Virtual Architect / Questionnaire Approach of Programming Modular Houses

Chuen-huei (Joseph) Huang / *Illinois Institute of Technology, College of Architecture, USA* / ***huanchu1@iit.edu; http://www.iit.edu/~huanchu1***

Abstract *By integrating the nature of modularity in prefabricated housing design, a web-based design **advisory system** provides interactive questionnaires to assist **customers** in selecting appropriate design components. The prototype model combines the result of client's requirement input and design configurations of a modular system. The digital model is created by Building Information Modeling (BIM) applications to streamline the **delivery process** from design to manufacturing. Finally, the BIM design model can be reviewed via Google Earth before sending the ready-to-build digital information model and building specifications to the collective manufacturers and suppliers.*

Introduction If mass production and prefabrication methods of the assembly line were the ideal of architecture in the early twentieth century, then mass customization and the development of digital technology are the recently emerged paradigms of the twenty-first century. The development of the digital revolution has already prompted the shift towards mass customization. In this new industrial model, computer-aided manufacturing facilitates variations of the same product. The Internet has increased the opportunities to apply the concept of mass customization to customer interaction by tailoring the content to individual needs. Within limited design parameters, customers can determine what options they wish by participating in the flow of the design process from the beginning. This concept has already been implemented in the computer, clothing, and automobile industries, but it has not been fully integrated in architecture, especially the housing industry which is more directly related to personal life style. The industry lacks a process that will lead to the customization of homes that respond to the unique values and needs of the occupants.

One of the problems that prefabricated housing industries failed to address in the twentieth century was the lack of variability and an individual identified design (Kieran & Timberlake, 2004). In order to transform the prefabricated housing design from mass repetitive production level to mass customization level to meet flexibility and variability, the research methodology integrates a participatory home design concept with web technology to create an online interface that the clients can make more choices and establish a better communication with architects and/or manufacturers. Moreover, face-to-face meeting time between architect and client is always limited and time consuming, while a computational web-based design approach is infinitely patient and always available with network connections (Larson, Tapia, & Duarte, 2001).

Background

Current Approach of Consumer Participatory Design in Modular Houses Sears mail-order kit houses, from 1908 to 1940, can be viewed as the first customer-tailored mass product in the housing industry (Thornton, 2004). Sears provided a house plan catalog with the added advantage of modifying houses and hardware according to buyer tastes, and shipped the appropriate precut and fitted materials to the customer's site.

With today's technology, the internet is the perfect medium for the dissemination of domestic design. Many pattern book companies now have big websites offering thousands of house plans stored on databases searchable by type, style, square footage, average cost, number of bedrooms and so on (Davies, 2005). Some websites also provide the design tool for customizing exterior and interior finishes after the clients have selected the base model from a house plan catalog.

Problem Statement Although the engagement of internet with pattern book concept can create a

power of e-commerce for the housing industry, the end result of web surfing may or may not fit the client's spatial needs. Unlike the other industries (shoes or watch), a suitable house design is not only judged by its appearance or architectural style, but also involves a series of architectural programming phases. Figure 1 demonstrates that by reversing the sequence of choosing a product image to get spatial features and functional details, a knowledge-based questionnaire can be a new format to collect client's input (Huang, 2007). The interactive web interface will provide suggested design solutions based on client's needs. The main goal of this research is to investigate the possibilities of customizing mass housing by internet and prefabrication technology beyond the finish material selecting process.

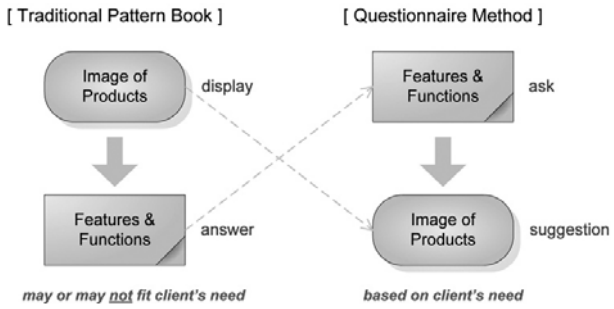

Figure 1 ***Difference methods of consumer-product interaction***

Methodology

Conceptual frameworkIn order to achieve the goal of mass customizing prefabricated modular housing, The conceptual design model must combine the results of two important parts: data collection of client's requirement and prefab system design combinations. The web-based prototype can simulate the interaction between clients and the adoptable systems.

The evaluation part can include a series of case studies to demonstrate and revise the data-input method within the design interface. Finally, the resultant design can generate building specifications prepared for manufacturing.

This research will be more focused on input methods of the end-users instead of architects for finding suitable design solutions of prefabricated housing.

Digital Questionnaire The proposed digital questionnaire model links a series of pre-established answers that define the architectural implementation from its database, and the users will receive real-time feedback to evaluate room layout and home design solutions from the digital interface. From general spatial need to detail preference, there are four different levels of questionnaire to be developed as the programming of this prototype system: (1) Generate a list of required spaces, (2) Determine each room size and relationship of plan by function, (3) Define the detail layout of individual spaces and the development of the plans and elevations, and (4) Customize material and color selections for exterior and interior components.

The method of questionnaire can be very effective in determining whether or not most respondents share the viewports of those initially interviewed. Like the interview, and unlike observation, the questionnaire can be used to get at why people do what they do, what they think works well or poorly, and how they think something might be done better – but only within the limits of the alternatives actually provided in the questions (Hershberger, 1999). Actually, the limited alternative options provided in the proposed model are represented the available modular systems and components in the existing market. With architect's modification after the chosen model from the advisory system, fully customized design solutions can beyond the limits of digital questionnaire.

Interface Design and Web

Organization The proposed i_Prefab Home design interface for customizing prefabricated housing shows in Figure 2. When a user puts the correct webpage address in the internet browser, a static HTML page will open with a welcome message and simple instructions for this intuitive system. The web page has been divided into six frames; besides the information and design process frames on the top plus view navigation and output services frames on the bottom of the interface for different purposes, the system actually only contains two main components:

client's input on the right window and design visualization output on the left window.

Figure 3 shows the general web structure and major consulting procedures. The navigation window on the top-left has four main categories: Gallery, Client (basic mode), Designer (professional mode), and Collaboration. The consulting procedures represent the different phases of architectural programming and highlight the current status in the Design Process Window. In this prototype simulation, only the consumer-driven basic mode will be implemented along with the related information contents. Future research will be described in the last chapter that the supply chain collaboration by online digital BIM models & available technologies will be integrated into a complete and comprehensive system.

The website organization diagram introduces six important steps of the design consulting process, and five of them can be achieved in the basic mode with fully participated by the client. At the end of each step, the system can provide a preview of the current result as a temporary reference, and at anytime during the process, the user can go back to the previous step for changing the selected options. The optimum goal of the prototype system is to record the client input data and output design results as the future reference for anyone who matched the similar input data may get the design suggestion form the database. Currently, the Amazon.com website already implemented this matching favorite concept. With the matured development of artificial intelligent (AI) technology in the near future, machine-learning capability is not just as a dream.

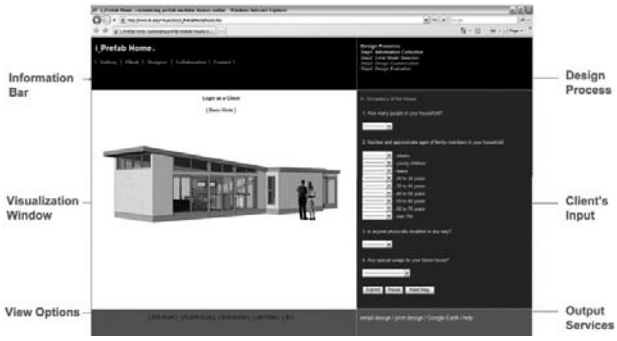

Figure 2. i_ Prefab Home Desing Interface

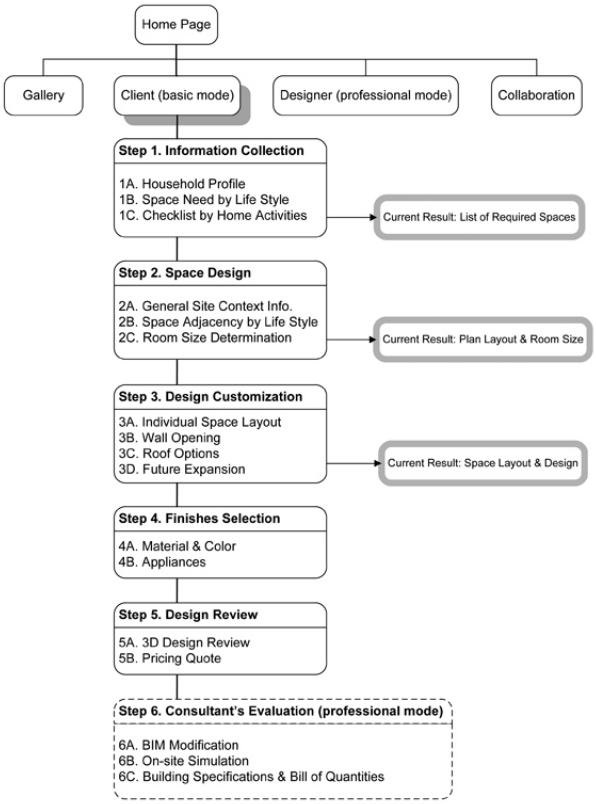

Figure 3 Website Organization of the Prototype Simulation

Professional Consulting and Evaluation Integrate BIM for Collaboration In order to transform the client selection design information and the evaluation process by professionals (architects and engineers) with the fabrication process by the manufacturer, the virtual design geometry should be represented as an information-contained object, not just a graphic entity. Figure 4 demonstrates the pre-design diagnostic website (left image) which is available anywhere with internet connections. All design suggestions are represented as a virtual building online and the digital design model with customized client-input data is then transformed into a Building Information Modeling (BIM) application using Autodesk Revit or a similar program (Figure 4, middle image). After professional review, the BIM digital design model includes all of the construction information and is

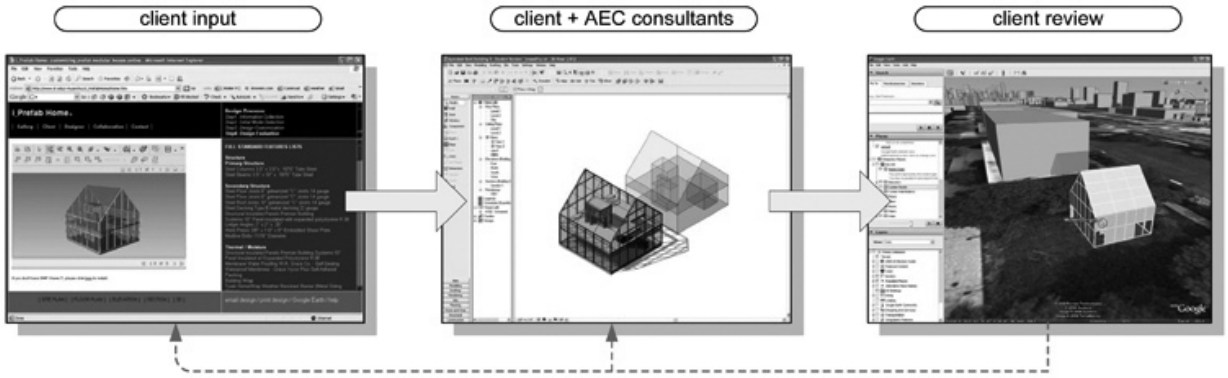

Figure 4 ***Expectation of proposed housing delivery process***

ready for the coordination with manufacturing and the assembly of the building components in the factory. The digital design model also can be exported from the Revit application to Google Earth (Figure 4, right image) to position directly with the exact site information and provide the client with a review of the house as a four-dimensional experience. Overall, the diagram shows the expectation of housing delivery process from web-based programming to digital design collaboration and virtual environment simulation.

Virtual On-site Design Review The professional modified digital model also can be exported from Revit platform to Google Earth for the clients to preview their future house with the virtual building site context from anywhere of the world with an internet connection. Since the plug-in connector contains all BIM data when exporting from Revit to Google Earth, professional users can easily control the layers of each individual building component (i.e. roof, wall, floor, stair) to see the interior space and do further modifications. The design review process may then go back and forth between Revit and Google Earth.

There are three reasons for integrating Google Earth: (1) Virtual on-site simulation for the clients and professional participants to have a four-dimensional experience (i.e. fly-through, walk-in) to review the design before the manufacturing process.

(2) Consideration of not only the individual house design, but also the harmony of integrating the new house into the neighborhood.

(3) Contributing and constructing the up-to-date virtual design buildings to the global database for future reference (public and private use).

Conclusion The results of this current phase of research establish an open-ended framework of a decision support system by dynamic questionnaire to find design solutions for future reference. The current research work will lead to more affordable housing that takes into consideration of personal preferences. The fruits of this research will support our society in the continuing quest of home ownership. The interpretation of translating the client's need to match different spatial configurations of the design models from the selected prefabricated modular housing vendors is based on architect's assumption. However, this is an online recommendation to replace the limited face-to-face first meeting time between architects and clients. Revising the modular unit to be more flexible and client responsive is the feedback to the modular housing architects and vendors. Overall, the research combines the theoretical idea of mass customization with the practical application of digital design and prefabrication technology. Addressing a particular problem in the design of prefabricated modular housing allows us to see bigger issues in participatory design approaches.

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