Automated Generation of Assembly Animation for Korean Traditional Building

Kyung-Kyu Kang, Jae Woo Kim, Ji Hyung Lee
Visual Content Research Department, ETRI, Korea
{kangk2, jae_kim, ijihyung}@etri.re.kr

Abstract— **Korean traditional wooden building has a beautiful appearance and long history. Recently, they are inherited as a digital cultural heritage by government and researchers. The digital heritage is able to use in the education experience and the restoration of heritage. Virtual assembly and its animation are also useful to observe the components and preview the assembly procedure. Our method makes an interactive assembly animation from pre-built virtual building model. We analysis the geometrical relationship between parts and its neighbor parts to construct a part-connection hierarchical graph. We finally make a feasible interactive assembly animation and virtual assembly sequence with the graph from the part selected by a user.**

Keywords—**Assembly Sequence Planning, Structure Analysis, Assembly Simulation, Building Information Modeling, Hanok**

I. INTRODUCTION

Building Information Modeling (BIM) is a common process to construct modern buildings to save various types of resources and to share data and information via digital building pipelines. However, Korean traditional buildings, called Hanok [1], are still manually made by professional builders following traditional process. Recently, many Korean architects and researchers try to apply BIM Hanok-building to create a standard building process. There are some problems that parts have various shapes and sizes without standard part-models and a building process is depend on only architect's experiences and hand tools without mechanical machines and devices. Especially, main parts of Hanok are made by wooden material using hand tools and they are assembled by human hands. Therefore, some mistakes can be happen from start to finish on building steps.

Virtual assembly and building simulation as a part of BIM are useful to design the wooden parts and preview assembly steps. Our method can generate an interactive assembly animation automatically from a pre-built virtual Hanok model. This method consists of two parts, a preprocessing part and a runtime part. In the preprocessing part, we analysis the connection relationship between parts and its neighbor parts and construct a part-relation hierarchical graph. A node of the graph represents a single part and stores its properties. Connections among nodes contain the procedure and method how to combine each other. In the runtime part, we can generate reasonable interactive assembly animations based on the graph with user selected parts.

We tested a Hanok model consist of hundreds of wooden parts using our technique to generate assembly animation. Our demo program is implemented base on a game engine and a touch monitor. When user select an interested part, the demo generates and shows the assembly animation immediately. So user can understand the structure of the Hanok better than 2D photos or CAD data. For animators, our system can help them to create an assembly animation more quickly and easily.

This paper consists of the following contents: after the preview of Hanok, BIM, and the related work in chapter 2, we explain on our system in chapter 3 and 4. Finally, we discuss about the conclusion in chapter 5.

II. RELATED WORK

A. Korean Traditional Building (Hanok)

Korean Traditional Building is made using wood material mainly. Especially, houses for a living are called Hanok [1]. Hanok usually has a single story, two or three rooms, a kitchen, a living room. The small size house is suitable for only one family. These days, most of the Korean lives in a very modern many-story building such like apartments. This type of house is effective to create for massive housing complex and have a perfect insulation system and offer a variety of amenities to residents. In contrast, Hanok which was made in a very eco material has gained popularity in the building of an alternative housing recently. However, disadvantages of the house are heat and sound insulation for the main material, it also has higher construction costs and its construction methods have not been standardized. To solve these problems, standard-improved Hanok have been studied [7-13].

Traditionally, construction methods of Hanok is a technique that has been taught handed down among carpenters. Recently, Korean government (Jeonlanam-do office) contacted Hanok-specialized builders for a documented project called Hanok Construction Manual [2]. The manual is composed of three books, the first volume is content for standard construction manual, the second one is content for blueprint standard, and the third one is content for maintenance, management, and repairment. It is a book that is more useful to non-specialists, including the exact drawings and the easy description of the real construction photos. In this paper, we have to reference information about the order and assembly method and the shape of the main parts with the contents of the first volume.

And, our research focuses on assembly of the main wooden parts of Hanok.

B. Building Information Modeling (BIM)

BIM is a procedures and S/W tools needed to enhance the efficiency of design, construction, and maintenance for buildings [3]. Unfortunately, in that system, there is no function for generating and displaying automatically the assembly process. It allows previewing architects assembly procedure to verify whether it is possible to assemble the parts through part-part assembly animation generated by our technique.

C. Effective Visual Communication

Assembly animation contains information about part-part relationship and assembly method. The visual way to convey information is absolutely advantageous then text. However, efficient transmission of information visually is not easy. Agrawala and his colleagues study the principles for creating effective visual aids efficient [4]. In our study, we attempt to implement our method on the basis of the principles. And our research is mainly inspired from an approach of Li et al. [6] as a part of the visual communication research.

D. Virtual Assembly for Hanok

Virtual assembly is an important process before actual building for any construction. Especially, Hanok is consist of wooden parts, architects should try to understand them completely how to design and assemble. In Kim's research [9], he designed an assembly animation player based on web3D for Hanok's parts to understand users their structure. The player just shows pre-recorded animation sequentially, we try to create the animation automatically in order to emphasize the interactivity.

III. SYSTEM OVERVIEW

Our system is composed of a preprocessing part for generating the data needed to create the assembly animation, and a runtime part to playback of interactive animations from user interaction. We should prepare a parts DB, a pre-assembled 3D Hanok model as references of our system. The parts DB contains a list of part's features and two-part assembly animation. The Hanok model is prebuilt with separable part models by a professional modeler or architect. In the preprocessing step, it analyses the shape of the parts based on shape feature data from the parts DB, and constructs a relationship graph from analyzing geometrical connection between parts. The runtime step, user select an interested part as an input to create assembly animation, the assembly information retrieve form the parts DB and the relationship graph (Fig.1).

While analyzing the 3D Hanok assembled with part models, we can obtain various information for creating assembly animation. The main information are relative locations between parts and assembly sequences. However, the detail building procedure how to couple between parts by carpenters is missing, so we store those information in the part DB as short-frame animation.

User selects a part on an available part list that wants to observe the assembly steps and the final position in the building. If the selected part is not assembled, we make a list of parts that have to be assembled prior and perform assembly following the list. If the user-selected part is already assembled, we generate and show a disassembly animation. Our system makes a list of parts to be disassembled before the part, and shows the disassemble animation following the list. In this manner, the user can observe how to assemble and disassemble the given Korean traditional wooden buildings with interactive generated animation.

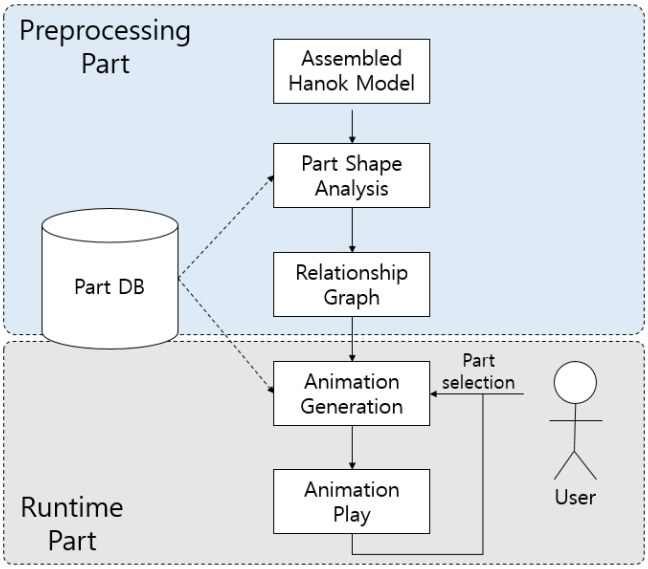

Figure 1. System Overview

IV. DETAIL

A. Part DB

Hanok is composed of unique shaped parts which have been assembled in various ways. Hanok Construction Manual [2] introduces the technique of part-assembly and the standard shape of parts. Following this guide, we build the part DB stored structured data of geometric features of standard parts. This information is used to determine the type of the parts. We convert the coupling steps of parts to key-framed animation and store them on the DB. This animation is performed when parts are prepared for final coupling.

The part DB has following information:

- Geometrical feature of standard parts,
- Coupling animation.

B. Part Shape Analysis

Every part in the pre-assembled Hanok model is determined a type by executing the part shape analysis step. The automatic matching algorithm needs a time-consuming calculation, moreover it can be failed to match types. In our

implementation, we employ a semi-automatic approach to allow user help to match correct part's type.

C. Relationship Graph

The geometrical relationship information between parts and its neighbor part is stored in a tree structure, Relationship Graph. In this graph, a node represents a single part and stores following information, 1) Part type, 2) Parent node index (already assembled parts for assembling this part). 3) Relative location from the parent, 4) Bounding box, 5) Sibling node index (parts should be assembled at the same time). The root node on the graph should be assembled in first before other parts in order to mark as a base point. And, a parent node is previously assembled before its child nodes.

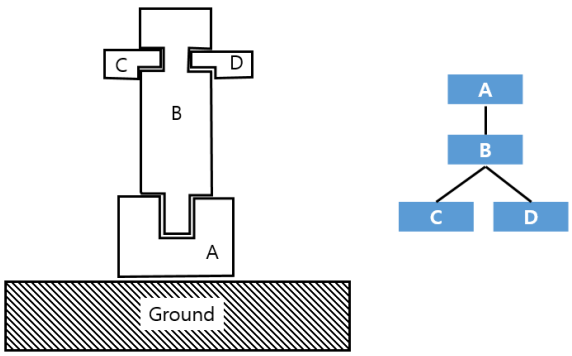

Figure 2. An example of the relationship graph (right) and a assembled part (left) of Hanok

D. Animation Generation

In this step, we generate a path the part to a proper position for coupling from the outside of assembly environment. This path is mounted position for moving to a location for assembly without colliding with obstacles or other structure already assembled. It is implemented by key-frame animation of rotation and translation transformation. If parent or child parts are needed a path to assembly, our system generates every path and makes a list of moving order.

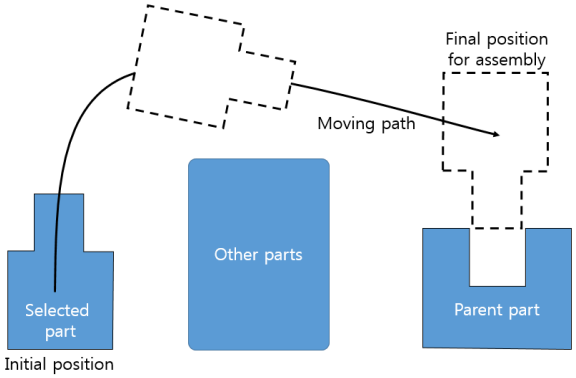

Figure 3. Moving path for a selected part.

E. Animation Play

Finally, we play the animation for moving a part following the pre-computed path. While a part is moving, we try to detect collisions between it and others with its bounding box. If new path is needed to avoid collision, we re-compute new path immediately. After a part is located on a proper position for coupling, our system queries for retrieving coupling method. And the coupling animation is performed as finish step

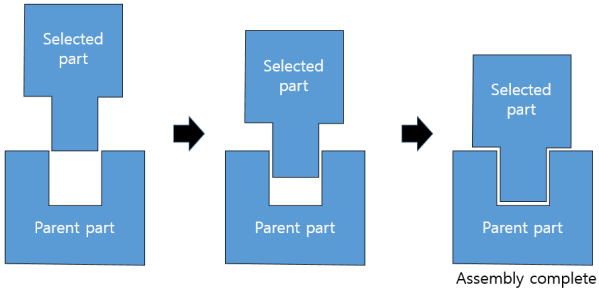

Figure 4. Coupling steps of assembly-prepared part.

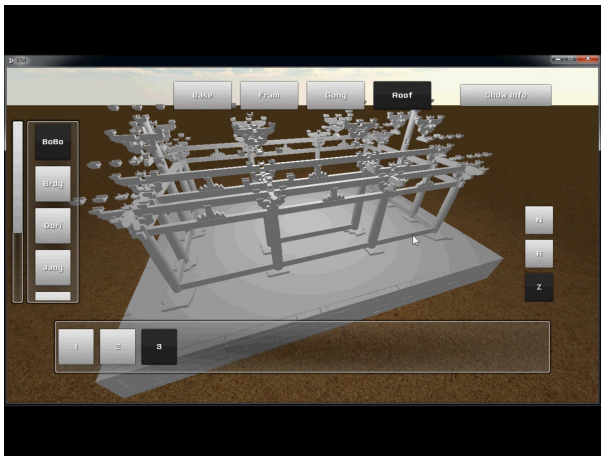

Figure 5. A screenshot of our system.

F. Implementation

We are implementing our system based on Unity [4] on windows PC and a touch monitor. Our goal is to allow user to observe the assembly animation from a user single touch command interactively and easily. As seen in Fig. 5, our interface of our prototype system is consisted of simplified button commands. User can choose high-level category of pats and then, choose mid-level category. A part list is shown in list box on bottom and user can select an interested part. Finally, the system plays the assembly animation.

V. CONCLUSIONS

We have proposed a method for creating an assembly -or disassembly- interactive animation of Korean traditional wooden buildings. Because it is based on the Korean traditional assembly technique, our method shows the reasonable animation with very high quality. Compared to the existing assembly animation techniques, content authors can create high quality animations with less effort. The user experience of our virtual assembly helps to understand about traditional buildings, assembly procedure can verify a construction program for making plans.

BIM is an essential part to construct buildings in efficient way, so we hope our technique to integrate into BIM pipeline. We also wish our animation technique to help users to understand the unique and beautiful structures of Korean traditional buildings.

ACKNOWLEDGMENT

This research is supported by Ministry of Culture, Sports and Tourism(MCST) and Korea Creative Content Agency(KOCCA) in the Culture Technology(CT) Research & Development Program (Project ID: R2013040060).

REFERENCES

[1] Hanok, http://en.wikipedia.org/wiki/Hanok, 2013.
[2] Hanok Building Manual (in Korean), http://hanok.jeonnam.go.kr/01kr/business/book/manual/, Jeonlanam-do, 2006.
[3] Building Information Modeling, http://en.wikipedia.org/wiki/Building_information_modeling, 2013.
[4] M. Agrawala, W. Li, and F. Berthouzoz, "Design Principles for Visual Communication," Communications of the ACM, Vol. 54, No. 4, pp. 60-69, April 2011.
[5] W. Li, L. Ritter, M. Agrawala, B. Curless, and D. Salesin, "Interactive Cutway Illustrations of Complex 3D Models," ACM Transactions on Graphics, Vol. 26, No. 3, 31:1-31:11, July 2007.
[6] W. Li, M. Agrawala, B. Curless, and D. Salesin, "Automated Generation of Interactive 3D Exploded View Diagrams," ACM Transactions on Graphics, Vol. 27, No. 3, 101:1-101:11, August 2008.
[7] S. Kim, S. Lim, S. Woo, and Y. Choy, "A Design of TopicMaps the Structure Modeling of 3D Virtual Architectures (in Korean)," In proceedings of Korean Multimedia Conference 2006, pp. 748-751, 2006.
[8] S. H. Kim, S. K. Kim, and Y. J. Cho, "A Study on the Development of an Intelligent Modeller for the Industrialization of Modernized Korean Traditional Buildings (in Korean)," Journal of Security Engineering, Vol. 5, No. 2, pp. 167-184, April 2008.
[9] J. H. Kim, "A Study on the Assembly System of Korean Traditional Wooden Architecture by the Web 3D VR Technology (in Korean)," Myoungji University, Ph.D. thesis, Dec. 2008.
[10] Y. J. Cho and G. Jo, "A Study on the Development of an Intelligent Modeler for Modernized Korean Traditional Buildings using BIM Systems (in Korean)." Journal of the Korean Housing Association, Vol. 19, No. 9, pp. 55-62, 2008.
[11] K.-H. Lee, "Study of Digital Implementation and Application for Cultural Heritage Based on Multimedia and Augmented Reality Technologies (in Korea)," Hansung University, MS thesis, Dec. 2010.
[12] M. K. Kim and H. J. Jun, "Han-ok Construction Simulation based on Environmental Analysis (in Korean)," Transactions of The Society of CADCAM Engineers, Vol. 16, No. 4, pp. 292-299, August 2011.
[13] J. Ju, H. Yang, and H. Jun, "A Basic Study on the Application of BIM Process for Supply of Han-ok (in Korean)," In proceedings of 2011 Korean CAD/CAM conference, pp. 265-268, 2011.
[14] Unit 4, http://unity3d.com/ , Unity Technology, 2013.

Kyung-Kyu Kang is a researcher at Computer Graphics Research Section, Visual Content Research Department, Creative Content Research Laboratory, Electronics and Telecommunications Research Institute (ETRI), Daejeon, Korea. He received his Ph.D, MS, and BS in Media Engineering at Soongsil University in 2013, 2006, 2004, respectively. His interests include real-time rendering algorithms and physically-based simulation.

Jae Woo Kim is a senior researcher at Computer Graphics Research Section, Visual Content Research Department, Creative Content Research Laboratory, Electronics and Telecommunications Research Institute (ETRI), Daejeon, Korea. He received his D.Sc. in Computer Science from the George Washington University and MS. in Computer Science and BS. in Physics from Hankuk University of Foreign Studies. His research interest includes geometric modeling, computer animation, and visualization.

Ji Hyung Lee is a principal researcher at Computer Graphics Research Section, Visual Content Research Department, Creative Content Research Laboratory, Electronics and Telecommunications Research Institute (ETRI), Daejeon, Korea. He received his Ph.D in Computer Eegineering at Chungnam National University and MS in Computer Science at Korea University in 2011, 1996. His interest includes computer graphics and digital imaging.