Integrated Physically Based Manipulation and Decision-Making Tree for Navigation to Support Design Rationale

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Abstract. We explore the idea of integrated physically based manipulation and decision-making tree for navigation to support design rationale. It introduces a way to support user participation. This paper also proposes and validates a framework which combines several techniques to aid user to make decisions. We hope this research can assist untrained users to quickly feel comfortable and satisfied for a computer aid system by rational way. This paper focuses on a system prototype for the client customization process in apartment plan design to exemplify our concepts.

Keywords: Rational, Navigation, Decision-making tree, Fuzzy.

1 Introduction

It places importance on user participation in contributing to the success of a generative system has been a long held theoretical belief [10]. There are two fundamental issues in user participation: First, most users have little knowledge about design professionals. Second, the users are novices who may not easily manipulate the software the designers use. Research prototypes and applications address the first question by rational knowledge-intensive systems. When users need the knowledge of design for rational, the system should guide them to the goal through vast information space. To search and visualize the vast information space, building decision-making trees is necessary for navigation. Navigation is the cognitive theory that incorporates landmarks as general orientation points and be able to display design spaces at arbitrary levels of details and allow users to identify their abstraction settings. Decision-making tree can provide a navigational manner that allows designers to access desired information in a generative design system easily. In addition, decision-making tree can be operated by user to enable knowledge management and reuse. It can help users to generate their alternatives and provide reasoning by causal relationships. Physically-based manipulation is introduced to address the second question, because it can let people understand their decisions easily by interacting design elements intuitively and iteratively in the schematic design layout process. This paper proposes a 3D generative system using navigation concept to integrate physically-based manipulation and rational decision-makings to help apartment buyer to participate the layout design through information space.

This paper also proposes and validates a framework which combines all techniques we mention above to aid user to make decisions. The objective is to provide the user with effective and appropriate decision-making representations and inference mechanisms to support the design rationale. We focus on a system prototype for the client customization process in an apartment plan design.

2 Literature Review

In the last several decades there has been a tremendous wave of interest in the relationship between rational and design process. In the past, design matter usually depends on professional designer's experience, ability, and preference. This kind of design always causes that design process has a lot of contradiction and irrationality.

Relatively, rationality brings about comprehension between profession designer and client. Rational is a good understanding of the ideal process will help us to know how to proceed and having a standard procedure. It becomes much easier to measure the progress that a project is making. We also can compare the project's achievements with those that the ideal process calls for. Decision making is an important part for rational design. A series correct decision is more approachable for rational. Gordon [6] introduced the generic information-processing model integrating views of naturalistic decision making. It helps us to know people's cognition and decision making in real-world. In this model, information enters the model and then is processed at one of three levels: automatic skill-based processing, intuitive rule-based processing, and analytical knowledge-based processing.

Parnas and Clements [8] also descript why irrationality will happen:

- (1). In most cases the people who commission the building of a design case do not know exactly what they want and are unable to tell us all that they know.
- (2). Many of the details only become known to us as we progress in the implementation, the resulting design may be one that would not result from a rational design process.
- (3). Experience shows that human beings are unable to comprehend fully the plethora of details that must be taken into account in order to design and complete and correct project.
- (4). All but the most projects are subject to change for external reasons.
- (5). Human errors can only be avoided if one can avoid the use of humans.
- (6). We are often burdened by preconceived design ideas, ideas that we invented, acquired on related projects.
- (7). Often we are encouraged, for economic reasons, to use design component that was developed for some other project.

The central purpose of this study was to investigate how to approach rational design. For catching people's requirement, Fuzzy logic is a rule-base type of control that uses concepts from fuzzy set theory, and it has emerged as a criterion of intelligent control capable of dealing with complex and ill-defined problems [5]. The

process of designing fuzzy logic systems is explained by the following development steps [5]:

- (1). **Fuzzification:** defining linguistic variables and types of membership functions to describe a situation.
- (2). **Inference:** formulating the proposition logic such as IF-THEN statements to make fuzzy rules for inference.
- (3). **Defuzzification:** obtaining the crisp results.

For having a steady rational design process, it builds a knowledge base system is necessary. Knowledge base system supports the user's actions or controls and prompts the user's intention so that the user can design drawings according to the standard or the best way [11]. The rule of knowledge in knowledge base system can include fuzzy theory and expert knowledge to infer recommend of design for user. But, knowledge base system has self contradiction and redundancy information problems [11].

Navigation is a way which can look for useful material in large information spaces. Navigable space has become a new tool of labor and a common way to visualize and work with any data, since it can be used to represent both physical spaces and abstract information spaces [7]. Many researchers have suggested that imposing a spatial structure to information spaces (regardless of their inherent structures) could make the task of seeking information a more effective and pleasing activity [3]. A decision making cone tree (Fig.1), it is one of the best known 3D graph layout techniques in information visualization [4], supports user to present and record user's motive and history path. It also navigators predict goal for design process.

Fig. 2. Cone tree (Image courtesy of Palo Alto Research Center; Brian Tramontana, photographer.)

In order to advance navigation, one of the geometric models, known as direct manipulation (DM), however, can support design integration in terms of continuous representation of the objects and actions of interest; physical actions or presses of labeled buttons instead of complex syntax; and rapid incremental reversible operations whose effect on the object of interest is immediately visible [9].

Physically based manipulation, a concept of DM, therefore, can be recognized as a promising approach to implement interactive computational tools to solve the user

participation problems because it allows people to communicate their ideas easily by interacting intuitively and iteratively with the design elements.

3 Developing Framework for Rational Design

This research attempts to approach rational design. So, knowing human's decision making process is helpful for creating a module to help user making decision.

Based on the Gordon's model, we want to develop and match our conceptual framework of the information processing procedures with the generic model, each of which has different level of details. We show the modified framework in Fig. 2.

3.1 Framework

Automatic processing and intuitive rule-based processing. Automatic processing, which is at the lowest level of the model, directly triggers an action response. Reflex is activated in this process. In a sense, this is not even really decision making or problem solving [6]. For intuitive rule-based processing, the cues trigger retrieval of appropriate cue-action rules from long-term memory. This research tries to integrate techniques from processing in order to aid people who can make decision easily. Navigation support will travel the information space to got useful path to approach the goal. Navigation operation will intelligently to highlight trick for user; and then, Physically-based manipulation can support design integration intuitively in terms of continuous representation of the objects and actions of interest; physical actions or presses of labeled buttons instead of complex syntax; and rapid incremental reversible operations whose effect on the object of interest is immediately visible [9].

Analytical knowledge-based processes. When intuitive rule-based processes do not provide a satisfactory solution or decision and situation is allowed, the decision action will go upward to the Analytical knowledge-based processes. There are three stages in this process: evaluate explanation, evaluate action, and evaluate plan. In our research, for evaluate explanation phase, we build decision-making tree which represents causal net by using scenario-based design. Scenario-based design (SBD) makes ambiguous and dynamic situations easy to evoke reflection in the design process by embodying concrete design actions [1]. A design scenario, in turn, can be expanded into more detailed sub-scenarios, each of which has a set of associated design moves that the respective process should accomplish. Each design move is associated with each operation procedure of physically-based manipulation as well as constructs a node of decision tree, which can help users to know the solution path of the design decision-making process. In evaluate action phase, we build a generative system which can generate prototype in a show time, so that user can find plausible solutions and judging the validity of solutions relative to the goals and selection among alternatives. Finally, evaluate plan phase will justify decision-making tree by rational design management. The process of designing consists of a long series of design decisions tree so that we can analyze causal-effect history path by rational design management that attempts to capture the rationale behind the design (required decisions, the reasoning behind the choice of final solution(s) and dependencies between decision

Fig. 3. Modified from the generic information-processing model by Gordon [6]

nodes). The system has an optimization design rationale network which will match with the decision making tree. After that, it can infer the related knowledge and suggest design advices or solutions to user.

3.2 Irrationality Reason and Solution

All of technique place to framework in order to deal with irrationality problem. We mention the cause in section 2. Table 1 is arranged for match the problems and solution.

Table 1. The irrationality reason and solution

irrationality reason	Solution
1. People do not know exactly what they want and are unable to tell us all that they know.	Fuzzy
2. Many of the details are not follow rational design process.	Knowledge based system
3. Human beings are unable to comprehend fully details.	Navigation
4. Subject to change for external reasons.	No
5. Human errors.	Decision-Making tree support to revise. Physically based manipulation.
6. Preconceived design ideas.	Rational design
7. Economic reasons use design component from other project.	Generative design

3.3 Difference from Original Model

Several theoretical positions have been sketched out here. This research has presented a general framework which includes technical method to reduce complex in decision making process. In intuitive rule-based processing, navigation guide people to deal with computer operation for easing off use obstacle. Forward, causal net assist to understand whole situation and encourage consistency in evaluate explanation. Generative design urges to explore different design alternative and show possible outcome immediately in evaluate action. Rational design provides a craftsmanship to support effective judge.

4 Prototype System

4.1 Implementation

The prototype implements various components based on the framework introduced in Section 3: the knowledge base and inference module implemented by commercial software (*fuzzyTECH*), a 3D layout generator implemented using physically based manipulation, a design justification module, and a graphical user interface (GUI) module. Fig. 3 shows the Fuzzy inference using by *fuzzyTech*.

The 3D layout generator is implemented using Jogl on top of OpenGL as APIs, to visualize and provide an efficient physically based manipulation mechanism to communicate between the user and the system. The design justification represented by a decision tree is implemented using the Java programming language. Finally, we built a GUI implemented by Java to communicate with the *fuzzyTECH* Java Runtime Library and Jogl for the 3D layout generator, and to seamlessly integrate all the modules with a coherent interface.

Fig. 3. Fuzzy Inference by fuzzyTech

The GUI of our system includes three major parts: (1) a query window to capture the user requirements and preferences, (2) a 3d decision cone tree window to record design alternatives created by the user manipulation and to support the design justification, and (3) a main window to visualize the 2D and 3D floor plan.

4.2 Result of the Application to Apartment Customization Process

The purpose of this research is helpful to apartment customization process in real world. We provide a scenario to describe practical application. We show the work flow between client and agency in Fig. 4.

When a client is willing to buy a pre-sale apartment, he/she will go to the sale agency to acquire information of unit. If all condition is satisfy except layout, he/she

Fig. 4. Describes the process of apartment plan customization between client and agency (revised from Cheng [2])

Fig. 5. Query window

could ask the agency that he wants to modify the layout. In this moment, agency can provide the generative system to help client express what kind of layout he/she want.

A client can start by answering a series of design move questions from the Query window (Fig. 5). According to the client's preferences, our system proceeds with the fuzzy inference mechanism.

The knowledge window (Fig. 6) provides related knowledge to the client in the plain language form via the defuzzification mechanism in the right column of the window. The left column of knowledge window shows a 3D decision cone tree. Decision cone tree can help to present a lot of elements in restricted space. It also has another advantage which can let user know forward goal or roll back from error situation. Each hierarchical step represents a corresponding design move, which is selected from the knowledge base. When the client selects an L-D-K configuration node from the decision tree, for example, the right column of the window explains the basic relations between the living room (L), dining room (D), and kitchen (K) to the clients. The main window (Fig.7) displays a 2D floor plan and 3D model. The client easily edits the plan via moving a component or physically selecting it and dragging the edge of the component. The updating immediately propagates to the 3D model.

After client is satisfied, he/she can make a deal with agency to change the layout of unit.

Fig. 6. A 3d decision cone tree window

Fig. 7. Main window for 2D & 3D floor plan

5 Conclusion

This paper presents a new rational approach by integrating the decision-making tree with 3D physically based manipulation for the client customization process in apartment plan design. We also provide a research model to validate system ability. This research project forms a comprehensive study, of which only a summarized version of the findings can be presented here. Nonetheless, there is clearly a large number of interesting research issues is raised. For example, intelligent adjustment is a good topic for fuzzy rule base. How does system use rational to assist in problem diagnosis and solution. And, how does system collect people's feedback and evaluation of design alternatives.

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