D modelling, 360º virtual reality photography, documentation, BIM

Resumen:

Los hitos arquitectónicos que representan la identidad de una cultura también son santuarios para la preservación del patrimonio cultural. La pagoda de madera de Yingxian en China, la estructura de madera de varios pisos más alta y antigua del mundo, se inclina a un ritmo constante que requiere encontrar soluciones urgentes que reviertan el daño. Para preservar la evolución humanística y la comprensión artística de la antigua arquitectura china, y para cultivar el razonamiento científico detrás de la antigua carpintería china, los nuevos medios de comunicación permiten asistencia digital y computacional a los usuarios humanos que analizaban manualmente los datos y la información de los sitios culturales y los artefactos. La evidencia alcanzada a partir de las investigaciones previas unido a que los métodos de documentación clásicos requerían una comprensión sólida de la información realizada por el investigador, conlleva a que los registros se puedan describir como estáticos y anticuados, y que solo pueden ofrecer información tal y como se presenta. Los nuevos medios de comunicación ofrecen a la Pagoda de madera de Yingxian la última asistencia digital para encontrar descubrimientos que no eran posibles de llevar a cabo en investigaciones anteriores usando los métodos clásicos. La ayuda de programas y herramientas computacionales amplía la evidencia ocultada en los sitios patrimoniales. Este artículo ejemplificará las nuevas herramientas de comunicación, como la animación a través del modelado 3D/2D, el escaneado 3D y la fotografía de realidad virtual para examinar la evidencia material de la Pagoda de madera de Yingxian, y el papel que los nuevos medios pueden desempeñar en su lucha por mantener la originalidad de esta pagoda budista de madera desde 1056.

Palabras clave: modelado 3D, modelado 2D, escaneado 3D, fotografía de realidad virtual 360º, documentación, BIM

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1. Introduction

Built in 1056, the Yingxian Wooden Pagoda, located in Shanxi province, China, is the world's tallest and oldest surviving fully wooden pagoda (UNESCO, 2013). The pagoda offers hope of a possible future in which environmentally-friendly wooden skyscrapers can become an actuality in its potential to replace concrete and steel skyscraper construction. Some authors posit that wooden skyscrapers may offer an effective means of slowing down global warming (Tollefson, 2017). By substituting concrete and steel with wood from sustainably managed forests, the building industry could curb up to 31% of global carbon emissions. This article also refers to the Yingxian Wooden Pagoda as the benchmark for wooden skyscrapers. Through analysis of its architectural characteristics, this Chinese national treasure may offer valuable insights for future environmental initiatives.

Wooden Pagoda Heritage Research Connections (WPHRC) is an interdisciplinary programme, established in 2016, by City University of Hong Kong (CityU) for the purpose of conducting fieldwork study on the Yingxian Wooden Pagoda. WPHRC integrates professors from academic backgrounds at CityU, architectural heritage specialists from Beijing University of Technology and researchers from the Chinese Academy of Cultural Heritage. The core research team consists of CityU student researchers from different university departments, such as Architecture and Civil Engineering, Media and Communication, Chinese and History, Creative Media, Accounting, Economics and English. The team was also able to showcase their 2018 fieldwork study on the Yingxian Wooden Pagoda in the documentary film *The Preservation of the Yingxian Wooden Pagoda* (Lai, 2018). This article will mention cultural heritage documentation methods with the assistance from computational technology (new media) as opposed to the reliance on human (user) creators for such data (old media).

Librarians are able to offer students, who wish to pursue more extensive research capabilities, the chance to conduct fieldwork studies of the pagoda. The Association of College and Research Libraries (ACRL) writes: "Research is iterative and depends upon asking increasingly complex or new questions whose answers, in turn, develop additional questions or lines of inquiry in any field" (ACRL, p. 7). To some, the library's platform may seem to be merely a collection of resources; but a library can offer much more. Ching (2018) writes: "Libraries are like archives, museums, and galleries in that they too are partly institutions of cultural heritage and have their responsibilities to collect, preserve, and pass on historic and cultural heritage materials to our future generations". It was through these fieldwork studies that new media technology was able to present the heritage site's information, not able to be displayed from previous (old media) methods.

WPHRC's fieldwork studies involved digital and computational technology for documenting the Yingxian Wooden Pagoda's framework and constructional background. The International Committee on Architectural Photogrammetry (CIPA), founded in 1968, encourages the development of principles and practices for the recording, documentation, and information management for all aspects of cultural heritage, and supports the development of specialised tools and techniques for these activities (Santana Quintero, Georgopoulos, Stylianidis, Lerma, & Remondino, 2017). Guided by this principle, WPHRC team members experimented with methods such as 3D modelling (supported by blueprints from previous surveyors and on-site photographic recordings), 3D scanning, and virtual eality photography to promote the value of the Yingxian Wooden Pagoda's cultural and historical significance.

2. Previous archives and recent preservation research

The Yingxian Wooden Pagoda's earliest form of documentation began during the reigning period of Wanli (A.D. 1573, Ming Dynasty) through an illustration (Fig. 1) depicting the city of Yingxian (Tian, 1984). A closer examination of this illustration will reveal three Chinese characters, translating to Fogong Temple. It can be presumed that the labelling refers to the Yingxian Wooden Pagoda by its Buddhist title, The Sakyamuni Pagoda of Fogong Temple.


Figure 1: Illustration from the Ming Dynasty of Yingxian County, China. Chinese characters for Fogong Temple (referring to the Sakyamuni Pagoda of Fogong Temple) highlighted in orange. 应州志 (1984).

In 2016, the Chinese Academy of Cultural Heritage published *The Yingxian Wooden Pagoda's Preservation Research* to highlight past and current research on the pagoda's history and cultural heritage. The Contributor and Representative from the International Council on Monuments and Sites (ICOMOS, China) presents in his publication early photographic documents of the Yingxian Wooden Pagoda (Hou, 2016). In 1903, Japanese architect Itō Chūta, visited the Yingxian Wooden Pagoda and conducted his own architectural observations while also photographing the structure. His observational endeavour on the pagoda was later followed up in 1933

by Chinese architect Sicheng Liang during his visit to the Pagoda. When compared with each other, the Itō Chūta (Fig. 2a) and Sicheng Liang (Fig. 2b) photographs of the Yingxian Wooden Pagoda are physically similar, which suggests that the pagoda went through a phase of little change during those 30 years. A third photograph provided in the publication (Fig. 3) is a photograph taken by the China Cultural Heritage Research Institute in 1950, which indicates a drastic change in its physical appearance. When comparing Fig. 2a and 2b with each other, there is not much difference to be seen as both photographs show the pagoda supported by wall structuring. Figure 3, however, shows a distinct change in the physical appearance, as window installations have replaced the previous wall structuring.
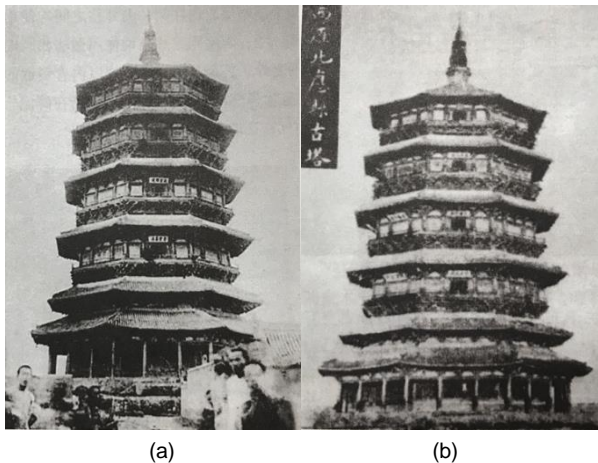
Figure 2: 20th century photographs of the Yingxian Wooden Pagoda: a) Photograph taken by Itō Chūta (1903); b) Photograph taken by Sicheng Liang (1933).
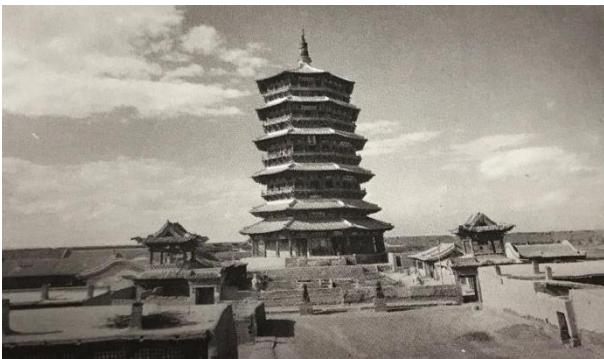
Figure 3: Photograph taken by the China Cultural Heritage Research Institute (1950).

Despite the Yingxian Wooden Pagoda's ability to withstand the forces of time, the pagoda is currently facing an ongoing crisis. There is the significant tilting of the structure, allegedly beginning from the second floor of the pagoda. During WPHRC's 2018 fieldwork study, a conservation specialist from ICOMOS (China) was interviewed in the documentary *The Preservation of the Yingxian Wooden Pagoda*. When asked about possible methods to fix the pagoda's tilting issue, the conservation specialist referred to a process of *dismantling and restoration*, in which damaged or deteriorating wood would be removed for repairing and reinserted back into the pagoda. The dismantling and

restoration process seems practical due to the structure's use of the *mortise and tenon* method of dougong, which allows wooden components to fit together without creating stress on each individual piece. This technique is a traditional repairing method on Chinese wooden structures. Another approach is to use the *total shoring* method, which exchanges the wooden beam and column load-bearing system with steel replicas, allowing the wooden bracket system and girders to be replaced by steel. Because the second floor is the source of wood deterioration, the *lifting* method was also proposed, which would physically raise and dismember the pagoda, starting from the third floor upwards, allowing repairs to be conducted on the second floor (Hou, 2016).

3. Scientific questions raised by WPHRC

WPHRC members, supervised by preservation scientists and engineers from the Chinese Academy of Cultural Heritage, were able to access the Yingxian Wooden Pagoda for recording and documentation purposes. WPHRC members from CityU's Department of Architecture and Civil Engineering used computational software such as Autodesk Revit, to experiment with digital reconstruction. With the specifications such as dimensions, measurements, and materials from previous architects and surveyors, the group sought to combine all related information for the creation of a 3D-modelled reconstruction of the pagoda.

Other members wanted to understand the marks and patterns in hopes of identifying the tools used in its construction. Through the process of wood rubbing, researchers were able to directly capture surface features from the wood onto paper. However, this conventional method of documentation is quite labour intensive. 3D scanning technology was then utilised. This method digitally captures precise measurements on targeted objects in high resolution which can be used for analysis. Afterwards, the severity, scale and shape of the tool marks are analysed to identify tool mark patterns. A process called *new evidence* (*old evidence* would relate to the collected information directly from the pagoda's physical features) would require WPHRC members to recreate tool marks using replicas of carpentry tools used during the Liao Dynasty (the period when the Yingxian Wooden Pagoda was built). Once this has been done, technology such as the Structure Sensor, a structured-light 3D scanner able to capture precise measurements of an object using infrared technology, will document the new evidence and provide information to compare with the old evidence. In summary, members focusing on this research would:

- Identify tool marks and the tools used for the construction.
- Collect data samples of the tool mark patterns using 3D scanning technology.
- Recreate new evidence by reproducing tool marks from replicated Liao Dynasty tools onto wood samples.
- Compare data from old evidence and new evidence for pattern similarities and differences between tools such as axe, adze, etc.

4. Literature review

New media can be defined in many different ways. According to the article "The Language of New Media", by Lev Manovich:

> Old media involved a human creator who manually assembled textual, visual, and/or audio elements into a particular composition or sequence. This sequence was stored in some material, its order determined once and for all. Numerous copies could be run off from the master, and, in perfect correspondence with the logic of an industrial society, they were all identical. New media, in contrast, is characterised by variability. (Other terms that are often used in relation to new media and that might serve as appropriate synonyms of variable are mutable and liquid.) Instead of identical copies, a new media object typically gives rise to many different versions. And rather than being created completely by a human author, these versions are often in part automatically assembled by a computer. (The example of Web pages automatically generated from databases using templates created by Web designers can be invoked here as well.) Thus the principle of variability is closely connected to automation. (Manovich, 2001).

Manovich's interpretation of new media can be understood as the transitional phase from human (user) creators (old media) to computational creators (new media). As shown in examples given later in this article, WPHRC members were able to greatly cut down on the time needed to input data and measurements with the help from new media software.

Another definition is offered by Malpas (2008), who characterises new media as a platform "to offer enormous potential for the recording, documenting and archiving of culturally significant –and often highly vulnerable– sites and materials" while also enabling forms of analysis and reconstruction that could not be envisaged previously. He further explains how new media allows for new modes of communicating and presenting information that would not otherwise have been possible. When applied to cultural heritage preservation, these characteristics of new media are highly beneficial. New media technology is demonstrated in cultural heritage preservation through the use of Autodesk Revit, in its ability to digitally reconstruct the Xiyu Pagoda Lighthouse, a non-existent historical structure from the 18th century into a 3D model (Leung, Davies, & Ching, 2018).

According to the National Centres for Environmental Information (NOAA, 2018), since 1056 (the completion of the Yingxian Wooden Pagoda), there have been 30 recorded earthquakes in Shanxi Province, China. The earliest earthquake documentation in this time frame was in 1102, with the latest occurring in 1999 (M=5.3). Based on this data, Shanxi has been, and still is, prone to earthquakes, which leads to the concern of the Yingxian Wooden Pagoda's resistance towards natural disasters given its current state. The pagoda's endurance is due to its weight distribution from its dougong bracket system, which helps to conjoin wooden pieces together while maintaining its original form. Nearly 7400 metric tonnes, dougong's bracket system is able to dispense the weight of the Yingxian Wooden Pagoda.

5. New media methods

Using 3D modelling from various sources, such as 2D imagery and video-captured screenshots of the Yingxian Wooden Pagoda, allows for systematic reconstruction for research purposes. Demetrescu (2018) states, "A transparent publication of a re-constructed study can improve the scientific quality of a research and can enable the possibility of the re-use of the 'raw' reconstructive record in future scientific researches as well as a standardised adoption in several digital outputs." By creating a model of the pagoda using computational software, WPHRC is able to conduct further investigations from digital samples while making valuable steps towards efforts in preserving the pagoda.

5.1. Dougong representation using Autodesk Maya

Dougong is a unique method of wood construction dating back to the Spring and Autumn period of China. Without support from nails or glue, dougong works by interlocking brackets based on the patterns. Bracket sets are created by placing a wooden block (*dou*) onto a column to form a solid base. Another wooden bracket (*gong*) is then inserted into the dou to support either a wooden beam or another gong (Hernandez, 2018). The wooden structure (Fig. 4) was constructed using the 'mortise and tenon' method (a type of joint that connects two pieces of wood) which requires precise measurements from carpenters. Dougong allows the eaves of the pagoda to expand outwards, creating the wing-shaped design commonly seen in Asian architecture. During the production of CityU's documentary *The Preservation of the Yingxian Wooden Pagoda*, WPHRC members from the Department of Media and Communication wanted to find an alternative to video production as a measure of explaining the function of dougong for audience comprehension. Animation would be evaluated as a possible representation of the science behind dougong's structure. Using Autodesk Maya v. 2016, 3D animation of dougong (Fig. 5) was achieved. Pieces of the wood formation and the science behind its precise placements were visually observed in real-time. Unless a representation of dougong pieces was animated to help explain the structuring of dougong, it is hard to present how dougong pieces are stacked, one by one, on top of each other. In its advantage, 3D was able to outperform 2D in its capability to present dougong's foundation.

Figure 4: Dougong system constructed on the Yingxian Wooden Pagoda. Screenshot from *The Preservation of the Yingxian Wooden Pagoda* (Lai, 2018).

Figure 5: Compiled screenshots of an Autodesk Maya rendering of dougong. Using animation, virtual stacking of dougong components are able to demonstrate the constructional formation (Lai, 2018).

## 5.2. 3D modelling using Autodesk Revit

Despite having visual references of the Yingxian Wooden Pagoda in the form of photographs taken by surveyors in the early to mid-1900s, WPHRC was not able to gather any information about the interior design and structure. During a fieldwork trip to the pagoda in 2018, WPHRC members met a wooden-modelling specialist, Yujiang Ma, from the Yingxian Lingtai Auspicious Culture Institution in Shanxi. Using only wood in his reconstructions, Ma has built a number of Yingxian Wooden Pagoda replicas. Ma, however, admits that his models do not uphold the same scientific principles of the actual pagoda. This is due to the obvious absence of certain traits, such as the pagoda's actual and physical weight, which necessitates certain measures not applicable to the smaller models. Ma's models are also completely constructed by wood, whereas the actual Yingxian Wooden Pagoda has different constructional materials, including tiled roofing. As such, his replicas are not able to be valid referencing models for architects and engineers.

In the past, and even still, Sicheng Liang's surveys of the Yingxian Wooden Pagoda have encouraged developers to reconstruct models of the pagoda in different scales. Wooden models of the pagoda simply cannot represent internal specifications, such as the weight of dougong components, which is a crucial detail pertaining to its structure. In order to preserve this part of the pagoda's heritage and identity, it is important to understand how the pagoda was constructed from the base upwards. This is where Autodesk Revit's capability can be appreciated with its calculation output ability, replacing the human (user) creator to systematically configure each wooden piece of the pagoda. To have 3D and 2D models that can be verified from past survey records, the constructional knowledge of the pagoda can be preserved for future generation to reference upon.

To safeguard the Yingxian Wooden Pagoda from further damage, both externally and internally, access to the pagoda's second to fifth floors is prohibited to the general public. In 2016, WPHRC, with approved authorisation, was able to access these floors for the purpose of researching and documenting the pagoda's interior design. Because the direct causes of the tilting are not confirmed, WPHRC members from the Department of Architecture and Civil Engineering focusing on this topic decided to use 3D programming software to assist their reconstruction of the pagoda into a 3D model. In his publishing *Ying Xian Pagoda: Ying Xian Timber Pagoda* (1980), measurements of materials were surveyed by Mingda Chen, a Chinese heritage architect who succeeded Sicheng Liang's research on the Yingxian Wooden Pagoda. These data were the main sources of information (Fig. 6a, 6b) for members to input into Autodesk Revit, a building information modelling (BIM) software used by architects and engineers to create 3D models, annotating 2D draft components and accessing the information from the model's database. Illustrations provided from Mingda Chen's surveying were the first source for WPHRC members to draw plans and sections into Autodesk Revit v. 2016 (Fig. 7a, 7b). Photographs from the pagoda's fieldwork studies and screenshots from CityU's documentary were used as a second source for modelling reference. After the completion of the 2D drawings in the software (Fig. 7a), WPHRC members were able to input the measurements from Mingda Chen's survey information (height, width and length of each wooden component) into Autodesk Revit which generated a 3D model representation of the pagoda (Fig. 7b). The first completed survey illustrations of the pagoda were finished around the 1930s by Sicheng Liang, and were later formally published in 2000, *The History of Ancient Chinese Architecture*. Prior to this, Sicheng Liang's original illustrations had suffered external damage, including colour fading, which was not able to be used as a reference for WPHRC members' 3D reconstruction of the Yingxian Wooden Pagoda. However, the descriptions and notes were useful in detailing the constructional background for the pagoda. For example, Liang (2000) implied that columns were constructed internally, so as to create more structural support for the pagoda's entirety (Fig. 7c).

Being an endangered heritage, which has a much higher oblique angle than the Leaning Tower of Pisa, the Yingxian Wooden Pagoda is undeniably considered as one valuable but diminishing architectural structure. Pocobelli, Boehm, Bryan, Still, & Grau-Bové (2018) suggests applying BIM technology to replace the traditional Computer Aided Design (CAD) software in order to squeeze all information relating a targeted building into one single file. Replenished building objects drawn using BIM are therefore considered *smart objects* which embeds different kinds of data and can include building properties and material. Xing, Beijie, & Zhuang (2017) also displays the information integration recorded for the Jingfu Palace (Qing Dynasty) by BIM.

With BIM's support, rich historical information about the pagoda was included from previous fieldwork studies and past survey reviews. In addition, Autodesk Revit may even be an extraordinary and powerful tool in helping to provide useful data from a built 3D model,

(a)

(b)
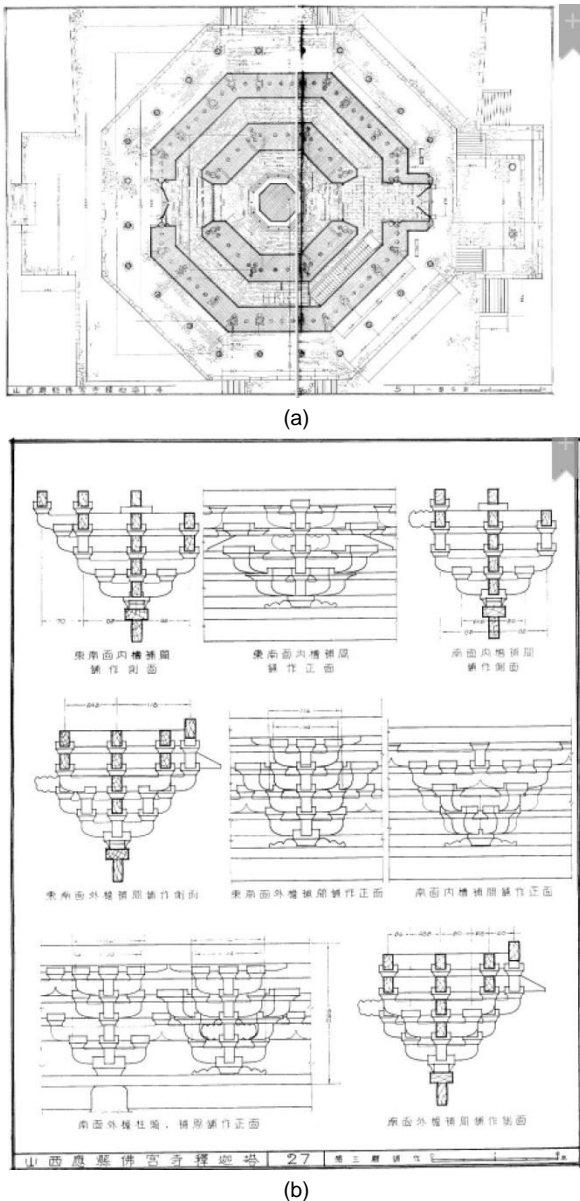
Figure 6: Yingxian Wooden Pagoda surveyed by Mingda Chen (1980): a) Blueprint survey drawing; b) Dougong illustrations.

including auto-calculation for material weight and volume (Table 1) after setting the formula in the software by the users facilitating survey archiving.

The Yingxian Wooden Pagoda is made up of nine floors, which includes five normal layers (also called as "activity floor") and four mezzanines (also called as dark layer/ structural layer) (Fig. 7c). By using the first floor as an example, which includes the first mezzanine respectively, Table 1 is able to show a representation of its weight distribution on the first floor. Unlike common architectural software such as Google SketchUp and Rhinoceros, Autodesk Revit allows users to set up formulas based on provided specifications. For instance, the calculated volume of the roof tiling of the first normal floor is 204.912 m^3. In this case, WPHRC members could determine the estimated weight (492.4 tonnes, roof tiling of the normal floors).

Moreover, this data can imply the weight distribution of different component parts in the pagoda and explain the existing deterioration status of the pagoda.

Table 1 explains that the overall weight of the roof tiling on the first normal floor is 492.4 tonnes when the structural elements are 2142 tonnes (wall) and 142 tonnes (column). Thus, structural elements must be able to support the roof tiles. However, most of the wall structuring (walls on the first normal floor remained) were demolished during the maintenance project of the pagoda around 1932. As a result, there are only columns used as structural elements on the first mezzanine. Unluckily, the overall weight of the roof tiling on the mezzanine is around 214.46 tonnes, which is much heavier than columns (31 tonnes). Even though the whole structure of the pagoda is still standing, the weight calculation from Autodesk Revit provides information on why the roof tiling on the pagoda may be a direct cause of the tilting starting from the first mezzanine.

Table 1: Data Sum Up for the Yingxian Wooden Pagoda: weight distribution on the first floor.

Items	Estimated Total volume (m³)	Estimated Weight (Tonne)
Roof Tile (Normal Layer)	204.912	492.4
Roof Tile (Dark Layer)	89.248	214.46
Wall (Normal Layer)	1339.174	2142.46
Wall (Dark Layer)	NA (No structural wall)	NA (No structural wall)
Timber Structure (Column) (Normal Layer)	203.595	142
Timber Structure (Column) (Dark Layer)	45.048	31

5.3. 3D scanning to identify tool marks

On-site fieldwork is the most direct way to gather primary sources. WPHRC members sought to identify specific tools used in the construction of the Yingxian Wooden Pagoda. *Yingzao Fashi* (translated to "Treatise on Architectural Methods or State Building Standards") was written in the 11th century as a means of documenting traditional construction tools used in China. These include tools such as the axe and adze, which are still used by farmers in Shanxi Province. Through these documents, a basic understanding of the general types of tools (axe, adze, etc.) is known. However, it became an objective to distinguish the specific instruments used during the Liao Dynasty, which required a reasonable sample from that period, in this case, the Yingxian Wooden Pagoda. During the fieldwork study, WPHRC members collected wood rubbing samples from the pagoda for analysis relating to its texture and markings (Fig. 8).

Wood rubbing samples contacted onto paper is obtained directly from the human (user) creator. Rubbing is a physical action relying on the user's skill to trace and capture the appropriate data for sample collecting. Also, data collected is non-direct data which results in a
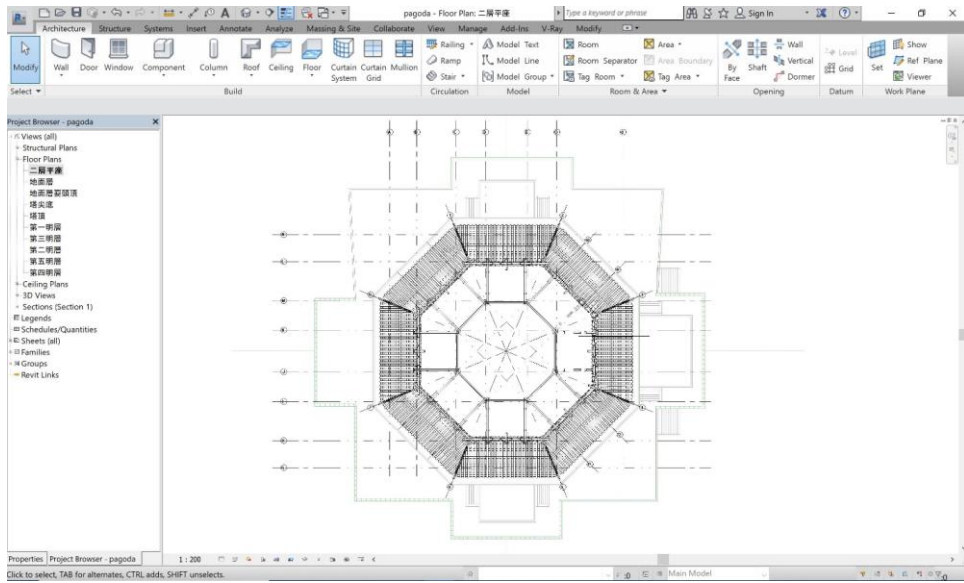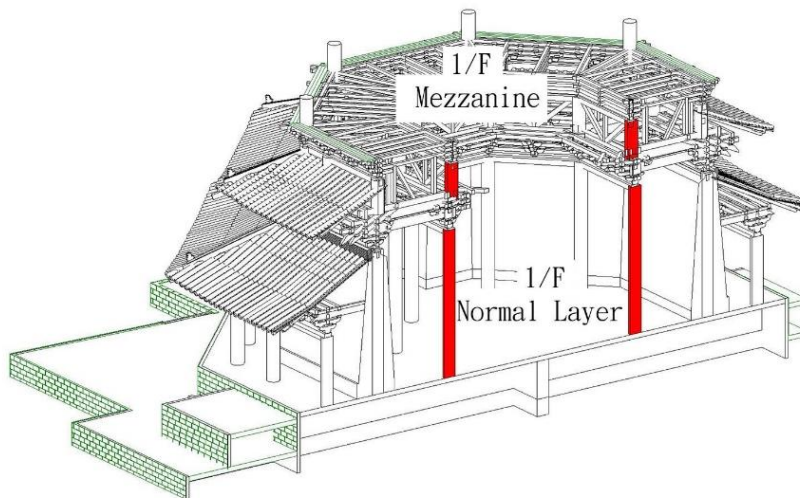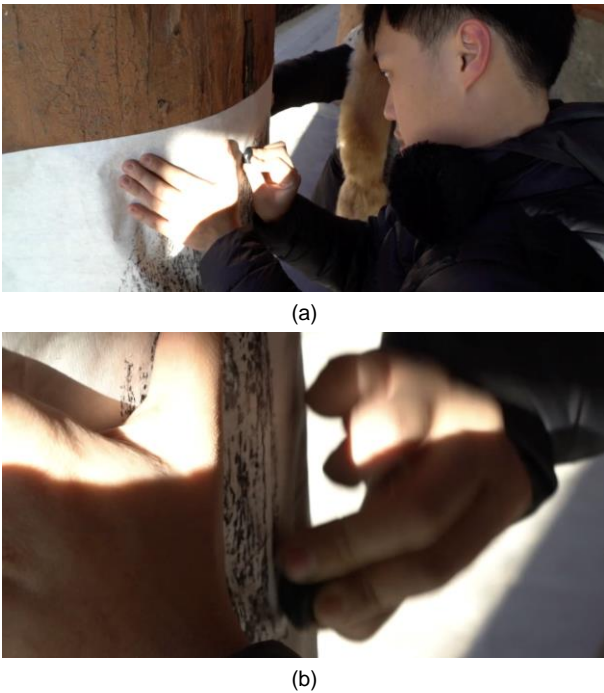
(a)

(b)

(c)

Figure 7: Reconstruction of the Yingxian Wooden Pagoda using Autodesk Revit: a) Floor plan reconstruction; b) 3D model reconstruction; c) Columns (example in red) constructed internally in first floor mezzanine and first floor normal layer (activity floor).

(a)

(b)

Figure 8: Wood rubbing on the Yingxian Wooden Pagoda: a) Data acquisition; b) Close up view.

certain amount of loss of information from the depth on marks. This is an unavoidable human error due to the application of force rubbed by the user. It also means different degrees of pressure will result in different levels of information collected. With 3D scanning, using the Structure Sensor 3D Scanner, data collection is quicker and more accurate in obtaining targeted samples. In fact, digital documentation for preservation is nothing new. Several groups of experts made efforts to introduce high-tech products such as laser scanning (Segreto et al, 2017). New methods of 3D scanning are able to produce higher data accuracy for tool mark analysis. As such, after initially using the wood rubbing technique, WPHRC members chose to use 3D scanning as another alternative for collecting such data.

Figure 9 displays representations of one of the tie-beams constructed on the Yingxian Wooden Pagoda. After 3D scanning and using the specified area of the beam as a sample method from the fieldwork study in January 2019, WPHRC members sliced the model into layers, with each divided sample layer numbered for reference and individual analysis. Using a grid chart, the individual samples had their markings observed. Based on observations, data was collected to determine the similarities of markings between different layers. New evidence is then needed to be created in order to compare with data collected on the pagoda. This could be achieved by having carpenters to strike wood, which is similar to that used on the pagoda's construction, using a range of replicated tools (axe, adze, etc.) from the Liao Dynasty. These samples would be 3D scanned in the same way that the Yingxian Wooden Pagoda (old evidence) was, for accurate computational comparison. If similar markings can be identified with the old evidence (obtained directly from the pagoda), an understanding of specific tools could be identified as to their significance.

(a)

(b)
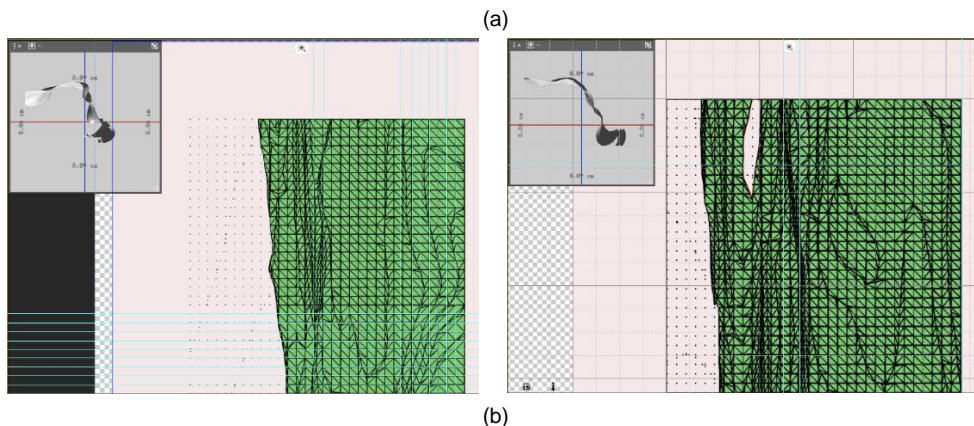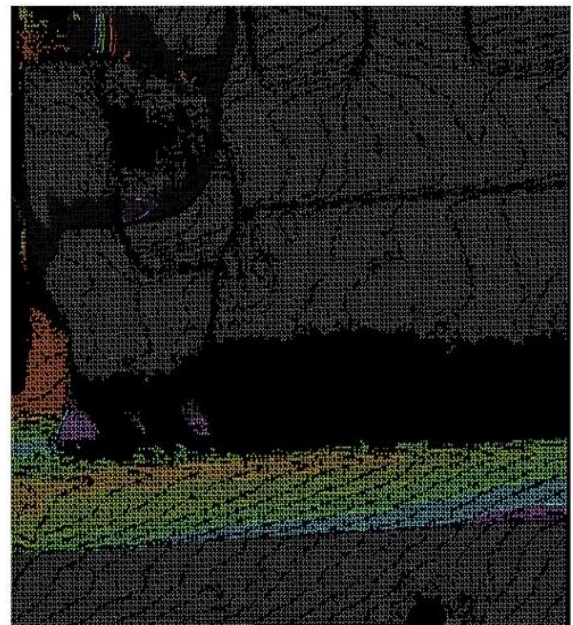
Figure 9: Digital tool mark data from the Yingxian Wooden Pagoda (captured by Structure Sensor 3D Scanner): a) 3D image of tool mark scanning: Lintel; b) 3D-scanned model samples (named as "Data 1 & 2" and displayed using Photoshop CC 2018).

This form of practice by comparing two sources of information to seek tool mark identification is most commonly used in forensic science to determine firearm characteristics with the bullet that was fired upon. Thompson (2017), in his article "Firearm Identification in the Forensic Science Laboratory", explains the science of "firearm and tool mark identification". For there to be a tool mark identification, the tool working surface (1) must have individuality, and (2) the tool marks must be reproducible for comparisons. In the case of WPHRC's research, the same principles are applied.

5.4. 360º virtual reality photography

The role that photography, and later videography, played in aiding the documentation of sites and locations was of paradigm shifting significance. In Heidegger (1971), Martin Heidegger says of the power of modern technology, "[Mankind] now receives instant information, by radio, of events which he formerly learned about only years later, if at all…what is least remote from us in point of distance, by virtue of its picture on film or its sound on the radio, can remain far from us. What is incalculably far from us in point of distance can be near to us." Nowadays, technology is again redefining what is possible towards site and location documentation, and Heidegger's above thoughts are particularly pertinent to new media technology.

Virtual reality photography is a new media technology which can bring the viewer into an immersive virtual environment of a documented site. A 360º representation, or entire spherical photograph, is generated through capturing wide-angle panoramic photographic images. To seamlessly capture such a photograph, a special camera with multiple lenses is rotated about a single central position (Leary, 2018). In their fieldwork study on the Yingxian Wooden Pagoda, WPHRC members utilised virtual reality photography. After being granted access to the upper floors of the pagoda in 2016, WPHRC was able to visually document the structure's interior using the LG-R105, a 360º photographic camera. Samples of these images are presented in Fig. 10.

To showcase the visual documentation of the Yingxian Wooden Pagoda, WPHRC held a guided tour, by WPHRC members, at their university library. The 360º photographs were displayed in the library's Cave Automatic Virtual Environment (CAVE), as seen in Fig. 11. This event was an opportunity for students and visitors to experience a new media approach to cultural heritage presentation. Rather than viewing a series of static photographs, visitors were able to immerse themselves within the captured areas, giving people the chance to view the interiors of the pagoda upper floors in a more personal and interactive approach.

6. Discussion

The ICOMOS (China) emphasises the importance of research in cultural heritage preservation. They write: "The use of heritage sites for research should be encouraged. Heritage sites comprise the physical evidence of history and the development of culture and as such is a resource for research. Research into a heritage site is an important means of actualising its values." (ICOMOS China, 2015). Libraries simultaneously act as places of education and research, as well as archives, museums, and galleries. They are

(a)

(b)

(c)

(d)

Figure 10: Panoramic shots inside the Yingxian Wooden Pagoda: a) Second level; b) Third level; c) Fourth level; d) Fifth level.

themselves partly institutions of cultural heritage and have roles to play in collecting, preserving, and passing on historic and cultural heritage materials to our future generations (Ching, 2018). Fieldwork studies provide students with an opportunity to become very much a part of this process, fulfilling the responsibility held by libraries to provide such opportunities for students. In this research, student members in WPHRC can increase their knowledge scopes and undertake cross-disciplinary studies through collaborations with other students from different academic backgrounds. By using the Yingxian Wooden Pagoda as a central theme, WPHRC enables student researchers to conduct their own investigations and fulfil their own research motives.

(a)

(b)

Figure 11: CAVE virtual reality exhibit on the Yingxian Wooden Pagoda: a) CAVE Poster; b) Student experiencing CAVE.

New media can assist student researchers in profound ways. In the case of tool mark analysis, 3D scanning's technology was used to digitally collect and display patterns of tool marks, a process which, if done manually by a human (user) creator (such as wood rubbing), would have been time-consuming and incredibly arduous. Rather than requiring tool mark analysis to be carried out with the naked eye and the accuracy determined by an individual's personal knowledge on tool marks and their patterns, 3D scanning reverse-engineers this process, and utilises computer technology which can identify even very partial or vague marks that may be overlooked from wood rubbing sampling. Now, as the case of the Yingxian Wooden Pagoda shows, computational methods using 3D scanning can help produce and present digital representations of tool mark data, rendering comparison to become more efficient. Additionally, virtual reality photography allows for more extensive imagery, as well as a more engaging and interactive experience for its viewers to partake.

Structural plans, blueprints and maps of heritage sites can be used to document vital information for future generations to refer to. However, 2D imagery can only go so far in presenting key information. To illustrate the Yingxian Wooden Pagoda more thoroughly, 3D modelling software was used by WPHRC. With the assistance of new media software such as Autodesk Revit, complex structural systems such as dougong can be better examined and visually represented in a way that would have required many static images. Using 3D modelling, individual components can be marked for analysis based on the size, weight and length of each wooden component. Zhang, Cong, Wu, Bai, & Wu (2017) explain that BIM technology is more effective than previous conservation practices, which relied on drawings and text. BIM allows researchers to include more historical, architectural, and spatial information to be presented. Yet, WPHRC's research goes beyond using BIM as a documentation source. Rather, the software has a sophisticated weight calculation function, which WPHRC members used to analyse the weight distribution from the normal floors to its mezzanines. From this analysis, it was indicated that the weight of the roof tiles may be putting a lot of stress on the deformed structural columns, and by reducing the roof's weight, or adding structural supports to the exterior of the pagoda, this may be an effective solution.

The iterative nature of WPHRC's research on the Yingxian Wooden Pagoda is emphasised through the ARCL Framework (2015), where it is stated that "communities of scholars, researchers, or professionals engage in sustained discourse with new insights and discoveries occurring over time as a result of varied perspectives and interpretations." Students who join WPHRC's fieldwork studies on the pagoda are encouraged to take an open-ended approach, so that they can creatively and critically adapt to any unexpected discoveries during their research.

Cultural heritage sites serve as living memories from past history. New media opens new paths of rediscovery through means of collection, creation and analysis that were previously unavailable. Integration between cultural heritage preservation and new media technology allows users to discover and experiment with new research methods. It allows researchers to create their own paths, in the likes of past innovators such as Itō Chūta, Sicheng Liang and Mingda Chen, whose collected data, in old documents, serve as a benchmark for progressive study on the architectural and engineering science behind the Yingxian Wooden Pagoda. This way, WPHRC members can serve as the new creators of information, using new media methods, which have surpassed old media methods' capability, in presenting such data.

7. Conclusions

7.1. From fieldwork studies to deliverables by using new media methods

Manovich (2001), in regards to new media's capability, states:

> New media is interactive. In contrast to old media where the order of presentation is fixed, the user can now interact with a media object. In the process of interaction, the user can choose which elements to display or which paths to follow, thus generating a unique work. In this way the user becomes the co-author of the work.

After on-site fieldwork studies on the Yingxian Wooden Pagoda, WPHRC members applied several types of new media technologies, including Autodesk Maya, Autodesk Revit, Structure Sensor 3D Scanner and LG-R105. These digital and computational tools helped WPHRC digitally collect and present information, from the past to today's audience.

BIM technology was commonly used for heritage conservation and surveying. Chapter 5.2 indicates how the use of Autodesk Revit, was able to replace the traditional 2D and non-information based software to redesign the pagoda. Moreover, the use of Autodesk Revit as an analysing tool to the pagoda's weight distribution was also possible, given the supplementary specifications provided by previous surveyors. It was determined that the heavyweight of roof tiling may be one of the reasons leading to the tilting of the pagoda. Thus, it is suggested that the existing repairing method (by adding new structural support inside the pagoda) may not be the most suitable way to stabilise the whole structure. It is recommended, after evaluating the digital information resulting from Autodesk Revit, that additional support mechanisms towards the exterior of the Yingxian Wooden Pagoda may be necessary to prevent further tilting.

WPHRC members from the Department of Architecture and Civil Engineering aimed at not only establishing tool marking similarities, but also to identify Liao Dynasty wooden components when compared to the replaced ones on the pagoda. The first step in tool mark identification is being able to identify distinguishable patterns and traits from different tools used towards constructing the Yingxian Wooden Pagoda. Once tool mark data can be singled out after comparison from old evidence (the physicality of the pagoda itself as a reference for sampling) and new evidence (which must be recreated onto similar wood by replicated tools from the same time period) to determine the construction tools responsible for building the pagoda, the process of identifying Liao Dynasty era materials on the pagoda can be followed. WPHRC civil engineering members focusing on this research praise the calculation work of toolmark analysis that has been reduced thanks to computational assistance such as 3d scanning, which its collected data offers more information to analyse than wood rubbing data.

Virtual reality photography's ability to enhance the interactive experience for users brings them into the environment of the imagery captured. Users are engaged in unforeseen surroundings that are not currently accessible to the general public. During CIPA's 26th International Symposium in Ottawa, Canada, a presentation by Yan He was given on "The Chinese '5R' (Realities) – New Potential for Digital Presentation of Cultural Heritage". One of the five principles in regards to applying digital technology in China focusing on built heritage was to "create diachronic and synchronic content that enables visitors to understand the evolution of cultural heritage, with creativity, linking heritage and people" (He, 2017). By implementing virtual reality photography as an evolutionary tool in cultural heritage documentation, students and visitors to CityU's CAVE exhibition (2016) were able to see the progressive efforts of digital technology's advancement in documenting and displaying the interior designs and foundations of the Yingxian Wooden Pagoda.

WPHRC members relied on past undertaken documentations and recordings of the Yingxian Wooden Pagoda to succeed the information inputted into computational software. For the use of 3D modelling, it was critical to use survey drawings as a reference guide. In an article relating to the Architectural Archives Construction of the Summer Palace in Beijing, Zhang et al. (2017, p. 727-728) explain survey drawing, in a passage worth quoting at length:

> Survey drawing is an important content of architectural information archives. Design is forward engineering, surveying is a reversed engineering. Reversed engineering has many unknown factors. The unknown factor of Surveying is that there are many hidden areas, and we cannot obtain structural information in normal condition… We find in surveying practice that the 3D scanner has obvious advantages in the acquisition of whole spatial relations of architectures. But for the component level, such as sizes of the beam, Fang, purlin section, dougong, door and window, the error is far greater than the manual measurement. It cannot achieve the nominal accuracy of the instrument… Therefore, the method of measurement is combining manual measurement with 3D scanning. Manual measurement is used to measure the size of the main component section, and to identify the structural relations between the components. 3D scanning is used to control the whole spatial relations and that between the components.

It is interesting to note Zhang's explanation of survey drawings being disadvantageous in the process of reconstructing a site into a 3D model without the appropriate information of the site's actual measurements. However, in the research involved on the Yingxian Wooden Pagoda, WPHRC members followed the same measures for achieving a presentational output, as quoted by Zhang, to determine certain findings. For example, Zhang emphasises manual measurement's accuracy when compared to 3D scanning's measurements. This actually helped to achieve the 3D reconstruction of the pagoda, through the survey data collected decades ago by Sicheng Liang and Mingda Chen. In regards to WPHRC members conducting tool mark identification, Zhang's description of 3D scanning's ability to "control the whole spatial relations and that between the components" justifies new media's technological advancement when compared to old media methods such as wood rubbing, since 3D scanning is able to obtain information that may not be collected through wood rubbing data.

New media technology, when defined as the ability of digital and computational assistance provided to the human (user) creator, is able to minimise time and efficiency in collecting and presenting information on cultural heritage sites. In the case of the Yingxian Wooden Pagoda, which its sustainability has been long documented since the 11th century until the 21st century, researchers relied heavily on previous data to create a progressive form of research to follow up on. These included old media methods, such as illustrations and 2D photographs. New media's potential in digital reconstruction and digital information analysis on the pagoda is able to help researchers, focusing on its sustainability, to obtain more data for new ideas to preserve its identity.

7.2. Future Works

To present all research materials from fieldwork studies since 2016, WPHRC held an exhibition in June 2019 as a means to enhance sustainability awareness on the Yingxian Wooden Pagoda. Because WPHRC's research on the pagoda is ongoing, the contents and results provided in this article hope to demonstrate the role that new media can play in cultural heritage documentation, through 3D modelling, 3D scanning, and virtual reality photography.

It is inevitable that computational advancement is on the approach to effectively succeed the use of human users, not just in the field of cultural heritage preservation. If it is able to magnify the scope and information of previous research, this transitional phase of data for researchers should be encouraged. At a time when a heritage site such as the Yingxian Wooden Pagoda is facing an ongoing deterioration of its originality, which its presence itself holds historical knowledge of Chinese architecture since the 11th century, researchers integrating their study objectives, with new media platforms to assist them, could provide the answers for the pagoda's future sustainability.

Acknowledgements

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