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VIRTUAL RECONSTRUCTION AND INTERACTIVE APPLICATIONS FOR KOREAN TRADITIONAL ARCHITECTURES

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Abstract

This paper describes a research project about Korean virtual architectural heritage. The aim of the project is to develop tools for virtual reconstruction and simulation. In shape and structure, Korean traditional architecture is different from Western building. Thus, it is difficult to adopt Western H-BIM (Historic Building Information Modeling) tools. Our tools developed in the project were designed to be suitable for Korean traditional buildings as well as architectural simulation that includes Korean characteristics. As a result, several virtual representations of Korean traditional architectures were made with our tools and used in the project's interactive applications, all of which have been showcased at Digital Heritage Expo 2015 in Granada, Spain.

Keywords

Digital, Cultural, Heritage, Virtual, Reconstruction, Simulation, Represenation, Interactive, Application, Korean, Traditional, Architecture

1. *Introduction*

For the past three years, we have researched and developed the technology for traditional Korean architecture, as well as its applications. Our primary focus has been on the virtual reconstruction of traditional buildings and their appurtenances.

Korean traditional architecture is similar to that of far-east Asia, but different from that of the West. Since most conventional tools are only able to deal with western and modern buildings, we could not adopt those tools. In order to properly reconstruct traditional Korean buildings, we came to develop several innovative tools that include geometric modeling, architectural simulation, computer animation, and computer-aided design technology (Lee & Lee, 2014).

We have taken the approach to reconstruct a traditional building by its 3D architectural components, and have successfully achieved

Fig. 1: Main objective of the project

accurate virtual representation with the same appearance and underlying structure (Lee et al., 2015).

The aforementioned virtual representation—stemmed from detailed information and expert knowledge of the existing traditional buildings—was put to use in our interactive applications. With this process, we can achieve the target heritage, as shown in Fig. 1.

1.1 Related works

Many of digital architectural heritages are reconstructed with the fast growing 3D technology. The digital reconstruction uses Various 3D digitizing technologies from 3D geometric modeling to 3D scanning, and it is mainly accompanied by heritage conservation, like the reconstruction researh of *The Castle of Coatfrec*, France (Barreau et al., 2014).

Recently, there have been many trials to conduct creative research in this field. As the leading-edge scanning device generates a massive amounts of data with high quality, the focus is now on effective and photo-realistic visualization of the digital reconstruction--the case of the *saltanat Gate of Dolmabanhce Palace* (Ergun et al., 2014), for example, some research focused on the other methods of 3D reconstruction. Instead of an expensive 3D scan device, Microsoft Kinect was used in 3D reconstrcution (Quintana et al, 2014). Image based modeling from multiple photos becomes increasingly popular.

As it is limited to use the 3D scan data only, digital documentation that integrates the hetero-genious data from various modeling method and detailed information of conservation has been a field of extensive research. Luca et al. (2011) presented an integrated platform to manage digital representations of buildings for architectural applications related to the analysis and the documentation of cultural heritage. Quintero et al. (2007) suggested a heritage documentation to close the gap between 3D scan data and professional information. Apollonio et al, researched virtual reconstruction of buildings and semantic construction of digital model which is conceptually smilar to BIM.

Building Information Modeling (BIM) is about managing and using 3D data effectively. Therefore, the adoption of BIM has helped significantly in the field of digital heritage, and hence Historic BIM (H-BIM) was introduced

The framework for generating archaeological model for Rome cryp of St Sergius, Bacchus Chrch was similar to H-BIM (Scianna et al, 2014). Brumana et al. (2013) tried to integrate visual materials such as 3d scan data into BIM for heritage.

The Korean traditional wooden building is known for its complexity of the inner-structure. It is composed of hundreds of components which are assembled into higher level assembly units in a successive manner (Lee & Lee et al., 2015). As it is challenging to reconstruct the architectural heritages, the conventional BIM tools don't support the Korean traditional architecture. So there are few case to apply korean traditional into BIM. Choi & Hwang (2005) attempted to explore the structure of Korean traditional wooden architecture in a systematical or computational manner. They showed a reconstruction case of *Buseoksa Muryangsujun* and a simple application to share the information. Park (2011) suggested a BIM-based parametric design method for the modernized Korean traditional house 'new hanok' which is simplified type

Heritages are classic and popular topics in interactive applications. So, there are many cases to suggest experiential applications. 3D Digital reconsruction is a base for virtual reconstruction.

In the early stage, previous works about digital heritage buildings focused on the digital appearance reconstruction (Park et al., 2001; Gaitatzes et al., 2001). However, it is not easy to use the reconstruction data directly in an application, they use the appearance only, not the internal structure of the heritage building. Recently many applications take the user interaction like VR. Loizide et al. (2014) introduce the virtual museum using VR HMD, and Rome Carnuntum (Valdelomar et al., 2015), Etruscan City of Kainua (Gaucci et al., 2015), Virtual cities of pre-earthquake Lisbon (Murteira et al., 2015) and so on.

1.2 Goal of the project

The project has two ultimate goals. The first is to research and develop the necessary tools to create accurate virtual representation of Korean architecture. In general, traditional Korean architecture can be categorized by its main material, such as wood or stone. Wooden buildings, for instance, were designed for habitation including houses, temples, and palaces.

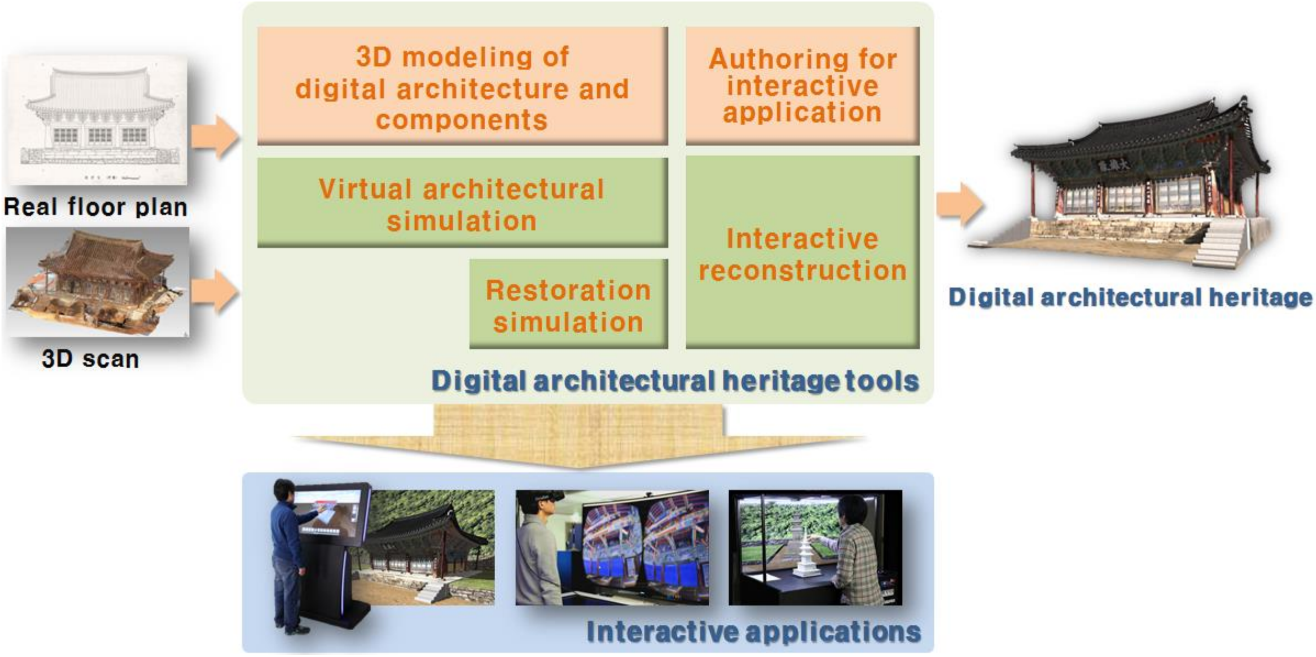

Fig. 2: Overal flow of the project

Buildings built with stone, on the other hand, were more for memorial monuments, including pagodas. A traditional wooden building is composed of various architectural components that are connected and inserted to mount each other in the traditional construction method. This method is an important characteristic in constuction of Korean traditional architecture. We designed a method to accommodate Korean characteristics and developed our own tools to make digital versions of traditional buildings by their 3D components. It takes more time and resources to construct an actual virtual restoration of a building, rather than creating a superficial 3D appearance. However, the resulting model is more accurate, detailed, and has the capacity to be used for more extensive purposes.

The second goal is to create an enjoyable experience for users, thus gearing public interest towards traditional Korean architecture. As mentioned above, the construction details of traditional architecture is frequently too convoluted for the general public to understand on first glance. In a true sense of understanding heritage, it is essential and necessary for us to provide a way for information as such to be displayed and understood effortlessly by the public. In the past, there have been few attempts at creating applications that effectively achieve that goal.

Consequently, we have attempted to construct interactive applications with an emphasis on the characteristics of traditional Korean architecture. It was our goal to convey detailed architectural knowledge using our interactive applications and to introduce the frequently overlooked, architectural excellence embedded in Korean culture.

2. Virtual reconstruction

We have been able to develop digital architectural tools to reconstruct virtual heritage. As shown in Fig. 2, our system starts 3D modeling, reconstructs the virtual structure, and finally creates a virtual representation. Unlike most conventional tools and research, our system has an extra 'authoring' module to add information and simulations for interactive applications. The authoring allows for the use of the virtual heritage data in our interactive applications.

2.1 Geometric modeling from CAD print

As shown in Fig. 2, our system takes the real 2D floor plan[1] or the 3D scan data of Korean architecture as the input. With the input data, our system can support two types of modeling: geometric modeling based on the 2D CAD plan and 3D modeling from the 3D point cloud (further explained in section 2.2).

[1] In Korea, the most of National architectural treasure has the real floor plan written by Korean Cultural Heritage Administration. And Korean citizens are able to get the CAD plans of Korean heritages from Korean government.

The geometric modeling in our tool system aids the user in making the components of traditional architecture. At first, the user prepares the CAD plan of a target building.

Based on the CAD plan, the user can generate points and triangles of the components in virtual 3D space—intuitively, as the program leads the user on. The resulting models are individually saved in the database. The user can load and edit the models in the DB and build up each component of the target architecture. The user can even load the components of other buildings from the DB and modify for reuse. This process is very similar to BIM.

For the effective creation and preservation of these traditional buildings of Korea, we have made the resulting data to be both solid and polygon models. The potential compatibility with conventional BIM and modern simulation tools were taken into account.

For an easy breakdown of this process in our tools, the reconstruction case of *Kukrarkjeon*[2] *of Bongjeong temple* is an example. Fig. 3 shows the real CAD plan of the building. Fig. 4 shows the component modeling. Fig. 5 shows the assembly of the building. And finally, Fig. 6 shows the authoring in our system, which will be described in depth in section 2.3.

2.2 Components modeling from 3D scan data

Recently, 3D scanning has emerged as a versatile technology in the digital heritage field and is used extensively. The data from the 3D scan is a mass of 3D points called the 3D point cloud, as shown in Fig. 7.

It is very useful to obtain and show an accurate appearance. But the data is not partitioned. If the 3D scan is completed about the entire building, it is difficult to partition and extract the components in the resulting data. Therefore, we attempted to develop partitioning and modeling tools for 3D point cloud by components. It functions as a plug-in S/W of Autodesk AutoCAD in Fig. 8. In Korea, there are few cases of 3D scanning for traditional wooden buildings. We, however, were able to test two buildings with both 3D scan data and real CAD plans. At first, 3D data from the 2D CAD plan is made—providing the opportunity to compare the 3D point cloud and 3D data from 2D.

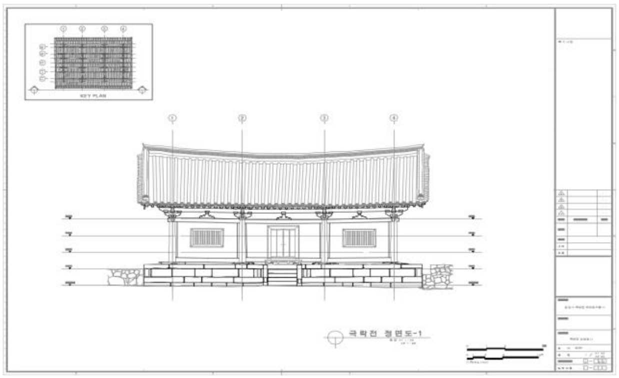

Fig. 3: A real floor plan (CAD) of *Kurakjeon* from Korean Cultural Heritage Administration

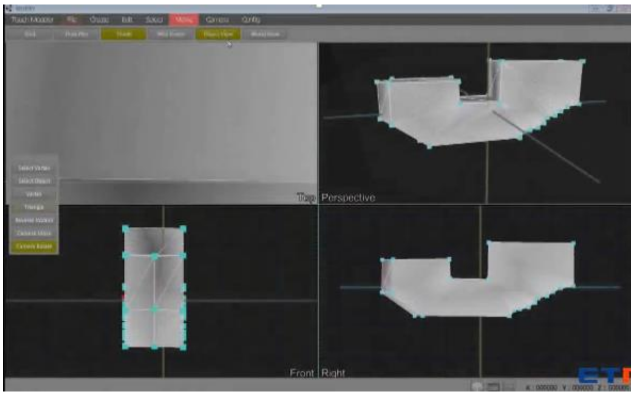

Fig. 4: A component of Kurakjeon in our modeling tool

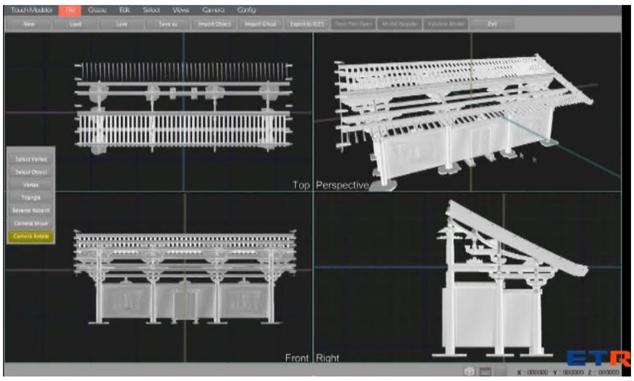

Fig. 5: *Kurakjeon* in our modeling tool

Fig. 6: *Kurakjeon* in our authoring tool

[2] Kukjakeon of Bongjeong temple is a Korean natonal treasure (No. 15), built in 1200 AD, and is one of the existing oldest wooden architecture in Korea.

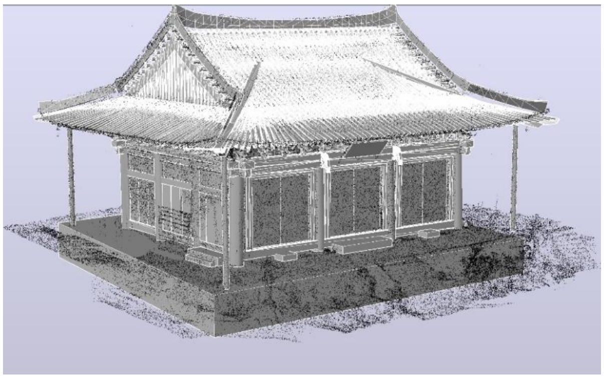

Fig. 7: A 3D point cloud data

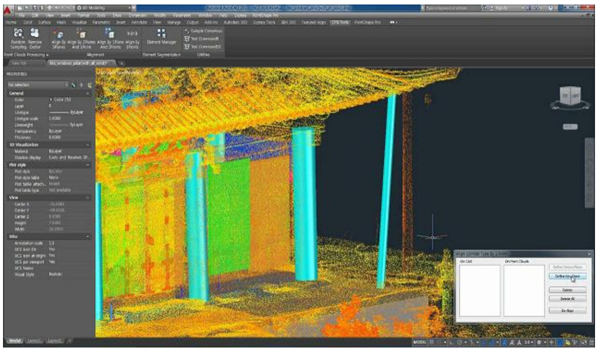

Fig. 8: Our 3D point cloud partioning plug-in for CAD

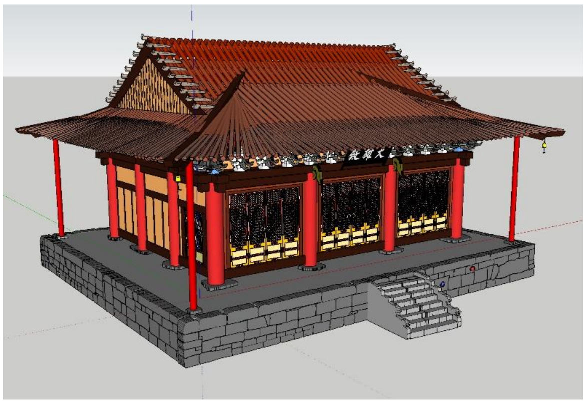

Fig. 9: Resulting heritage data

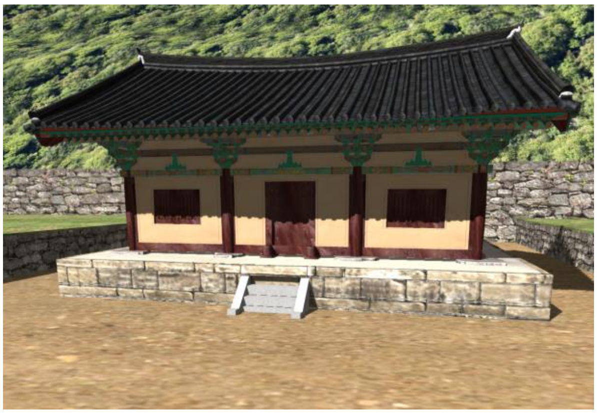

Fig. 10: Final virtual represention of *Kukrakjeon* in our interactive appication

Our tool registers spatially the two different sets of 3D data in 3D space, then compares the range of components, partitioning the data from the 3D point cloud. Fig. 9 shows the result of partitioning.

2.3 Authoring tool for interactive application

Although the reconstructed architecture with its components coherently shows the appearance and the support of the structure, it is limited when directly used in other applications. The applications are not satisfied with just exterior and structural data. In fact, they require the proper settings, internal relations, information, tags, and so on. Consequently, we developed an authoring tool for our interactive applications.

As shown in Fig. 6, we were able to arrange attributes and parameters of architectural components. We placed background, set experience environments, and organized stages of our application. We add the information and simulation to be shown. It is possible to, in advance, test architectural simulation that has been developed, including construction, deconstruction, physics of a collapse, lighting, and so on. Fig. 11 shows an assembly simulation of a stone pagoda.

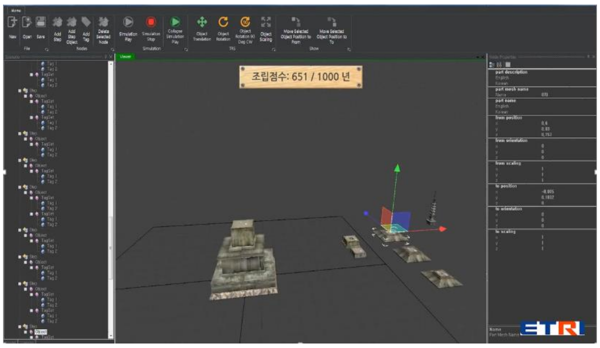

Fig. 11: Simulation tools

After these works of the authoring tool, finally we complete the virtual representation of a Korean traditional architecture.

2.4 The resulting virtual architectures

In our project, we made 5 Korean wooden heritage buildings: *Kukrakjeon of BongJeong temple* in Andong (Fig. 10), *main building of Chungryong temple*[3] in Anseong, *main building of Heungguk temple* in Yeosu, *Kukrakjeon of Eunhae temple*, the reconstruction plan of *the palace in Iksan Wanggungni Historic Site* by UNESCO.

[3] Main building of Chungryong temple is a Korean treasure (No. 824), built in 1364 AD, and is famous for natural pillars and murals in wall.

And we have 2 Korean stone heritages: *Seokga pagoda*[4] in Gyeongju and the reconstruction plan of *Miruksaji stone pagoda*[5] in Iksan, both shown in Fig. 12. Then, we were able to make some foreign heritages: *Solitary Joy Temple*[6] in China, and *Ananda pagoda*[7] in Myanmar (Fig. 13 and 14)

Fig. 12: *Miruksaji stone pagoda* and *Seokga pagoda*

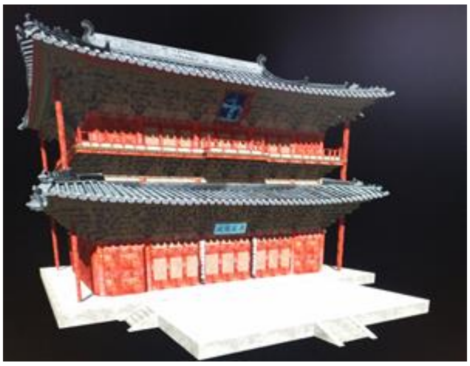

Fig. 13: *Dulesi, Solitary Joy Temple* in CHINA

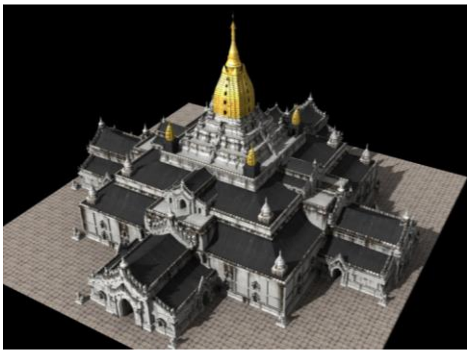

Fig. 14: *Ananda pagoda* In MYANMAR

[4] Seokga pagoda is a Korean natonal treasure (No. 21), built in 751 AD, and is very famous and representative pagoda in Koera.

[5] Miruksaji stone pagoda is a Korean natonal treasure (No. 11), built in 600 AD, and is the existing oldest and biggist stone pagoda in Korea. Now it is dismantled and under the reconstruction.

[6] Solitary Joy Temple is the existing oldest wooden architecture in China, built in 984 AD.

[7] Ananda pagoda is famous for Sophisticated beauty, One of four surviving temples in Bagan, built in 1105 AD

3. *Interactive applications*

To evaluate and popularize our Korean traditional architectural technology, we have implemented several interactive applications for digital architectural heritage reconstruction and simulation. This paper introduces three applications that have been showcased at Digital Heritage Expo 2015 in Granada, Spain.

3.1 TouchBIM

TouchBIM is a touch-screen kiosk system for Historic BIM of traditional wooden buildings. Fig. 18 shows the appearance of TouchBIM (Lee et al., 2014). It provides heritage building assembly simulation capabilities using 3D building-component models, as shown in Fig. 15.

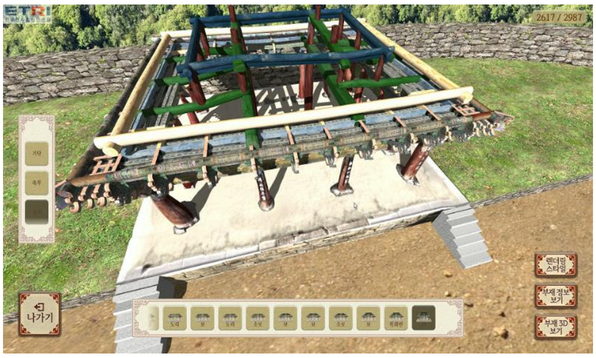

Fig. 15: Screenshot of simulation in TouchBIM

Fig. 16: Assembly process of *Chungryong temple* and a real photo of it (right bottom)

The interactive application supports a unique interactive simulation of fabrication by a pre-built virtual model. It can also produce a graph for hierarchical component connections by analyzing the geometric relations between the 3D components (Lee et al., 2014). The resulting digital building data and animations can be retrieved through the description of the building.

In TouchBIM, the user can experience assembly and disassembly simulations of the digital heritage buildings, step by step. As shown in Fig. 16, the user can intuitively and interactively control the process in whichever view or point in time.

After first release of TouchBIM (Lee et al., 2014), we updated the TouchBIM's function and data about interior. Fig. 17 shows the interior reconstruction data of *Chungryong temple*.

Fig. 17: Interior reconstruction of *Chungryong temple* in TouchBIM

In reality, the construction site of an architectural heritage is dangerous and closed for entry. TouchBIM, therefore, is very useful for the education of a student or a young worker.

3.2 hRealview

hRealview is an interactive VR system for heritage buildings in immersive environments. hRealview is made for people who want to see the assembly simulation inside digital heritage or in immersive environment.

The user can have opportunity to experience a Head Mounted Display (HMD) or large tiled display, as shown in Fig. 18 and 19. First, users take a realistic VR tour into heritage buildings using head mounted display in Fig. 20. Second, they can view actual size of heritage buildings using large tiled display. It has Interactive e-learning, integrated with VR pre visualization technology that supports simulation capabilities of traditional buildings.

Actually, hRealview is designed as a kind of TouchBIM expansion. We added the HMD and Large tiled display to TouchBIM. So hRealview is synchronized by network and is under the control of TouchBIM.

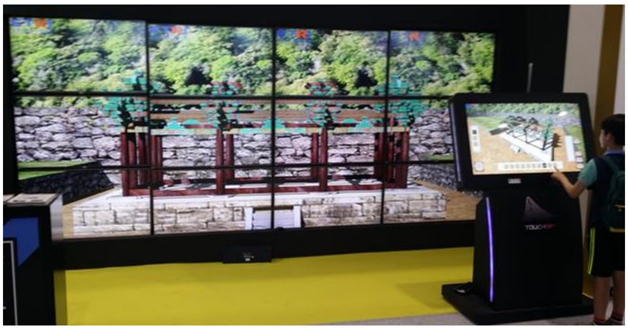

Fig. 18: Large tiled display environment of hRealview and TouchBIM (right bottom)

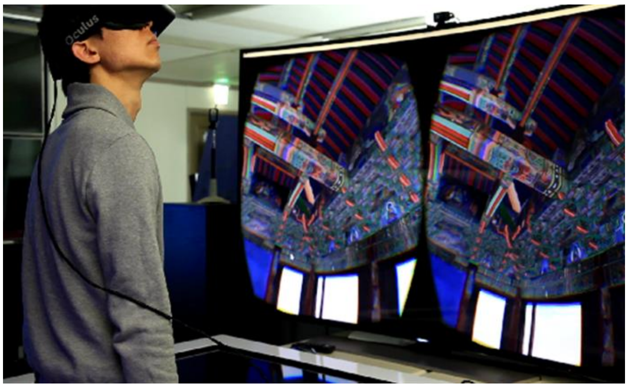

Fig. 19: Head Mounted Display (HMD) environment of hRealview

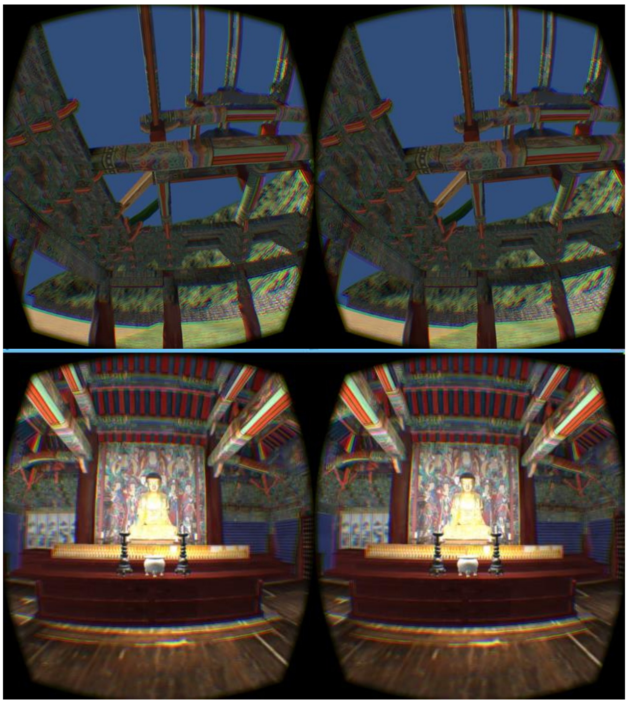

Fig. 20: Screen shots of hRealview, HMD

3.3 X-Top

X-Top is an experimental system of construction and simulation for traditional stone architectures (Kang et al., 2015). It supports double experience of Korean pagoda in both real and virtual worlds. As shown in Fig. 21, when the user constructs the structure with miniature building-components in real world step by step. X-Top tracks the user's assembly in real-time and represents the construction process in virtual world like in Fig 23. The background of Fig. 21 is a display to show the tracking in the virtual worlds.

When the user finishes the construction in Fig. 22, X-Top conducts dynamic simulation for the virtual stone pagoda based on the user's construction and displays the result of the simulation in Fig. 24.

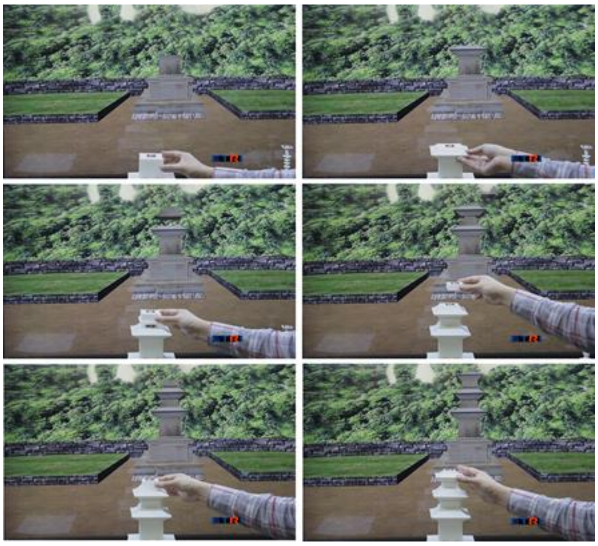

Fig. 21: Tracking of X-Top

Fig. 22: Completion of assembly in X-Top

Of course, it is possible to make a user's own pagoda, ignoring the original heritage, but the simulation results would be not be as strong. If the user mimics the shape of the original pagoda but has a fatal mistake in construction, the pagoda might collapse.

Fig 23: A screen shot of construction in X-Top

Fig. 24: A screenshot of simulation in X-Top

4. *Conclusions and future works*

In this paper, we introduce a research project about virtual reconstruction and interactive applications for Korean traditional architecture.

We were able to develop technology that can reflect the characteristics of traditional Korean architecture. Also, we developed interactive applications that allow the user enjoyment of Korean heritage and increased public interest.

Fortunately, our products are focused and quite popular to public, and we would keep trying to apply our technology on world heritages.

In the future, we will look for a method to directly use 3D scan data in our applications, as well as ways to simplify our tools to generate more digital heritages. Moreover, we will be attempting to enlarge capability that will allow several buildings to be handled simultaneously.

5. *Acknowledgement*

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