A Web-Based 3D System for Home Design

Anthony Chong, Ji-Hyun Lee, and Jieun Park

Graduate School of Culture Technology, KAIST, Daejeon, Republic of Korea
Anthony.sk@gmail.com, jihyunlee@kaist.ac.kr,
jieun315.park@gmail.com

Abstract. Buying a home is a big investment and is one of the most important decisions made in one's life. Home owners after purchasing the apartments are interested in having their own home unique design identity. They often seek expert interior designers to assist in designing the homes and bringing out the uniqueness in them. In current interior design industry, designers have to meet the owners often to discuss the designs and alter the housing layout design accordingly to the owners' preferences. This process is often repeated many times before a finalized housing design layout will be accepted by the owners. In this paper, we propose a rule-based housing design system to generate many sets of alternatives housing design layouts based on the initial designer's housing design layout. Designers, therefore, are able to produce alternative housing designs for the owners and also able to explore various alternatives done by the rule-based design system that they have not encountered before.

Keywords: Housing design, rule-based system, web-based system.

1 Introduction

Buying a home is a big investment and is one of the most important decisions made in one's life. Selecting a house or an apartment for a buyer often involved many considerations. Location, cost, family size, neighbors, even to the extents of considering design of the house's feng-shui (Chinese Geomancy) especially for Asian buyers where they believed certain layout of the home design will affect their wealth, health, career and family harmony.

The Korean housing market, which accounts for 43.4% of the construction industry [1], is faced with a highly competitive environment due to various customer needs and the growth of the housing supply ratio (expected to attain to 11.6%), and the changes in housing policies where Korea Ministry of Construction and Transportation has set up plan to construct 5000, 000 housing units every year from 2003 to 2012. By 2012, there will be 5 million housing construction in Korea [2].

However, in most countries (including Korea) apartments/houses are often built with standardized plans that traditional reflects commonly house types. These apartments often come with standard design. Home owners after purchasing the apartments are interested in having their own home unique design identity. They often seek expert interior designers to assist in designing the homes and bringing out the uniqueness in them.

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In a customer-oriented environment, the design of housing however requires intensive communication between the customer and the designer, as well as complicated processes in design and construction phases. Designers and the owners often need to meet up very regularly to determine and to confirm the house designs on papers. These initial design concepts are then be further defined, criticized, and rejected, or revised, refined, and developed until a housing design is accepted by the clients. Regular changes to the design are made very often on the spot due to many reasons, for example, budget costing, materials of furniture, lightings and so on by owners. Rough plan proposals are reviewed and revised until a finished plan which meets all requirements is presented and approved.

In housing design, there is decision which an interior designer take is likely to have implications that cut across multiple aspects. Removing a room's balcony, for example, may result in a bigger comfortable room with more space, but at the same time, the room will feel warmer during summer and colder during winter along with bad noise insulation problem. These isolated issues themselves are the interconnectedness which makes interior design a highly complex activity.

The paper is organized as follows: Section 2 is the literature review describing the housing design concept development and listed some of the commercial home design software products available in the market. Section 3 introduces the basic design rules. Section 4 describes the implementation of the rule-based home design system to a design scenario. Section 5 concludes this paper.

2 Literature Review

2.1 Housing Design Concept Development

The final design of a housing layout accepted by clients often involves intensive discussion between the customers and the designer. This is the information acquisition process where time should be spent to gather as many facts as possible about the inhabitants of a home, getting the idea of who they are and what they like. It is important for a designer to conceptualize the future housing layouts his or her clients would prefer. There are the basic four elements in planning a house design that a designer have to consider, understand and gather before the graphic stage of planning any housing design drawing on paper [3].

The designer has to form (1) a Client Profile to find out the number, ages, sex, activities and relationship of people who will make up the household in order to met the special needs and interests of each individual and of the group. Normally this planning also involves the degree of privacy and the interaction. Designer also has to know and understand his or her clients' lifestyle. For example, the clients have a hobby of rearing fishes and the designer has to consider the fish tank in his or her housing design stage. Designer has to know whether the clients like to invite friends to their home on every weekend or prefer to spend the weekend quietly working on a hobby in the house. In this case, the living room's size has to be taken in mind during the design stage.

Designer also need to consider the (2) Functional Goals during the design of the housing layout. Lifestyle of the family determines the home functions for which it is

being planned. The designer needs to consider any special needs for the clients who might need a home office with separate access or special facilities for an elderly or disabled person.

When designing the layout of the house, designer needs to look at the (3) Equipment Needs where designer needs to know what kind of equipments the clients will be having in the house, for example, electricity appliance (television, sound systems) during the planning of the housing design.

Designer needs to look into the (4) Space requirements where it is highly based on the careful study of the activities, behavior patterns, development needs and desires of the clients. The clients might love to read and have a big collection of books and the collection will generally increases slowly. The designer will have to put this information into consideration when allocating the space for during the design process.

In the complexity of housing design, it is necessary to allow creative ideas and inspiration to develop and evolve freely. At this stage of the design process, creativeness begins to synthesize all the previously gained data with professional housing design knowledge and experience into a concept which will determine the outcome of the housing layout design. Designer uses bubble diagrams from adjacency studies and schematic drawings to generate floor plan via a series of sketches which begin to allocate more concrete layout shapes to activity spaces. A two dimensional floor plan drawing may seen as plain and it is sometimes hard to read, but its importance in determining the kind of life possible in any given space. Designer must first digest, analyze, and evaluate the information gathered in a systematic way. The design process provides a number of ways by which to organize and translate information into solutions. Interior zoning (zones) and adjacency studies are often used in design principles.

In zoning principle, regardless of the size of the house, space divides itself into zones that group similar kinds of activities accordingly to the degree of privacy or sociable interaction. Designer normally starts the design accordingly to three activities -Social (living, dining and balcony), private (bedroom) and work (Kitchen) activities.

In adjacency principle, the relationships between various spaces and activities can be outlined roughly using a bubble diagram to group and organized accordingly to zoning principles. The Bubbles represent interior spaces and their importance and relationship to each other. The connecting lines between bubbles indicate access and flow. It is easier to do this with the abstract tool of a bubble rather than to begin defining spaces with walls and the technical relationships between rooms, access and flow. Errors can be seen by conceptualizing what was a thought into concrete relationship on paper. This process is critical and precedes formal space-planning and help to clarify how space relates and flows before floor plans are drawn.

Schematic drawings are made to help visualize concepts. They are refinements of the bubble diagrams used in analysis, with greater details, more accurate proportion and with measurement, suggesting how the space might look and feel. A bubble diagram with correspond to its schematic diagram is shown in figure 1.

2.2 Home Design Software Products

Designer often uses 3D modeling software (example 3D Studio Max and 3D Maya) to assist in their job. However, in recent years, commercial home design software

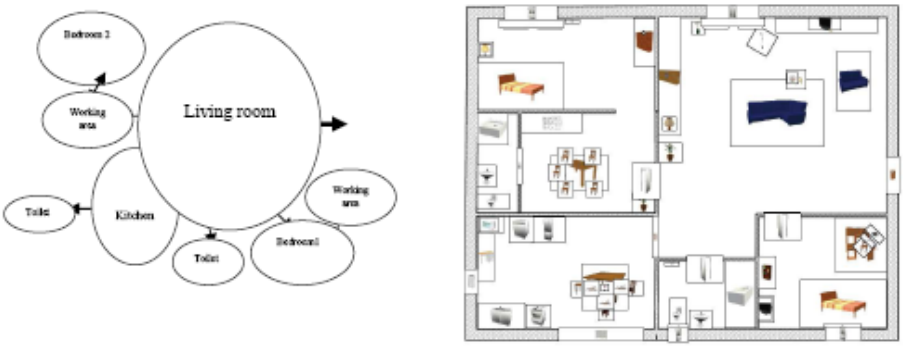

Fig. 1. A bubble diagram and its 2D schematic representation diagram. In bubble diagram, larger bubbles represent larger space. Overlapping bubble are common spaces that are accessible from another space (Kitchen and Living room).

products can be found in the market. 1) Punch! Professional Home Design Suite [4], 2) Better Homes and Gardens Home Designer Suite [5], 3) Instant Architect [6], 4) Total 3D Home & Landscape Design Suite [7] 5) My Virtual Home [8] 6) 3D Home Architect & Landscape Design Deluxe Suite [9] 7) Instant Home Design [10] 8)Your Custom Home [11] 9) Design Workshop Classic [12] 10) Quickie Architect [13]. All these packages offer easy-to-use application software products offer carious degree of features such as 3D household objects libraries with license fees involved. These commercial home design software products are not web-based and their functionalities are limited.

Therefore, we propose to modify an open source home design software to allow the introduction of design rules to generate new housing layout automatically. The next section will describe the basic rules for developing the rule-based housing design system.

3 Design Rules

In housing design, designer often requires intensive communication with the customer to finalize the housing design layout with the clients. During these period of communication, designer often draw multiple design layouts to show to the clients. This is very time consuming for both parties. In this work, we aim to develop common housing design rules that will allow computer to help the designer in generating housing layout automatically.

In previous section, the 4 elements are often used by designer in collecting information from their clients. Designer uses these information to manually design the first housing design layout for the clients. Taking the first housing design layout, introduce the basic rules to the home design software to generate multiple new housing design layout based on the initial housing design layout.

The 3D coordinates of all objects in the housing design layout will be defined. This is to ensure objects faced the correct direction as determined by the initial housing design layout. The 15 basic rules are determined as followed.

1. All objects (furniture) must be within the dimension of the walls of each individual room. Designer would have considered the furniture style for each individual room during the initial design.
2. Toilet cannot be relocated. The reason is due to the understanding of the drainage piping system of apartment building.
3. All windows cannot be move and resize due to the windows locations in apartments are fixed.
4. Living room area dimension size cannot be changed as the designer would have considered the lifestyle of the clients.
5. All doors must have a clearance of more than 1 meter facing inwards and outwards. This is to ensure doors are not blocked by other objects in the design.
6. All enclosed dimension (4 walls) will generate a door. This is to prevent an enclosed area without a door.
7. Door dimension cannot be changed.
8. All four edges of the door must be in collision with the wall and the floor. This is to ensure no stand-alone door appearing in the new housing layout design. The collision detection algorithm will be used.
9. At least one edge of wall must be adjacent to any other wall. This is to ensure no stand-alone door. The collision detection algorithm will be used.
10. No penetration of furniture with any other object by employing collision detection algorithm.
11. No less than 2 meter gaps between two parallel walls. This is to ensure proper housing layout.
12. The x-axis of the L-shaped couch is always in the direction of the LCD TV.
13. Backside of all bookshelves must collide with the wall. The collision detection algorithm will be used.
14. Headboard of the beds must collide with the wall. The collision detection algorithm will be used.
15. Base (-ve X-axis) of all objects will always be in the direction of the floor. This is to prevent objects from appearing upside down.

These are the common rules that the home design software must be receiving and with these rules, new multiple housing design layouts can be generated automatically by the computer. These rules, depending on the owners' requirement and needs, can be changed and updated to the home design software. The next section, we will introduce a free open source home design software (Sweet Home 3D) to demonstrate our work.

4 Implementation

4.1 Software Environment

In our work, Sweet Home 3D (http://sweethome3d.sourceforge.net/), an open-source free interior design application, with a 3D preview was used for the designing and modeling of an apartment. Sweet Home 3D enables designers to easily design their housing layout with ease. This allows the designers to design and make the changes with ease with the home owner's concepts in mind. In this section, we will use this

software with the basic rules as set in the previous section to generate many sets of alternatives housing design layouts based on the first initial designer's housing design layout. Designers therefore are able to produce alternative design for the owners done by the framework and also able to explore various alternatives done by the design framework system that they have not encountered before. This rule-based housing design system offers the designers a promising application for the housing domain because it allows times and efforts to be saved from showing multiple housing layout design to customers. Sweet Home 3D is written in Java and offers the ability to extend the functionalities of this application to include rule-based design to generate multiple housing design layouts. Sweet Home 3D has an applet version which supported web-based home design.

4.2 A Design Scenario

We will describe a scenario in this section to demonstrate of our rule-based housing design concept. A woman and an adult son purchase a new apartment. The mother (62) is a retired teacher who teaches private knitting in her home. She has over 30 years experience in knitting and has is now teaching knitting at the comfort of her apartment. Her son (30) is a freelance 3D computer animator who works at home accepting various computer animation modeling jobs from his agency located in another city remotely.

The designer will design the housing layout and furnish these specific rooms for the clients.

1. A knitting room for the mother
2. A Dining/Living room
3. One bedroom for the mother
4. One Bedroom/home office for the son
5. A Kitchen
6. Two toilets

The bedroom/home office: Is to be a quiet, orderly work environment for the son who can work from home. He will not have on - site clients. The home office needs to have a computer server (to save his data and work), a computer with a large scale monitor and professional books. The son has requested a desk, a bookshelf, an ergonomic office chair; appropriate lighting; floor, wall and window treatments; and furnishings, finishes, and accessories (FF&A) for his office.

The knitting room: Is to be a space that will be a well - lighted inviting creative environment for teaching knitting to students of all ages. The space should be big enough to occupy up to 5 students. She has requested storage for knitting equipments (needles, yarn).

The Living Room will serve as a combined relaxing social and informal entertaining area. There is natural light from windows. Access to the home office and knitting room will be through the living room. The client would like an informal designated eating and serving area to seat a maximum of 8 people.

Bedrooms: Standard furnished common bedroom.

Client Preferences: The clients have asked the designer to begin with the rooms as if they were white boxes. Architectural details are to be appropriately drawn to scale and all floor, wall, window, and ceiling treatments are to be decided by the designer.

The designer based on the requirement of the owner and created the initial housing layout as shown in figure 2. This initial housing design layout which the designer designed is based on the information gathered from the owners. All requirements from the owners are met: two bedrooms, two toilets, one knitting room, a kitchen and one living room with enough space to entertain 8 people. The mother's bedroom (upper left hand corner) is next to the knitting room with a single partition. The son's room is at lower right hand corner.

Fig. 2. This initial housing design layout which the designer designed is based on the information gathered from the owners

4.3 Implementation of the Design Scenario

We executed the rule-based Sweet Home 3D to generate new alternative housing design as shown in figure 3, 4, 5 and 6 based on the initial housing design. Each figure shows different housing layout designs with comparison to the initial design from the designer.

In figure 3, a new partition wall has been created in the son's room (lower right hand corner) to create a mini-office environment. One of the edges is adjacent to the side wall obeying the basic rule. There is no object collide with that new wall. The partition between the mother's room (upper left hand corner) and the knitting area has been extended to provide an enclosure for the mother's room. An extra door has been created for the mother's room. The two toilets and windows remain at their original location.

As shown in figure 4, the couch and bookshelf in the living room have been shifted but not out of the dimension of the living room. The locations of the mother's room (now at lower left hand corner) and the kitchen (now at upper left hand corner) are switched. A corridor has been created between the knitting room and the mother's room obeying the rules (>2m gaps) between parallel walls. The doors for the toilet and the knitting room have been re-located.

Fig. 3. Computed layout based on the design rules with comparison with figure 2 (designer's design)

Fig. 4. Computed layout based on the design rules with comparison with figure 2 (designer's design)

As shown in figure 5 below, the couch and bookshelf in the living room have been shifted. The kitchen is now at a new location (upper left hand corner) and the mother's room is now created at the lower left hand corner. The knitting room has is now at the lower left hand corner. The mother's room has been shift to the center. A new door for the mother's room has been created. The door obeys the rule of clearance at least of 1 meter. Location of the bookshelf at the living room and the bed itself does not allow the door at the other walls to have a 1 meter clearance. A new wall partition has been created in the son's room to ensure better privacy. The doors for the toilet and the knitting room have been shifted.

Figure 6 below shown the couch and bookshelf in the living room have been shifted. The son's room is now at a new location (upper center). The area dimension of the living room remains the same obeying the dimension rule of the living room.

Fig. 5. Computed layout based on the design rules with comparison with figure 2 (designer's design)

Fig. 6. Computed layout based on the design rules with comparison with figure 2 (designer's design)

5 Conclusion and Future Work

We proposed a rule-based system where the Sweet Home 3D is able to accept rules as listed in section 3 to generate new alternative housing design from the initial housing design. Designer will have the first meeting with the owners and will collect design layout preference information from the owners. Designer will use sweet home 3D to create the initial design and introduces rules to the modified sweet home 3D software to generate multiple housing design layouts for the clients at the second meeting. This will reduce significant time and efforts for both parties to reach to an agreement on the housing design layout.

For the future work, the system could be improved by using a Case-Based Design approach where past experience of home designer will be stored and updated. This to allow the designers to look at each problem as a new case and computer is able to search for a related solution from the database. The system will revise the former solutions and adapt to the new situation. Designers can re-use the stored past experience to assist them in their housing design.

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