

## FUZZY-BASED DIRECT MANIPULATION

*Focusing on user participation in the apartment plan design process*

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**Abstract.** Physically-based manipulation can be recognized as a promising approach to implement interactive computational tools to solve the user participation problems. To support the designer's justifications as well as to clarify the innately ambiguous expressions provided by the clients, we propose to build a fuzzy-based expert system integrated with a 3D physically based manipulation. This paper focuses on a system prototype for the client customization process in apartment plan design to exemplify our concepts.

### 1. Introduction

As the design progresses from formulation to detailed design, a considerable amount of information is generated. This information is currently communicated through drawings, and nowadays computer-based geometric models in which inconsistencies and justifications are hard to find (Gero and Maher, 1987). 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 (Shneiderman, 1997).

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. In this context, we want to develop a physically based manipulation system for designers to help the client customization process in the schematic phase of apartment plan design. To simulate the customization process, performing tasks by DM of design elements should be flexible and intuitive, to represent the user's *intentions* for the requirements. At the same time, each of the plan layout solutions should include the designer's *justification*. A good justification requires that a description of the solution space and a rule for selecting one solution should be given (Musso, 1983).

Currently, however, most home buyers who have preference for changing need have little knowledge about design professionals, when they do the

customization. Instead, clients may be able to explain what they want to the designers using design actions with several adjectives, for example, "...I want to make my living room a little bit wider like this (drawing or pointing to the amount of extension)...".

To support the designer's justifications as well as to clarify the innately ambiguous expressions given by the clients, in this paper we propose to build a fuzzy-based expert system integrated with a physically based manipulation. The objective is to provide the user with effective and appropriate fuzzy-based 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. Background

### 2.1. SCENARIO-BASED KNOWLEDGE ACQUISITION

Because most clients are not professionals in layout designs, many of them may not easily describe or communicate their ideas nor may they realize all the different aspects of a situation that they have to consider when they decide to customize the design (Cheng and Lee, 2005). A scenario-based approach makes the process easy and manages ambiguous and dynamic situations. (Carroll, 1999).

There is quite a wide range of views on scenario-based design (Benyon and Macaulay, 2002). In this paper we borrow the definition of the term *scenario* from Bruegge and Dutoit (2000), which follows the object-oriented software engineering concept: "A scenario is a concrete, focused, informal description of a single feature of the system from the viewpoint of a single actor...A scenario is an instance of a use case, that is, a use case specifies all possible scenarios for a given piece of functionality". Use cases are the primary artifacts of use case-driven software development. Scenario-based analysis integrates with use case approaches to object-oriented development. Scenarios are used to represent paths of possible behavior through a use case, and these are investigated to elaborate requirements (Sutcliffe et al, 1998).

From the viewpoint of human-computer interaction and software engineering (HCI-SE) field, Benyon and Macaulay (2002) have illustrated that the scenario concept becomes more formalized from 'user stories' through 'abstract scenarios' to 'concrete scenarios' and finally to 'use cases'.

### 2.2. USING THE FUZZY APPROACH FOR KNOWLEDGE MODELING

A design scenario description is typically written in standard prose. Most of the sentences of a text in natural language contain fuzzy denotations (Dubois and Prade, 1980). 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 (Lin and Peng, 1994).

The process of designing fuzzy logic systems is explained by the following development steps. (Lin and Peng, 1994):

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

### 2.3. DESIGN EXPLORATION BY PHYSICALLY BASED MANIPULATION

DM prescribes a general set of rules that have applications across the field of human-computer interaction. Because DM systems present the user with an easy to use, familiar method of interaction, novices in particular have an easier time with these systems. For experts, well-designed systems can be sufficiently fast, though using keyboard inputs will often allow an expert to work faster (Golbeck, 2002).

Layout design is often characterized by its explorative nature. Given a set of design requirements and constraints the designer searches through a number of possibilities seeking the *best* solutions (Cheng and Lee, 2005). Because of the benefits described above, DM gives users confidence to explore and is present in many design fields. Harada (1997) proposed mixed continuous/discrete models, emphasizing the constrained 2D layout problems that arise in architectural domains. The simulation techniques in this paper follow her work. The suggested system, however, extends 3D graphical models to simulate the user operations during the customization process.

## 3. A Framework for Integrating a Fuzzy-based Expert System and DM

Figure 1 shows a framework for integrating a fuzzy-based expert system to capture and formalize the design knowledge and to make inferences from the fuzzy rules to support the design justifications with a 3D layout generator that is able to represent, generate and adapt the geometry of the apartment plan implemented by the DM, especially the physically based layout manipulation.

The process at the bottom most level of Figure 1 is called **knowledge acquisition**. In order to develop design scenarios for the apartment plan customization process, interviews with housing domain experts who have experience in apartment building design were conducted. Each plan customization process can be captured by a sufficient number of design scenarios. Different scenario has dissimilar adjective property. Example, designing kitchen is a scenario which relate a lot of adjective like bright, fresh air, and so on. We set up fuzzy rule for different strength of property. Inferred result of rule will relate expert knowledge to deal with the problem of scenario.

The next higher level is called the **knowledge inference** process. The linguistic variables and types of membership functions are defined and built. The design moves developed from the previous process, knowledge acquisition, go into the knowledge base to develop the fuzzy logic rules. The user inputs will be converted into linguistic variables via the fuzzification mechanism, interacting with the knowledge base and inference engine to

conduct the knowledge, and out the crisp results represented by the linguistic approximation to the system (Figure 2).

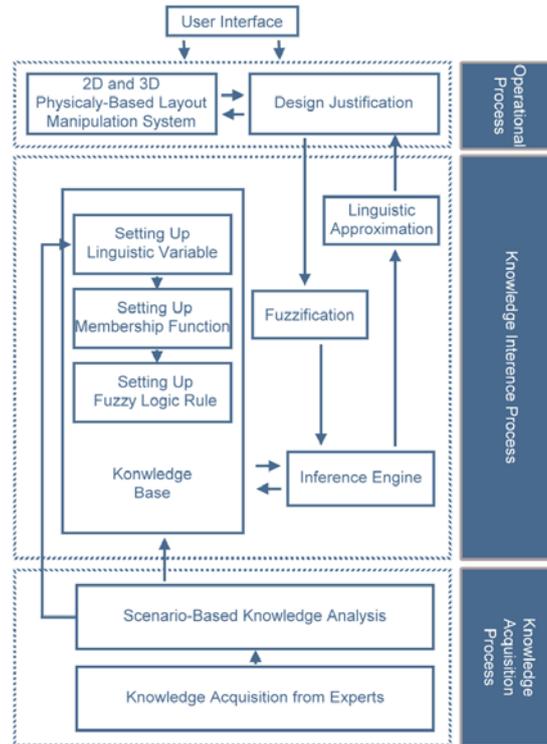


Figure 1. Integrating SBD and fuzzy-based expert system.

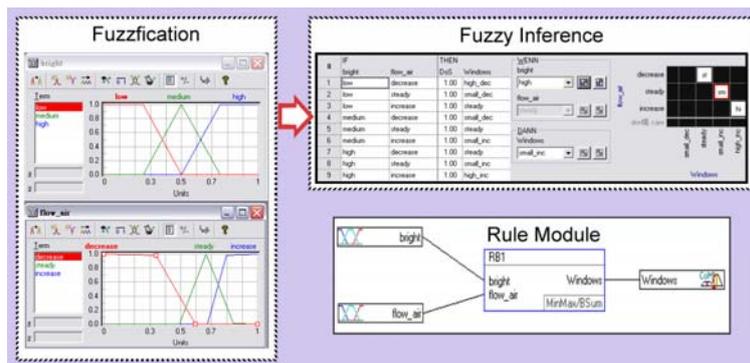


Figure 2. Fuzzy inference process.

The top most level is called the **operational process**. The results from the knowledge inference process go into the design justification module, which is connected with a 3D layout generator implemented by the physically based manipulation. Each user operation can be explained and rationalized by the design justification module, which is represented by a decision tree. The decision tree is supported by a knowledge inference mechanism (Figure 3).

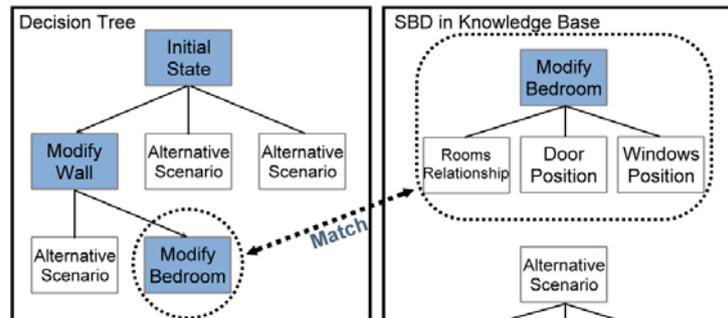


Figure 3. The relationship between the decision tree and knowledge inference mechanism.

#### 4. Prototype 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.

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.

The GUI of our system includes three major parts: (1) a query window to capture the user requirements and preferences, (2) a decision 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 (Figure 4).

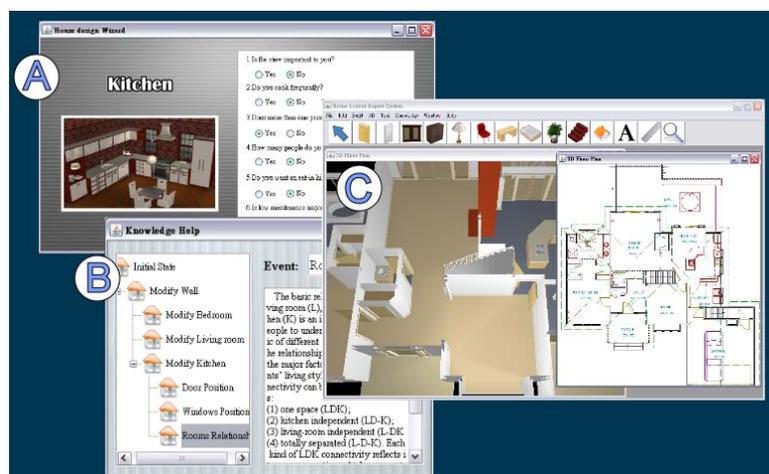


Figure 4. Three major parts of our system interface.

A client can start by answering a series of design move questions from the Query window A. According to the client's preferences, our system proceeds with the fuzzy inference mechanism. The area B 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 window B shows a decision tree. Each hierarchical step represents a corresponding design move, which is selected from the knowledge base. When the client selects a 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 C 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.

## 5. Conclusion

This paper presents a new approach by integrating the fuzzy-based expert system with 3D physically based manipulation for the client customization process in apartment plan design. We expect fuzzy-based inference connected with physically based manipulation to be one of the best combinations to support the client participation process. The following issues have been raised in this paper: (1) using fuzzy theory to capture the user requirements and preferences, (2) a design justification supported by scenario-based analysis and a decision tree, and (3) Physically based manipulation to interact and communicate intuitively with the CAD system.

## References

- Benyon, D. and Macaulay, C.: 2002, Scenarios and the HCI-SE design problem, *Interacting with Computers* **14**, pp. 397-405.
- Bruegge, B. and Dutoit, A.: 2000, *Object-Oriented Software Engineering*, Prentice Hall.
- Carroll, J.: 1999, Five Reasons for Scenario-Based Design, in *Proceedings of the 32nd Hawaii International Conference on System Sciences (HICSS)*, January 5-8, Maui, Hawaii, USA, Vol. 3, pp. 3051.
- Cheng, Y.-C. and Lee, J.-H.: 2005, Integrating Scenario-Based Design and Case-Based Design for User Participation in Apartment Plan Design Process, in A. Bhatt (ed), *Proceedings of the 10th CAADRIA Conference*, April 28-30, Indraprastha University, New Delhi, India, Vol 2, pp. 233-239.
- Dubois, D. and Prade, H.: 1980, *Fuzzy Sets and Systems: Theory and Applications*, Academic Press, Chestnut Hill, USA.
- Gero, J. and Maher, M.: 1987, Future roles of knowledge-based systems in the design process, *CAAD futures '87*, May 20-22, Eindhoven, The Netherlands, pp. 81-90.
- Golbeck, J.: 2002, Direct Manipulation, in *Theories in Computer-Human Interaction*, <http://www.cs.umd.edu/class/fall2002/cmsc838s/tichi/dirman.html>.
- Harada, M.: 1997, Discrete/Continuous Design Exploration by Direct Manipulation, PhD Dissertation, Department of Architecture, Carnegie Mellon University, Pittsburgh, USA.
- Lin, X.-C. and Peng, Q.-F.: 1994, *Oh! Fuzzy*, The 3<sup>rd</sup> wave, Taipei. (in Chinese)
- Musso, A.: 1983, Justifying designs, *eCAADe '83*, Brussels, Belgium, pp. 0.1-0.9.
- Shneiderman, B.: 1997, Direct Manipulation for Comprehensible, Predictable and Controllable User Interfaces, in *Proceedings of the 2nd international conference on Intelligent user interfaces*, January 6-9, Orlando, USA, pp. 33-39.
- Sutcliffe, A.-D., Maiden, A.M. -N., Minocha, S. and Manuel, D.: 1998, Supporting Scenario-Based Requirements Engineering, *IEEE TRANSACTIONS ON SOFTWARE ENGINEERINGs*, Vol. **24**, No.12, pp. 1072-1088.