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Customer interactive building information modeling for apartment unit design

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ABSTRACT

Although apartment houses are efficient buildings in an urban society, they have a drawback in that the design of a unit is so monotonous that it cannot meet various customer needs. To provide customers with individually tailored unit designs, this study proposes customer interactive building information modeling (CIBIM), a type of parametric unit design method. In CIBIM, a parametric 3D modeling tool has been used to create separate fixed walls and movable walls which were linked to lighting and furniture families. Customer satisfaction with CIBIM was evaluated through a survey comparing an actual model house and a new design. The efficiency was evaluated by comparing a number of drawings using conventional methods and CIBIM. In comparison, the results show that the CIBIM provides various designs which reflected individual desire to change. CIBIM represents a means to meet customer needs as well as a way to reduce labor requirements by designers.

1. Introduction

Apartment houses which accommodate many people within a spatially limited area are efficient buildings in an urban society. Especially in Korea, among all types of housing, apartments accounted for the highest proportion, at 59.0%, as of 2010 [1]. Therefore, as a type, apartment houses are one of the most important products in the architecture, engineering, and construction (AEC), and facilities management (FM) market. However, apartment houses have disadvantages in that the designs of unit plans are monotonous such that they are unable to meet various customer needs [7,13]. Therefore, there are many people who undertake the remodeling of their apartment unit despite the fact that it may be newly built [4,12]. This represents not only a waste of funds but also generates unnecessary emissions of environmental waste and pollution.

Furthermore, although family types change continuously, designers and engineers could not reflect such changes [7,17]. In 1985, four-member families, the most common type, numbered 2,421,627 (25.3%), whereas in 2010, two-member families were most common, at 4,205,052 (24.3%). It is projected that by 2035, one-member families will be most common, at 7,628,065 (34.3%) [1]. Unit designs should reflect this trend. In addition, the apartment market is faced with a competitive environment due to the over saturation. In 2008, the supply of housing per family was 100.7%, and the rate is becoming gradually higher [1]. Therefore, in such circumstances, the housing market must change from a supplier-oriented to a customer-oriented market [18,21]. Moreover, architectural designers should begin to actively accept the variously changing needs of customers.

However, traditional 2D drawings are limited to the generation of separate drawings such as floor planes, elevations, sections, and details of a building. Therefore, if the design is modified, all of the drawings should be modified individually, which is exhaustive in terms of time and labor, resulting in numerous errors [10]. Furthermore, traditional 3D models are also used for only graphic visualization. They do not provide any information about design analysis and data integration, lacking in consistency within the projects [3]. For these reasons, variation of the design in apartment units with hundreds or thousands of units in a project is hesitantly accepted, not only by designers but also by owners, managers, and engineers.

To resolve these problems with the traditional process, "Building Information Modeling (BIM)", based on parametric designs, has been designed. In a BIM environment, accurate and consistent 2D drawings and 3D models can be extracted for any specified view of a project. This principle reduces the time, labor, and errors associated with generating drawings and models [9,19]. Therefore, when modifications of the design are required, consistent drawings and models which operate parametrically can be generated as soon as the design is changed. In addition, in a parametric design, instead of drawing each building element, such as a wall, window or the furniture separately, a designer defines a model family which varies according to their context [3]. Therefore, using a parametric design in apartment units can be an innovative solution for a designer

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who seeks to diversify the monotonous unit. It can lead to the creation of more various unit designs which satisfactorily reflect the individuality of each customer with high quality in a more efficient manner.

Furthermore, to express the designer's reflection of customer needs, the concept of "Interactive" is stressed in this paper. Recently, due to the development of ubiquitous technology, interactive architecture plays an increasingly important role in urban society [15]. Interactive architecture emphasizes information exchanges including conversations [11], and expresses an appropriate representation to those who seek to resolve the disconnection between customers and designers. Therefore, based on parametric methodology and interactive architecture, "Customer Interactive Building Information Modeling (CIBIM)" is proposed in this paper to improve the communication between customers and designers.

2. Material and methods

2.1. Major features of case project

The CIBIM system proposed in this study was tested at an actual construction site to verify its feasibility. The case is an apartment housing project which is on sale at a model house, scheduled to be completed in June of 2014. The project is appropriate as a case study because it contains a large total number of 2603 units. In this paper, the 84 m^2F type, which accounts for 300 units out of the total of 2603 units, was selected as the case study unit. The major features of the project are summarized in Table 1.

2.2. Application of the CIBIM in unit design

There are several effective BIM authorizing tools on the market, including Revit from Autodesk, Bentley Architecture from Bentley, ArchiCAD from Graphisoft, and Digital Project from Gehry Technologies. In this study, although other similar digital applications could be used, Autodesk Revit Architecture, a universal and user-friendly program for parametric design [3,14] is used to apply the CIBIM. The process to make a parametric unit design system of CIBIM using the Autodesk Revit Architecture program is as follows (Fig. 1):

- Step 1: generate immobile walls. The outer wall and structural wall were locked.
- Step 2: generate mobile walls. These walls are not locked so that the customers can move or remove them as they want. For example, if a customer increases the distance between two walls by 200 mm, the locked wall does not move while only the unlocked wall moves 200 mm. Create the door and window families and locate them in the wall. In the parametric design, designers use a model family, which is a set of relationships that vary according to their context. Families are defined using parameters which involve distances and rules such as "attached to," "distance from," and "same interval." These relationships allow the families to be verified according to their contextual relationships [3]. In addition, create the floor and attach it to the wall.
- Step 3: calculate the area of each room. The guide lines of the area are attached to the given walls so that they can be changed parametrically when the walls are replaced.
- Step 4: create the ceiling and place the lightings on the ceiling. Link the lighting locations to the walls so that they move parametrically with the walls.
- Step 5: create the furniture families and locate them in the appropriate place of the unit. Because the furniture families are defined by the above-mentioned family rules, they can also be modified parametrically when the unit design is changed.

The process using CIBIM is as follows:

- Step 1: the participants see the 84 m^2 F-type model house.
- Step 2: they learn how to use the interface of CIBIM briefly.
- Step 3: they move and remove the walls and furniture of the unit. They can communicate with designers who consult with them about the unit design and assist with the use of the program. The participants can view 3D images at any view of their new design and can alter the design as they please immediately.

Table 1
Major features of the case project.

	Major features	
Address	Hwagok-dong, Gangseo-gu, Seoul, Korea	
Usage	Residential building	
Estimated completion time	2014. 6	
Design parameters	Area of site	132,026 m^2
	Floor area ratio	258.6%
	Number of stories	3 floors underground–21 floors above ground
	Number of apartments	37
	Area of apartments	59 m^2, 84 m^2A, 84 m^2B, 84 m^2C, 84 m^2D, 84 m^2E, 84 m^2F, 119 m^2, 128 m^2A, 128 m^2B, 128 m^2C, 128 m^2D, 128 m^2E, 152 m^2
	Number of households	2603

2.3. Customer satisfaction survey of CIBIM

The CIBIM was evaluated by customers who visited the model house of the case project. They could compare the model house unit design and the modified CIBIM design. In the first step, new apartment unit designs using the CIBIM program were conducted. In this step, participants could communicate with architectural designers who could facilitate a unit design which is appropriate for each participant. Because the design in the parametric modeler automatically adjusts to changes by users [3], customers can reflect their requirements in their new unit design through the exchange of ideas with the designers. In the second step, a questionnaire survey was conducted to compare the different levels of customer experience satisfaction when they viewed the model house and new unit by CIBIM. Ninety eight of the participants responded to the questionnaire survey. Age, gender, cohabiting family number, and computer experience were collected as the general information. Computer experience was evaluated by referring to a previous study measured on a seven-point scale (1 representing no computer use and 7 representing persons who were involved in developing computer software) [23]. In order to evaluate the CIBIM result, the questionnaires focused on three areas: serviceability, design improvement, and availability. To extract the evaluation criteria for "serviceability" and "availability," this paper referred to questionnaires which were used to study the satisfaction of users after using a newly proposed system [6]. The "design improvements" were evaluated through a reference to the semantic environmental (SMB) scale developed by Küller [5]. The purpose of the SMB scale is to systematically evaluate an environment which a customer perceives. Although the SMB scale has mostly been suggested for use in real environments, Küller noted that it could also be used for environments shown with sketches and 3D models. For this reason, the SMB scale was chosen to evaluate the environments of the CIBIM models. Each question was rated on a seven-point Likert-type scale (Table 2).

2.4. Comparison of the work efficiency of conventional CAD and CIBIM environment

To compare the conventional CAD drawings and parametric CIBIM system objectively, this paper proposed counting the expected number of drawings to modify when the design is changed. The number of drawings represents numerically the labor, time and costs required