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VR-DIS Research Programme

Design Systems group

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Abstract: This paper presents a summary of all on-going projects within the VR-DIS research programme at Eindhoven University of Technology.

1. INTRODUCTION

The VR-DIS research programme is the research work done in the Design Systems group of Eindhoven University of Technology. It was established in 1998, at the same time when the former groups of Building Information and Design Methods were fused. The research programme is based on the main premise that interactive and immersive representation of design (knowledge) will best support the design process in the future. The VR-DIS acronyms Virtual Reality – Design Information System and Distributed Interactive Simulation conform to this belief. Not only the design itself, but also interaction with the design, knowledge of the user, and behaviour of the building design should be accessible in a responsive environment.

Organisationally, the VR-DIS research programme is facilitated by the fact that the Department of Architecture and Building of Eindhoven University of Technology has a wide array of disciplines in the building sciences: not only Design Systems, but also Structural Engineering, Building Physics, Urban Design, Architecture, Real Estate Management, Construction

Management, and Building Technology. Therefore, VR-DIS is not only located with the Design Systems group but also in the other research groups as well. In a wider context, VR-DIS is embedded in the DDSS (Design Decision Support Systems) research programme of the Department of Architecture and Building, in which the group closely operates with the Urban Planning group.

In this paper, we will present an overview of running projects. Design support is the first main issue, in which the work by de Vries and Segers is presented. Feature modelling is the main information modelling approach, which receives attention by van Leeuwen, Achten, Coomans, and Fridqvist. The assessment of designs on building and urban level in various ways are then tackled by Dijkstra, Orzechowski, Tan, and Saarloos.

2. DDDOOLZ

Project conducted by B. de Vries

Sketching in 3D seems to be a paradox. The sketch activity is inherently 2D since it is executed in a plane on a flat surface using some drawing device (e.g. a pencil). Three dimensional creation and manipulation of objects presumes the activity being executed in a 3D environment on spatial objects. DDDoolz (www.ds.arch.tue.nl/Research/DDDoolz/) is a new innovative dedicated system for mass study and spatial design in the early design stage. While designing, the model can be inspected and even experienced from any viewpoint. It is a low-end user system in the sense there is almost no learning time and the software will run on standard computers.

Sketching with DDDoolz is like painting blocks in space. Creating new blocks is best described by a 'copy while drag' operation. For determining the copy direction the Face Orientation Method is introduced (Achten and de Vries 2000). Crossing the edge of an existing block while moving the cursor of the blocks' side will result in creating a new block adjacent to the previous selected one. This fairly simple principle gives the user a sketch-like feeling when dragging a block through space. To support 3D perception of the model, the system provides two windows, one to orbit the viewpoint around the model and another, which allows navigating the viewpoint through the model.

DDDoolz is used in the first year's CAAD course next to other CAD tools like AutoCAD. In research DDDoolz is used as a platform to experiment with different input device combinations like a tablet, pressure sensitive pen, trackball, Desk-CAVE, head tracking, etc.

Figure 1. Sketch object and Orbit model (left).
Navigate model and Import environment (right)

3. TOWARDS COMPUTER-AIDED SUPPORT OF ASSOCIATIVE REASONING IN THE EARLY PHASE OF ARCHITECTURAL DESIGN

Project conducted by N.M. Segers

The early phase of the design process is a seemingly chaotic, complex process, involving many methods and representations. Architects try to get a grip on the assignment, and come up with their very first ideas. In general this research (Segers et al. 2000) serves two purposes: understanding architectural design in the early phase and supporting the architect in his/her design process during this phase. We want to improve the architectural design process by means of a design system, which has the advantages that the architect experiences in the traditional design process, but with additional aids. This will be done by a joint effort of three groups, namely the Design Systems Group (DS, Faculty of Building and Architecture), the Computer Graphics Group (CG, Faculty of Mathematics and Computer Science), and the Center for User-System Interactions (IPO).

The data handling of the envisioned system is supported by knowledge on creative cognitive processes (Finke et al. 1992), and knowledge on the design process of the architect. If the data handling of the system resembles how in the human mind ideas and relations are present and used, the design-information can be stored and retrieved in a more or less natural way. The architect manipulates small amounts of data, constructing them together from and to a personal world (Schön 1983); he tends to tell himself stories

(Witt 2000) and imagines how ideas for the future users will work. The basis for constructing a personal world and of telling stories is the personal 'idea space' and the cognitive processes to alter it.

In the system we will make a division between general design-data and personal design-data. The general design knowledge databases or case bases contain information that the architects use from former projects or from other architects. The current design assignment that the architect is working on is represented in the 'idea space'. It consists of a totality of nodes – representing ideas –, links – representing relations between ideas –, and their properties. These properties imply the time and date of creation or use, the design assignment when it was created or used, next to which nodes was the node or link created or used, and content related properties. The envisioned system must be able to tell what kind of ideas and relations it is dealing with, in order to describe the nodes and links.

With this structure, it is possible to show the development of ideas in time, to show the current state of the design and to suggest ways to continue via association. The emphasis of this research will be on the 'idea space' and it's possibilities, i.e. association.

4. FEATURE-BASED MODELLING

Project conducted by J.P. van Leeuwen and A.J. Jessurun

Management of design information is a crucial part of design and decision support systems. The information modelling approach developed in the VR-DIS programme is derived from Feature-based modelling (van Leeuwen 1999). It provides three major capabilities: (1) it allows for extensibility of conceptual schemas, which is used to enable a designer to define new typologies to model with; (2) it supports sharing of conceptual schemas, called type-libraries; and (3) it provides a high level of flexibility that offers the designer the opportunity to easily reuse design information and to model information constructs that are not foreseen in any existing typologies. The latter aspect involves the capability to expand information entities in a model with relationships and properties that are not typologically defined but applicable to a particular design situation only; this helps the designer to represent the actual design concepts more accurately.

The VR-DIS system consists of a growing number of modules for different kinds of functionality in relation with the design task. These modules access the design information through an Application Programming Interface (API) that implements the meta-layer of data definitions in both conceptual models and actual design models. This API has previously been implemented using an Object-Oriented Database, but is now based on eXtensible Markup Language (XML) (van Leeuwen and Jessurun 2001).

Research in this project currently focuses on Internet-based applications that support designers in the utilisation of distributed libraries of product-information, design-knowledge, case-bases, etc.

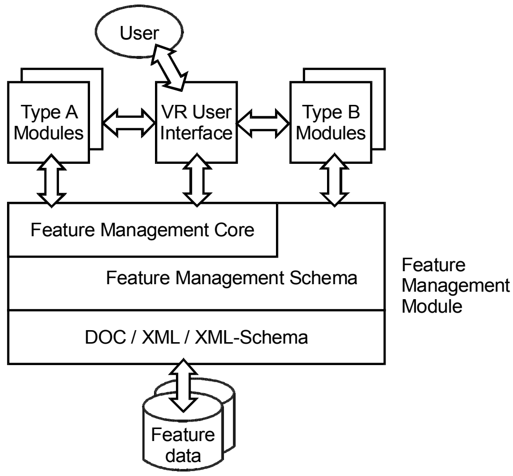

Figure 2. XML Schema based system implementation (van Leeuwen and Jessurun 2001)

5. DESIGN SUPPORT BY FEATURES

Project conducted by H.H. Achten

As stated above, Feature-Based Modelling is the basic information model that is being used and developed in the VR-DIS research programme. One of the main goals is to provide an extensible and flexible approach to information modelling, in order to better support architectural design. The provision of an information modelling paradigm alone is not sufficient to accomplish this, since the formulation itself does not incorporate the dynamics and complexities of everyday design processes. In this project therefore, we are investigating how Feature Models of designs change during the design process. For this purpose, we analyse concrete design cases. The analysis is based on the drawings produced throughout the design process. Each drawing is taken as a step in the process, and described as a Feature Model. We can then describe changes in the Feature Model related to design actions in the design process. Based on this work, which has been reported in (Achten and van Leeuwen 1999; 2000), we can then determine what kind of tools the designer needs when working with Features.

A second track in the research work concerns the implementation of the work on generic representations (Achten 1997). Generic representations are well-defined graphic representation of which the design decisions associated with the drawing can be inferred. Currently, we are investigating how generic representations can be modelled as Features. When this has been done, then other techniques such as Case Based Reasoning can be utilised to support design (Achten 2000).

6. DDDIVER

Project conducted by M.K.D. Coomans

A core part of the VR-DIS research is the innovative, Feature based design-information modelling technique that was developed by van Leeuwen (van Leeuwen 1999). In this modelling technique, the architectural designer is offered a way to control how abstract design data is structured and stored. With this new information modelling technique, we expect that the designers will be better capable of handling the complexity of linking diverse kinds of information involved in a building design process. The drawback of the gained information modelling freedom is that this new technique also puts the responsibility for the content of the CAD database entirely in the hands of the designer. In order to be able to enjoy the design freedom fully and at the same time handle the responsibility over the design database, a computer tool is needed that shows the precise content of the database, and that is easy and quick to interact with. A 3D graphical tool was developed to meet these demands, called DDDiver.

DDDiver visualises the Feature database in two interactive graphs (see figure). One graph shows the Feature *model* (an actual design), and another the Feature *Type library*. Features and Feature Types can be inspected and manipulated on transparent layers. An interactive data exploration mechanism was developed that dynamically moves data objects to layers laying more at the back, in order to maintain context-data in view during data navigation (Coomans 2001).

DDDiver can be controlled by a standard mouse and keyboard. Optionally, these standard devices can by complemented with head tracking and tailor-made manipulation devices, in order to obtain a so-called *fish-tank VR* set-up. These additional input devices facilitate improved depth perception and easier object manipulation.

User experiments are conducted to validate the tool's performance on a larger audience and to guide the further developments.

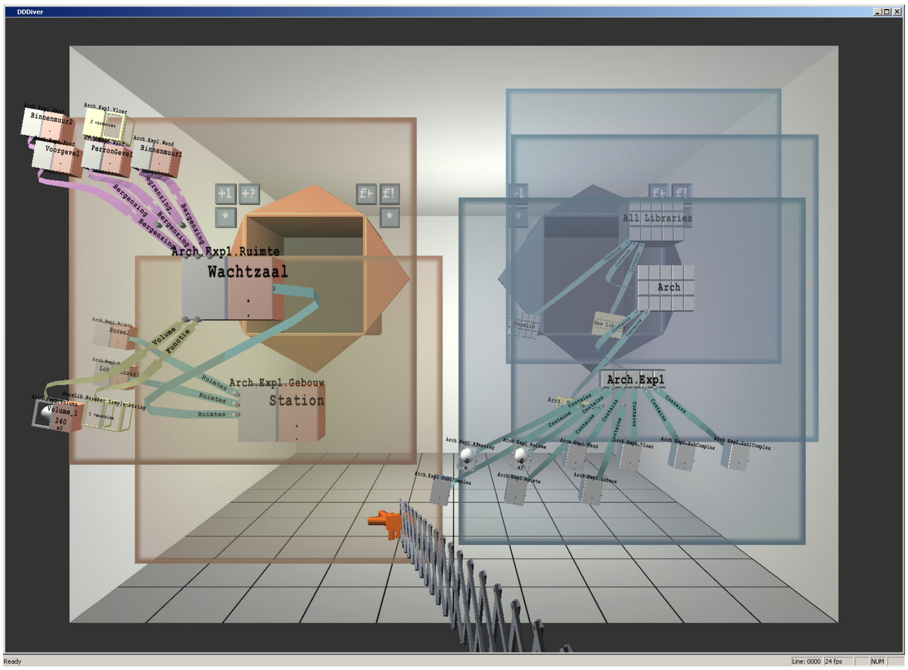

Figure 3. The interactive visualisation of the Feature model (on the left) and the Feature Type library (on the right) in DDDiver

7. IMPLEMENTATION AND APPLICATION OF FEATURE TYPE RECOGNITION

Project conducted by S. Fridqvist

The Feature Based Modelling (FBM) system addresses the most foundational questions of how to construct information systems for the construction and facility management industry (van Leeuwen 1999). Several benefits that are possible to gain with the FBM system, however, require an additional technique, Feature Type Recognition (FTR) (van Leeuwen and de Vries 2000).

While the FBM paradigm gives great flexibility and expressiveness, it also opens the risk to create models with little or no reference to common practices. This will of course render such models unusable for communication of design information. The FTR technique can decrease this risk by automatically or semi-automatically link the user-defined classes to approved class libraries, thereby giving models with user-defined classes the necessary basis for communication.

Additionally, a FBM system augmented with FTR could assist designers and other professionals in several common tasks. Since FBM is a general modelling technique, several kinds of information might be modelled using FBM. Feature type recognition could then be used to analyse different aspects of design models, to search in common depositories for missing model information, and to translate models between different national or industrial standards of modelling.

This sub-project within the VR-DIS frame will add Feature type recognition to the FBM system, gaining from the main researcher's earlier experiences at another institution (Fridqvist 2000). It will also investigate and demonstrate FTR by applying it to one or several design tasks.

8. AMANDA – A MULTI AGENT SYSTEM FOR NETWORK DECISION ANALYSIS

Project conducted by J. Dijkstra

Architects and urban planners are often faced with the problem to assess how their design or planning decisions will affect the behaviour of individuals. Various performance indicators are related to the behaviour of individuals in particular environments. One way of addressing this problem is to develop models, which relate user behaviour to design parameters. For example, models of pedestrian behaviour have been developed to support design decisions related to the location of facilities, parking policies, etc.

Graphical representations and 3D simulations may be powerful tools to assess design parameters in terms of such behaviour. Therefore, we formulated a research project that aims at exploring the possibilities of developing such a tool in a virtual reality environment using multi-agent simulation and cellular automata technology. The particular problem of reference is to assess planning and design decisions related to the design of shopping malls in terms of pedestrian behaviour, which in turn will influence the performance of the mall.

The purpose of this research is to describe a multi-agent system that can be used for network decision analysis. The term network decision analysis is used to encompass all design and decision problems that involve predicting how individuals make choices when moving along a network (corridors in a building, streets, highways, etc.). This model is based on cellular automata and multi-agent technology. The underlying idea is to model how agents move in a particular 3D (or 2D) environment. A cellular automata model of an environment in which space is represented as a uniform lattice of cells with local states, subject to a uniform set of rules constitutes the base of the system. These rules compute the state of a particular cell as a function of previous state and the states of the adjacent cells. An extension of the basic model of cellular automata allows cells to be influenced by more than their immediate neighbours; state changes may depend on the aggregate effect of the states of all other cells, or some proportion of them. Another extension is to build models in which cells preserve state information and calculate their next state on the basis of their neighbours and their own history of state changes. Agent technology will be implemented to build a framework for multi-agent simulation. Agents represent objects or people moving over the network. Each agent is located in a simulated space, based on the cellular automata grid. Agents positioned within an environment need sensors to perceive their local neighbourhood and some means with which to affect the environment. In Dijkstra *et al* (2000) this research has been described.

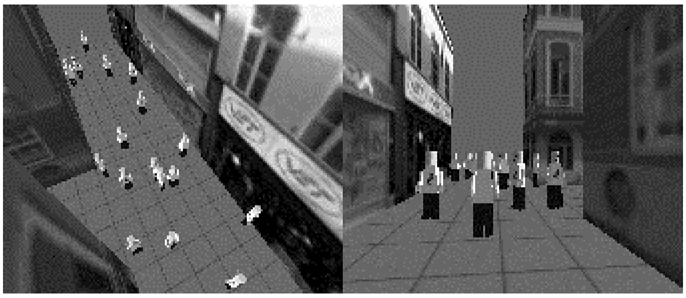

Figure 4. Movement Visualisation

9. MEASUREMENTS OF USER'S SATISFACTION IN VR FOR BUILDING ENVIRONMENT

Project conducted by M.A. Orzechowski

The key notion of this research is to measure user's satisfaction unobtrusively by having them interactively create their preferred design. We will develop and test a VR System for interactive measurement of user satisfaction. Furthermore, we intend to improve on the method of conjoint analysis for predicting user satisfaction on design alternatives.

Artificial intelligence technology will be introduced by employing the agent technology, aiming for a truly user-friendly VR System for non-architectural designers. Modification and manipulation of elements of the design will be possible in a Virtual World (VW) by browsing through a library of design elements (alternatives). Changes are immediately visually represented. The user is able to judge the outcome and respond on-the-spot. This interaction is the main advantage over text-based and image-based experiments to measure user satisfaction. Agent tools will be used to collect process data and analyze information provided by a user.

An exploration of possibilities to use VR to interactively change architectural design is accomplished via MuseV, a system developed for this purpose.

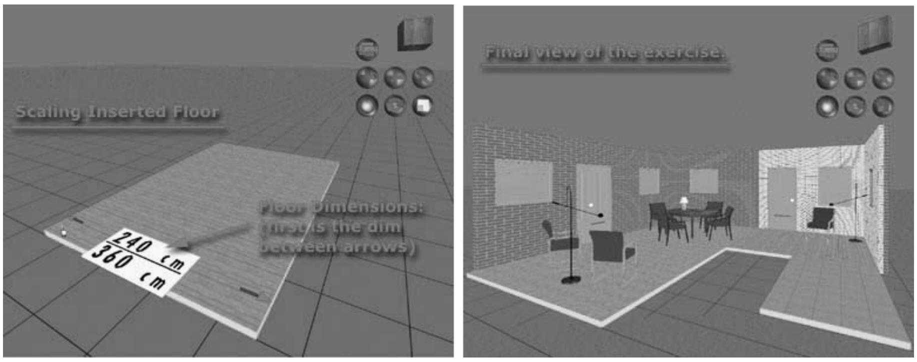

Figure 5. Muse V screen shots

10. MASQUE, A MULTI-AGENT SYSTEM FOR SUPPORTING THE QUEST FOR URBAN EXCELLENCE

Project conducted by D.J.M. Saarloos

A local land use plan gives regulations, in both quantitative and qualitative means, for the types of land uses to be applied in a strictly bounded area. During the making of such a plan an urban planner is confronted with many problems he cannot properly solve on his own. For this reason, he is forced to consult different sources of knowledge, being mainly persons and software tools. A hampering factor is that different sources often need to be consulted simultaneously in an interrelated manner. Urban planning practice has shown that, especially when multiple persons are involved in such multi-source consultations, the planning process can be slowed down dramatically due to the time it will take to simply arrange a meeting and to reach overall agreement. Additionally, when multiple software tools are to be consulted, the urban planner will be discouraged by the fact that these tools are often separately implemented, making it hard to combine them. Due to the described problems, the urban planner often turns to intuition-based decision-making, a rather questionable way of working.

What could really improve the practice of making local land use plans is a computer system incorporating all needed sources of knowledge. MASQUE (Saarloos et al. 2000) will become such a system, built up out of the following four components: Geographical Information System (GIS); Virtual Reality (VR); Multi-Agents (MA); and an extensible set of design and decision support (DDSS) tools. The sources of knowledge will be implemented by using multiple software agents, making a distinction between basically three types: *Interface Agents* taking care of assisting the user and contacting other agents; *Tool Agents* representing modelling experts by offering support on the use of specific decision support tools; and *Domain Agents* representing the multidisciplinary experts taking part in the planning process. By enabling the agents to communicate, the system will offer full support for multi-source consultations.

11. THE RELIABILITY AND VALIDITY OF INTERACTIVE VIRTUAL REALITY COMPUTER EXPERIMENTS

Project conducted by A.A.W. Tan

This research (Tan et al. 2000) explores on how to employ virtual reality in setting up interactive computer experiments as a means to probe the attitudes, motivations, reasoning and principles underlying travel decision-making. The concept of the problem of scheduling and implementing daily activities is viewed as a complex decision making process where individuals develop strategies to realize their needs and goals. A transportation system serves to provide the necessary links between locations of activities.

By establishing the combination of an interview with the technology of virtual reality display equipment in an interactive survey procedure we postulate that this will enable us to collect data that replicates realistic feedback to responses in not-yet-existing scenarios of a transportation system and/or in the introduction of new conditions of the travel options as opposed to real situations.

The environment representation used in virtual reality can incorporate features of the activity framework including the deductive logic of the time-space format that aids in the comprehension of circumstances, acts as a (passive visual) prompt, and serves as an aide-memoire. An essential idea is to automatically collect contextual information about daily human activities and their characteristics, and to use this information to help the later recall of past activities. Some aspect of simulating the actual physical action of walking, cycling, or driving creates the experience of movement. Behaviour in the virtual environment can be monitored by an observing agent that collects information about the interactions amongst the various objects in the virtual world. Agent tools generating statistics about subjects' movement and choices, their response performance will be used, as well as recording the number of inconsistencies and unaccounted time. We hope to infer from the experiential information "extracted" from the subjects their reasoning, attitudes, and motivation of decision-making in the context of activity scheduling.

12. CONCLUSION

From 1998, the VR-DIS research programme has been running in the Design Systems group. In the meantime, already some prototypes and methods have been developed (see Table 1).

Table 1. Products and methods in VR-DIS

Products	Methods
Feature Manager	Feature Based Modelling. Flexible and extensible data information model for design.
CRB system	Generic representations. Analysis method for capturing design decisions. Retrieval of cases based on design drawings.
Exspect simulation	Message exchange model. Simulation of the information exchange process between participants in a building project.
Feature view / DDDiver	Feature visualisation and manipulation in Virtual Reality.
DDDoolz	Face Orientation Method. The face of blocks as plane of reference for generating new blocks.
VIP (with IPO) / E3DAD	Augmented reality system for collaborative design. Design support for associative reasoning in design.
3D Realtime Constraint solver (with W&I)	Geometric constraints. Constraint definition between 3D objects. Propagation and maintenance in a designerly fashion.
Blocks (with W&I)	Implicit geometric relations. Relations and actions defined and used without explicitly stating them.
ACAD-3DS-WUP Walker	VR cycle. Fast cyclic method to incorporate VR in the design process.
WEDA & ILSA (with Building Physics)	CBR and KBS. Reasoning and design support in the areas of lighting design and workplace comfort.

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