

Virtual Reality CAD system for non-designers.

Investigation of user's preferences.

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In this paper we will summarize the development of a virtual reality system called MuseV3. This system allows the modification of a basic architectural design and thereby collects preference information about design variations. A technical description of the system as well as a summary of user evaluations is given. In addition, a brief explanation of the methods that were used to elicit user preferences will be given.

Virtual reality, Bayesian networks, user preferences, Desk-CAVE.

Introduction

Virtual reality comes to the surface and starts to play important role in modern life. No surprising that housing companies are turning their attention towards such systems that allow users to imagine and appreciate not yet built dwellings. The paper describes a virtual reality system that was developed to allow non-professionals designing their house and simultaneously elicits their preferences. We will describe how non-designers can benefit from such a system. Also we will present and discuss the results of the experiment to test the developed system.

The developed virtual reality system, named MuseV3 helps respondents to understand the complex architectural drawings by visualizing them in the form of 3D geometry. The system was designed for non-experienced users; therefore much effort was spend on developing interaction methods and the user interface. The modification and creation process in MuseV3 is easy as click, drag and release. Users are not bothered with details, and tedious operations like inserting walls around just created space but the design process is semi automated. The unique feature of this application is that a space with its boundaries is considered as the main component, the base for all user modifications and the connection between all design elements. The description of the core of the MuseV application as well as the principles of the modification methods can be found in the previous paper (Orzechowski, 2001), hence are omitted in this publication.

MuseV3 versus professional CAD applications.

Supporting non-designers requires a different approach to the user and to the design process than available and supported in professional Computer Aided Design (CAD) systems. The approach is characterized threefold: system functionality, interface and design presentation. Those three characteristics describe three separate problems but refer to one general feature: interaction with a design. MuseV is simple. It requires very little time for a user to absorb necessary knowledge and to use the application. MuseV3 offers many possibilities to non designers that the professional applications lack. The Table 1 illustrates the interface, the system functionality, and the design presentation characteristics of MuseV3 and compares them against professional CAD.

Table 1. Comparison of MuseV and professional CAD systems

		MuseV	Professional CAD application
Interface	Presentation method	Virtual reality	Various projections
	System Set up	Dual screen and view projection	Optional multi screen and view projection.
	Navigation	Walk / fly	N/a (pan and zoom)
	Menu	Two-level toolbar	Rich and complex, multi-level
System Functionality	Complexity	Three main modifications (complexity solved by semi-automation design process)	Most operations are object dependent. Great number of commands.
	Difficultness	Easy to use (semi-automation design process)	Requires long time to learn and deep understanding of architectural design.
Design Presentation	Constrained Design	Yes	No
	BLD (base line design)	Yes	No
	Modification freedom	Restricted to rectangular shapes based on grid 30x30 cm	Full
	Internal design evaluation	Yes (user gets a feedback about completed modifications)	No

The first conclusion coming out of the table is that MuseV3 is a dedicated application. It was design for one purpose only – support non-architects. The professional CAD's are multi purpose and interdisciplinary. This feature makes them very general. The same application can support mechanical or architectural design. There are also packages (like ArchiCAD) that are meant only for architects, still due to the nature of an architectural design very complex. In current CAD we can observe a simple compositional approach (hierarchical association of building components) but still the major modifications are performed rather on separate elements then on complex structures. This decompositional approach is something we wanted to avoid while developing MuseV3. The professional applications do not facilitate navigation in any kind of modes: walk or fly. Finally, none of those packages support design evaluation and preference information assessment.

The functionality of MuseV supports adapting a product (an architectural design) to fulfil clients' personal needs and wishes. However, these adaptations are not fully unconstrained. Constraints are imposed by codes and standards, manufacturability, spatial limitations, structural stability, and last but not least, the available budget. The CAD applications are not constrained, hence do not prevent non-designers from making mistakes in space arrangements or creating impossible to build design solutions.

In MuseV the adaptation process starts from a so-called baseline design (BLD), which is in our case a standard house layout. Determining what is the base line of a specific product is not a straightforward procedure. It requires reinterpreting the design and specifying the constraints. Except from codes and standards one could argue that there are hardly any constraints if the available budget is unlimited. Practically speaking however in case of housing, it is feasible to determinate a baseline design.

Unconstrained CAD design opens various possibilities to the designer and does not limit one's imagination. For non-professionals the design process usually starts from re-adaptation of already see design, hence the ideal of using BLD in this case not limits but enhances their design capabilities.

Interface.

People that are not trained in architectural design usually have problems in reading floor plans and cross sections to create a mental image of the building and the rooms. Traditionally, perspective sketches were drawn for this purpose and today we see an increasing use of 3D renderings and VR models.



However, housing layout design is still predominantly a 2D activity. 3D modelling is a tedious process that requires a lot of technical knowledge. Also, manipulation of objects in VR environments raises many technical and ergonomic questions and still is a research topic (Mine et al). Resembling the traditional design space, MuseV3 provides a dual presentation of the design, namely a floor plan view and a perspective view. The perspective view is projected on a vertical screen in front of the user and the floor plan view on the horizontal desktop with a tablet (Figure 1). The complete set up consists of the table with the vertical screen, the tablet, two LCD projectors, standard mouse, keyboard and especially developed navigation cube to maneuver in the VR environment.

Figure 1. MuseV3 setup.

The modification operations are identical in both views, such as selecting objects or drag-and-drop from a toolbar. A user communicates with the application via the toolbar that is displayed in the view where the user is currently operating. This allows the customer to choose the interaction mode quickly and effectively. The toolbar provides six different operations to modify a design. However, some of them might bring the same final result (like resize space and addition). The decision regarding which mode to use is very subjective and depends on many factors such as experience in design, experience with 3D models (games), the current viewpoint position in the world, etc.

To resolve coverage of one floor by another floor that is closer to the viewpoint, each floor can be switched on and off independently. The baseline design is projected in the environment where it will actually be built. The situation plan provides important information like north orientation, distance to the street and to the neighbours, and additional environment information. For user's convenience, the current location and viewing direction are indicated in the floor plan view. Both views can be synchronized in the navigation mode.

As already mentioned, the budget can be one of the design constraints, hence during a session the consequences of all the changes are calculated and the actual building cost is printed in the active screen. Next to that, a history list is maintained with information about all the changes and their financial participation in the overall building costs. The system looks for budget overflow and as soon as the overflow is detected, the user will be signalled. However, budget overflow does not prohibit the user from making more modifications.

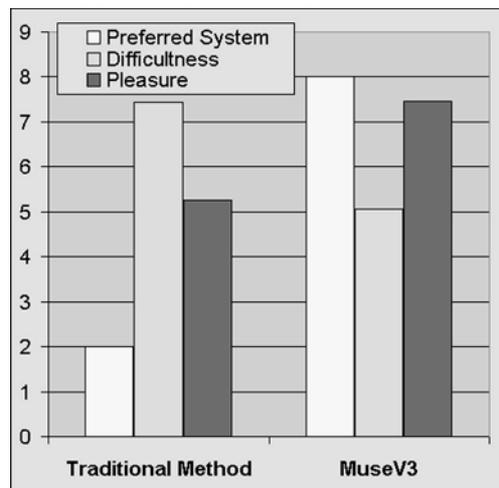
Eliciting preferences.

The modification of a design instead of responding to already pre-designed options encourages people to explore the virtual house and think deeply about the best and the most preferred options for the future real home. During the modification process the system recognizes users' actions and translates them into choices for design alternatives or elements. Behind the system, a Bayesian network (Jensen, 1996) transforms the choices into probabilities (beliefs). Choices of each user are entered into the network, what changes the current state of its knowledge about respondent's preferences. In other words, each

subsequent respondent uses network's knowledge that reflects the real preferences more accurately, as the network increases its prediction capacities with an increase in the number of respondents. The preference information contained in the network is used twofold. First, it is used during a user session with the system to create a direct feedback about the design state and to prompt users with options that they might have omitted. Secondly, this information generalized across a sample of users provides the basis for developing options for particular market segments and predicts the market potential of particular designs.

Experiment & Results.

The applicability of the system was tested against traditionally used methods to investigate user preferences. To that effect, each respondent had to complete two tasks; one – preset option questionnaire



consisted of images of design alternatives (created by combining design elements – attributes), second – MuseV3. The results revealed a high preference for the MuseV3. The house project used in the experiment was supplied by one of the Dutch housing companies. The project came in a form of a selling brochure that included Figurea basic design and options. Based on the information we constructed and constrained the model used in MuseV3 experiment and set of attributes for the traditional method was established. More information about the methodological approach can be found in (Orzechowski, 2000), (Timmermans, 1984), (Timmermans, 1994).

Figure 1. Experiment Results: Preferred System; Difficultness and Pleasure

The Figure 2 illustrates results of the experiment regarding the most preferred method to present an architectural design. As the figure and respondents comments indicate, the freedom that MuseV3 offered was highly valued, even though that the system was quite difficult to use. While evaluating the results and the floor plans created by users, we came across a great number of designs fully furnished and textured. That might show a high involvement into the design process. It may also mean that in order to gain a better idea of space users find it easier to visualise the environment with details suggesting a “home” instead of a spaces with dimensions. The newly created layouts have the same notion of space arrangement, but a completely different implementation that was not offered in the original brochure.

Navigation through the virtual world introduced some problems (mainly with loosing orientation, and with using navigation devices). The most popular navigation device was the mouse, but we observed that generally the users did not take enough time to exercise and train their navigation skills. Those who started to use the navigation cube usually kept on using it through the whole experiment.

Conclusions.

In this paper, we have described an interactive, VR system for non-designers. The system offers users the possibility to change a base line design according to their needs and preferences. As such it can be used to create designs for *individual* clients. In addition, however, underlying the system is a Bayesian network that allows one to derive aggregate demand estimates for types of houses and design attributes. This information can be used for market analysis. An explorative application of the system suggests that users appreciate the system and that it encourages the involvement in the design of their house.

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