Design Integrated Parametric Modeling Methodology for Han-ok

Jeonghyun Kim¹ and Bong Hee Jeon*²

¹Ph.D. Course Student, Department of Architecture, Seoul National University, Korea
²Professor, Department of Architecture, Seoul National University, Korea

Abstract

Han-ok, the traditional Korean house, has the timber frame structure which is common in East Asia. Because the timber frame structure requires a vast amount of hand-cutting woodwork, prefabrication based on computer aided manufacturing (CAM) should be applied to reduce the construction cost of Han-ok. In order to implement them successfully, it is necessary to manage the building information in an organized system based on data handling technology, such as building information modeling (BIM) and parametric modeling. Three-dimensional, object-based parametric modeling technology not only enhances the construction process but also associates well with design study, especially when applying it to Han-ok. By applying the principle of Kan, the Korean traditional concept of a bay, this paper suggests a parametric modeling methodology that reduces modeling tasks and increases the efficiency of design study.

Keywords: Han-ok; the traditional Korean house; BIM; parametric modeling methodology; Kan

1. Introduction

Recently in Korea, public interest in Han-ok has increased remarkably because of the need for sustainability and a desire for cultural identity. Modernizing Han-ok has become both an urgent task and a rising market for Korean architects. The Han-ok shares a common tradition of East Asia in terms of having a timber frame structure. While the aesthetics and the design logic of Han-ok are still valuable and applicable, they are not easy to modernize for several reasons. The traditional timber frame structure requires the hand-cutting method of woodwork which involves much higher labor costs compared to building in concrete. On the other hand, the construction business environment is completely different in comparison to the past. While the roles of architect and engineer are clearly divided at present, the traditional way of building Han-ok did not separate design and construction.

In this paper, we aim to solve these problems by applying the latest information technologies, BIM and parametric modeling technology. Through modeling based on BIM, architects can have a complete three dimensional digital model which associates with a woodcutting machine. (Fig.1.) This enables prefabrication and considerably reduces labor costs to the minimum.

With parametric modeling technology, architects can control the dimension of the digital model of their building through mathematically variable parameters. (Fig.2.) Because the parameters are related to each other with functions, changing the value of a parameter leads to an automatic calculation. In other words, an architect's decision on one part of a building is automatically applied to the other relevant parts. This mechanism minimizes the effort of design study and helps to determine the optimized alternatives. Architects can also use modeling technology to estimate construction costs during the design process.

*Contact Author: Bong Hee Jeon, Professor, Department of Architecture, Seoul National University, 39-525, Gwanak-ro, Gwanak-ku, Seoul 151-742, Korea
Tel: +82-2-880-8761 Fax: +82-2-871-5518
E-mail: jeonpark@snu.ac.kr
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This paper suggests a parametric modeling methodology as a design process. We synthesized the information technologies and the inherent design principles in Han-ok. To clarify the methodology, we discuss a limited number of building elements or specific parts of Han-ok that are important for its structure and design. The fundamental idea of our methodology can be applied to the whole of Han-ok construction and design. As a parametric modeling tool, we used Digital Project developed by Gehry Technologies. It offers more options in parameter definition and customization compared to other parametric modeling tools, such as ArchiCAD by Graphisoft and Revit by Autodesk.

2. Concept of Assembly Unit
2.1 Structural principles of Han-ok

One of the most important characteristics of Han-ok is that they are assembled by separate wood building elements. Each building element of a Han-ok is separately fabricated and assembled on site. This characteristic of Han-ok is well suited to the object-oriented feature of BIM modeling. To be an object-oriented model, each building element has to be separately modeled. This allows property information, such as material, unit cost, and maintenance, which are integrated to the geometrical information of each building element. This feature of BIM modeling is fundamentally different from that of a generic three-dimensional model which only represents the form of a building.

BIM modeling is somewhat problematic in terms of efficiency. Tens of thousands of building elements are needed to build a simple house and there are various kinds of combination of building element. (Fig.3.) In the design process, it takes a vast amount of effort to make BIM models for every alternative. Therefore, we need a simpler modeling methodology that is based on the structural principles of Han-ok.

2.2 Assembly unit

We applied Han-ok structural principles to the concept of the assembly unit for modeling, which makes the modeling much simpler. For example, over 17,000 building elements are needed to make a model of a house, while just 16 assembly units are used to make the same model (Fig.6.)

An assembly unit is a bundle of building elements that are closely related to each other. For example, the building elements of six columns, six foundation frames repeatedly in the longitudinal direction (Beam-direction). (Jeon and Lee, 2006) This set of structural frame and purlins is recognized as a Kan, the traditional concept of a bay, which is bounded by four columns. As shown in Fig.5., a house plan can be divided into structural bays no matter how complex it is.
stones, five purlins and six beams comprise an assembly unit. (Fig.7.) Furthermore, an assembly unit can be combined with other assembly units to complete the entire structure of a house.

Assembly units are divided into three types: structural, wall and floor (Fig.8.). The BIM model for Han-ok is completed by the proper combination of these three types of assembly unit. Structural-type assembly units consist of such elements as columns, purlins, beams, and foundation stones. Wall-type assembly units consist of such elements as windows, window frames, wainscots and lintels. Floor-type assembly units consist of On-dol and Ma-ru, which are traditional Korean floor systems.

3. Assembly Unit Application

The next question is how to define the assembly unit specifically, and how to apply it in the design process. This chapter will discuss the process from extracting to application of assembly units with an existing case of Han-ok.

3.1 Extraction from existing cases

This chapter discusses the extraction process of assembly units from two existing cases, Mr. Kim's House and Un-hyeon-gung. Both of them are designated as examples of Korea's national heritage. Fig.9. is the process of defining assembly units from Mr. Kim's House. Mr. Kim's House is a typical □-shaped house. Phase 1 shows the structural frame. In phase 2, we can understand the building based on the concept of Kan. In phase 3, we can divide the building into 11 assembly units according to the concept of Kan. There are two kinds of assembly unit according to the size. In phase 4, we can see that there are three different types of assembly unit in the structural section. In phases 5 and 6, we can divide the types of assembly unit according to the roof shape. There are three types of roof shape: body, corner and end. Because the structural frame and the roof shape are directly related to each other, we can define the type of assembly unit by roof shape. In phase 7, we can finally extract assembly units from Mr. Kim's House. There are five different types of assembly unit, and we can reorganize Mr. Kim's House with them (Fig.10.). We applied the same process of extraction to Un-hyeon-gung in order to verify it. In the case of Un-hyeon-gung, we could extract eight assembly units. (Fig.11.)

3.2 Customizable planning

Architects can use assembly units at the early part of their design process. Fig.12. shows a brief exercise using assembly units from Un-hyeon-gung. Cases 1 to 3 from Fig.12. show the representative
planning types of the traditional house, such as the ㄱ-shape, ㄷ-shape, and ㅁ-shape. They are based on the existing houses designated as being of national heritage. Cases 4 to 6 from Fig.12. show the customizable feature of the assembly unit, from which we can easily imagine numerous combinations.

3.3 Parametric Operation

Each dimension of the building elements in the assembly units are defined as parameters in parametric modeling. If an architect changes a value of a parameter, the value of the other parameter that is relevant to the first one is automatically recalculated. Fig.13. shows an example of parametric operation in a structural type of assembly unit. If Gan-sal-i, (the distance between two columns), is increased, the dimensions that are related to Gan-sal-i are changed as a consequence. In the same way, an architect can control the height of a column or the depth of a beam.

In the case of a floor type assembly unit, the parametric operation is different to a certain degree. Ma-ru, the traditional Korean floor system, consists of many pieces of wooden plate and block. As the Gan-sal-i increases, the length of the wooden plate increases according to the functional relation until the increase reaches 299 millimeters. If it increases to 300 millimeters, the number of wooden plates increases by 1 (Fig.14.). We translated the construction logic of Ma-ru to an algorithm so the number and the length of wooden plates are automatically calculated according to Gan-sal-i. To summarize and clarify the methodology, Fig.15. shows the whole design integrated parametric modeling process of Han-ok.
using assembly units. When the assembly units are composed as step 4 in Fig.15., we can control the size of structural assembly units by parametric operation. After that, wall and floor-type assembly units are added to complete the process.

4. Conclusion
To integrate parametric modeling technology to the design process of Han-ok, we applied the concept of Kan as a standard modeling unit. With assembly units that consist of multiple building elements, architects are able to design a Han-ok using a simple set of logical combinations. We classified assembly units into three types. According to the design process, each type of assembly unit is used to complete a parametric model of Han-ok. The customizable feature of assembly units allows us to represent not only the traditional house, but also to implement contemporary planning into the process. Through parametric operations, architects can control the dimension, quantity, and geometry of each building element of an assembly unit. As a result, the parametric modeling methodology using assembly units reduces the tasks associated with modeling and increases the efficiency of design study.

In this paper, we focused on the assembly units and their application as a parametric modeling methodology. Further work should focus on how to guarantee the diversity of individual building elements and determining the type of variance of assembly unit.

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