

BIM+VR Technology for Visualized Application in the Substrate Restoration of Wooden Heritage Buildings

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Abstract. In the dissertation it is about Constraints in Visualization with Traditional timbered historic building preservation. Take the pagoda of wooden structure in Yingxian for example, AI and BVR cooperate, a "Gather Information— Create Model—Adjust Scenery" is put forward. It works well in the immersive displays of how to repair a mortise-and-tenon and how to assemble dougong. And improve on interactivity and prediction of danger, help refine the problems build technical talk which is quite practical. At the same time, also recognize some problems related to simplifying models and verifying them practically, then it highlights the need for more accurate models, better simulators, lighter weight software. The framework also facilitates multi-stakeholder communication by providing a shared visual platform for engineers, conservators, and heritage experts. Additionally, it enables non-destructive pre-construction simulations to minimize risks to the original fabric during restoration. It further supports the documentation of restoration processes for future research and educational purposes.

Keywords: traditional timbered historic building preservation, Yingxian Wooden Pagoda, BVR, mortise-and-tenon, heritage visualization.

1. Introduction

Timber legacy buildings are the most special and all-encompassing expression of traditional Chinese building wisdom and values. As the tallest existing example of an entire historical wooden tower, it has a very complicated wooden building structure. But, after years and winds of degradation, the fact that it is a necessary subject of study and preservation for the culture is now absolutely imperative – yet incredibly challenging [1]; We need to know that standard visualization methods currently used for rehabilitation of wooden historical edifices are mostly 2D Computer Aided Design (CAD) schematics and basic 3D modeling. There are several problems with this. And there are some abstract space representation with no immersion on the reconstruction process simulation thus is impossible to anticipate danger before the construction stage. Hence they can not meet the function need of exact and orderly repair of old timber building [2].

Lucky thing is, there are some advantages given with BIM methods on parametric design and comprehensive data combination which makes them really good for exactly copying the architecture characteristic and repairing information about wooden stuffs [3]; And, and also when vr system gives us the ability to travel through an entire immersive environment but we can also simulate things procedurally at that point. This is just like having both those things in one combo and creating some sort of more advanced technical base on how we protect our Wooden Cultural Relics [4]; Therefore this research takes it as the main object of research and observe the substrate repairing work on the ground about highly deteriorated ones, mainly dougong bracket and mortise-tenon connection. In the beginning, it makes clear about how the current implementation stands and what is the software integration behind Building Information modeling (BIM) + Virtual Reality (VR) methods for wooden heritage structures conservation. Then it follows logically with the development of a BIM+VR Visualization Modeling Strategy Grounded on Revit and BIM-FILM. And then we analyze about the actual immersive-simulation implementations with regards to two fundamental backgrounds: first is repair work flow for mortis-tenons; second is substrate's assembly procedure. Finally, we look at how useful this methodology could be on making restoration strategies better and reducing building dangers and also have visualized tech talks to reach an end goal which is giving real world

benchmarks of sorts for exact timber cultural property repair work. In order to do that, we naturally want the BIM+VR systems used for protecting old buildings to be put into use more easily and widely. And we must note that what “substrate restoration,” as used here, means is just the construction techniques adopted on removing the defect part, reinforcing certain parts and rebuilding the structure for lower foundation of timber based cultural relic like its column base, douzong bottom, hidden supporting frame. This is an important process which relates to the structural maintenance of historical buildings [5].

2. Relevant theories and technical foundation

2.1. Wood substrate restoration of wooden heritage building

Traditional techniques exhibit notable deficiencies. Specifically, two-dimensional CAD drawings fail to adequately represent complex spatial configurations and node relationships, leading to potential misunderstandings when conveying design intent [2]. Meanwhile, conventional 3D modeling lacks information correlation and interactivity, and thus cannot naturally or reasonably simulate dynamic restoration processes [5]. In the context of dougong restoration at the Yingxian Wooden Pagoda, traditional drawings cannot clearly depict the interlocking relationships and stress states of the arched and block components, compromising installation accuracy [1]. They also fail to pre-identify workflow interface issues, directly reducing construction efficiency. It is worth noting that research on the seismic performance of the inclined dougong-fork column combination at the Yingxian Wooden Pagoda has provided important theoretical foundations for restoration efforts [6].

2.2. Theoretical basis and technical conditions for the structure and fusion reasons of BIM and VR

BIM tech is mainly good because it can parametrically model stuff and bring together all the info in one place which makes revit super good at making complex models of timber things and keeping records of them. The complete geometric metric information and material feature, as well as structure flaws is allowed here. And it could help precise representation of overlapping connection among dougong bracket and mortise-tenon joint too [3]. VR Technology is due to its strong sense of immersion and interaction so the Bim -film plat form allows us to add inthe bimmodel easily, set up some virtual cameras, set some interactive logic etc. this will enable a user to do all the restoration building step beforehand as well as give engineering personnell an opportunity to have a preliminary try [4]. The combination goes via a logical flow: ‘data modelling →format transformation →application scenarios’, it could even just simply put as using Revit to make an accurate BIM model with repair details which transforms the form that is known to be understood in the mind of BIM-FILM after going through some small modifications during this stage before building immersive VR restoration environment. The final scene can therefore enjoy it [4]; The digit conservation method based on HBIM is proved in a number of wooden heritage protection [7].

3. Now that is being used/software

3.1. Limitation of conventional visualization technique

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3.2. Software's fit, and problems about software

The combination of revit with BIM-FILM is very flexible. It's reasonable to believe that Revit is able to meticulously document specifics on elements and the way they deteriorate which helps put together data for VR environments but BIM-FILM can properly manage various format in-gestions as well as streamline optimizations [4].

There are three major obstacles preventing me from doing so: At first because there is a tradeoff between geometric precision and light weight in VR, the scale and substance and condition of the structure within the simulated environment must match real life [4]. The need is also the second to have an easy shift from simulation of a building work flow to working hands on [5]. Finally, we have to deal with worries about degradation of data. This is true for the hidden parts of the digital stupa as well as translating format between different software packages [1]. And importantly the unified modelling strategies, incorporating Ground Penetrating Radar alongside Geographic Data Science gave new thoughts on how to obtain information about things that were hidden [8].

4. Practical application to the substrate of the wood in the pagoda of the pagoda

4.1. Construction of visualization model

In terms of the bracket system and mortise-tenon joint of the main level structure, they are two typical degradation examples from the Yinxian Wooden Pagoda, with obvious differences: The dougong part is compressed and deformed perpendicular to the wood fibers; The arch base has cracks; The mortise-tenon gap has widened; And the connected link is loose [1]. In accordance with the "Data Collection—Modeling—Scene Modification" logical model construction process presented by this article. Which means to start with gathering the proportions of geometry and deterioration info on the elements [1], then create the main model in Revit, and enter repair parameters [3]. And then it's exported as an Industry Foundation Classes (IFC) file which we take into our BIM-FILM and do just a tiny bit of refinement, set up some lights and add in interactivity to create the vr repair environment. Throughout this workflow, it is precisely preserved that the mortise-tenon joint coupling in the dougong bracket and the genuineness of the stratified associations between them.

4.2. Core simulation scenario using value

Concerning dougong repair simulations: I do the structurally degrade-remove -> element strengthen -> assemble reposition kind of thing. So people can easily watch structural weaknesses through exploration, see if strengthening substances and equipment are easy enough to get to, then logically and confidently guess how loads will change in different elements [1]. In terms of the modeling process for restoring a truss beam, it is divided into stages such as 'separation-purification-restitution-reintegration,' which helps us logically determine the points where work should be checked and regular inspection checkpoints. Like load imbalance when dismantling or the wrong angle when reattaching, it is possible to predict some dangers; rapidly calling up information about BIM entities helps with making judgments, which would obviously increase how productive and good a building is.

And it has a lot of practical applications. By checking if a strategy makes sense, we can find safety problems early on, make sure all professions follow the same rule book, and possibly save this as something important later on. In-depth literature analysis with regard to the safeguarding and reconstruction approaches on timber architectural sites has bolstered up how we put this into effect in my study [9], but looking at other studies such as using robotics to maintain the pagoda of the Yingxian wooden are examples of what can be used later [10].

5. Conclusions

5.1. Reaserch conclusion

Because the common visualizing technique can not display all aspects of complicated structure, combining the bim+vr makes this procedure much more interactive and predictably for the process, which also allow us to do a better restoration plan and anticipate hazards as well as exchanging knowledge about this. This article takes the Yingxian Wooden Pagoda as its main topic and explains the incorporation mechanism of BIM & VR system, as well as the adaptation of Revit and BIM - FILM program. Our model-producing process was based on a practical method of “collections-modelling – modifying scene”, and our immersive simulation created this process too. Here are two basic scenes, "mortis - tenon repair" scene is the first type; another one is called "dougong assembly"scene. The above said is like the methodology shows how it could beat the limits that traditional CAD schematic drawings along with standard 3D rendering usually make when speaking about space or getting immersed in places or predicting risks - taking good advantage of things like reshaping restoration methods, reducing building dangers, so on, for a better way to talk about stuff technically. In general, the above technical process that has been formed is quite practical and versatile, it provides a certain concrete path in terms of technology for precise preservation of wooden cultural relics.

5.2. Limitations and future directions

This study has clear limitations: model lightweighting leads to insufficient detail expression, and no practical engineering verification is carried out. Future research will focus on three directions: first, adopt deep learning 3D reconstruction algorithms to balance model lightweight and detail retention; second, refine full-process simulation to build a complete "inspection-assessment-restoration-monitoring" technical system; third, develop dedicated lightweight plugins and mobile VR applications to reduce data loss and application threshold. Multi-source data collection and on-site restoration experiments will also be combined to establish a quantitative evaluation system, promoting BIM+VR as a standard tool for wooden heritage building restoration.

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