A New Design Studio

Intelligent Objects And Personal Agents In Virtual Environment

by

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ABSTRACT

As design processes and products are constantly increasing in complexity, new tools are being developed for the designer to cope with the growing demands. In this paper we describe our research towards a design environment, within which different aspects of design can be combined, elaborated and controlled. New hardware equipment will be combined with recent developments in graphics and artificial intelligence programming to develop appropriate computer based tools and find possible new design techniques. The core of the new design studio comprises intelligent objects in a virtual reality environment that exhibit different behaviours drawn from Artificial Intelligence (AI) and Artificial Life (AL) principles, a part already realised in a tool called 'Sculptor'. The tasks of the architect will focus on preferencing and initiating good tendencies in the development of the design. A first set of software agents, assistants that support the architect in viewing, experiencing and judging the design has also been conceptualised for this virtual design environment. The goal is to create an optimised environment for the designer, where the complexity of the design task can be reduced thanks to the support made available from the machine.

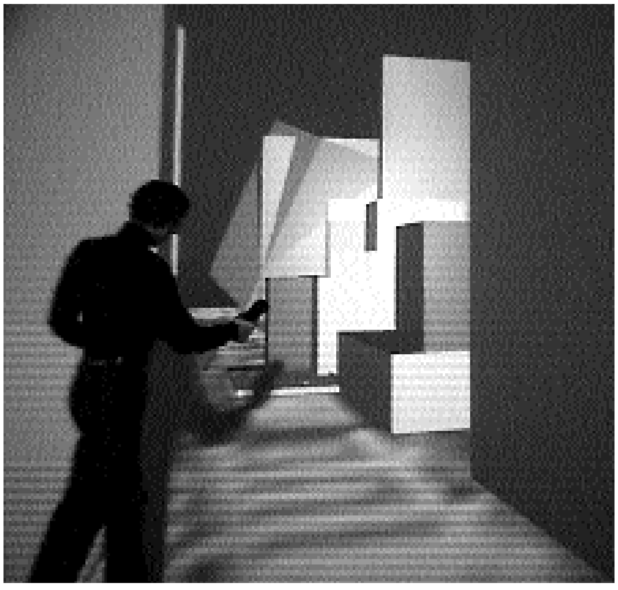
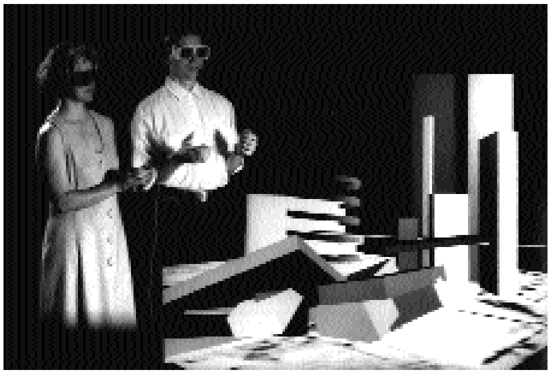


Figure 1: A designer (wearing 3D-glasses) is going inside the virtual project (projected onto a large screen with a video beamer)

INTRODUCTION

The main motivation of our work is to look for solutions to problems like: 'How would designers like to work?', 'How would a computer-supported design environment look like?', 'How can the design process and result be enhanced thanks to computers?', and 'How could problems of current design systems be solved differently?'. This leads to the vision of a new kind of design environment that should cover many aspects of

Figure 2: Designers in the new design studio



designing, and for which the different aspects of designing are re-evaluated and tools reformulated. Future design environments should take advantage of the new technologies that computers offer, and, if successful, they will be followed by new theories for their application and discussions on their implications on design.

First and very promising steps have been taken with the development of ‘Sculptor’ [Kurmann, 1995], an experimental computer tool which has enabled us to integrate direct specification and manipulation of intelligent objects and scenes in 3D. It is not any one single feature in Sculptor but a judicious combination of many separate features that makes it possible to generate and explore 3D models in a very fluid and visually engaging way. The next step towards a new kind of design environment was taken by embedding Sculptor into a Virtual Reality (VR) environment, which augmented the immediacy of the design project and process to the designer [Schmitt et al., 1995]. At the same time more Artificial Intelligence (AI) based software agents were added, which assist the designer when interacting and navigating in this new environment.

Vision of A New Design Studio

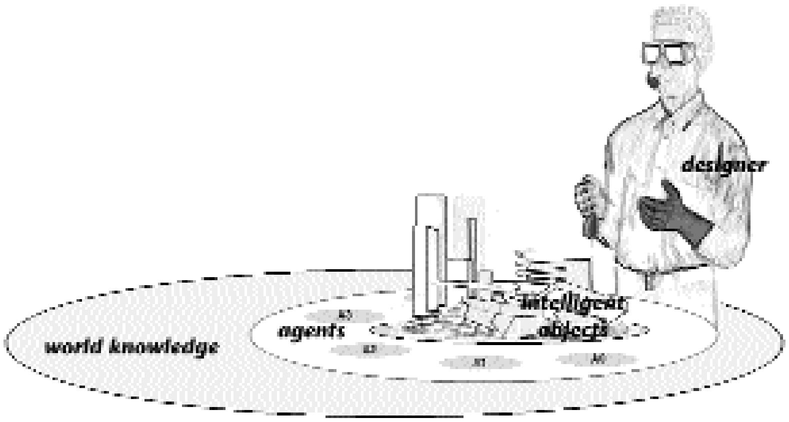
‘To improve the design process and therefore the quality of the result’ is the primary goal we want to reach with the new design studio. This involves further developments on different levels: the interface, the interaction, the functionality of the tools, and even experiments with new approaches to the design process.

Environment and Interaction

We envision the new design studio to happen in Virtual Reality, in a set-up where one or more designers can participate, while they are physically in the same or different locations.

Virtual Reality means that there will be new possibilities to experience the architectural design. In addition to plan views and model views in different scales, the architect gets the possibility to virtually enter the design, to experience the spaces that get created. This experience can be enhanced by simulating different lighting situations and adding a sound atmosphere. Using these techniques more of the designers perceptive senses get

Figure 3: The relation between model, agents, outside information sources and the designer.



involved, which leads to a higher commitment and also an easier concentration on the task.

A Virtual Reality set-up allows the use of spatial input devices, like 3D joysticks or data gloves. This is important for two reasons: The interaction can happen directly in 3D so that it feels almost like modelling with physical building blocks or clay (specially if the left and the right hand hold an input device), this enables the user to formulate design ideas in 3D. It is also important that such a set-up allow the whole body to take part in the process of designing and add the memory of motor actions to the activities of the brain, which again leads to an intensified involvement with the task and enhances the designer's productivity and satisfaction.

Virtual Reality environments can show things that are not real. Non realistic features can be used to display additional information. Walls can become transparent to display the plumbing. Parts can start blinking to draw the attention to an unresolved or conflicting situation. Non existing elements can show up to illustrate other activities in the design studio. Surfaces can display texts or movies to give additional information. Further there are possibilities for simulation, possibilities to change the scale of time and also the linearity of time, which allows to study a project's qualities and consider different possible influences during its whole lifetime.

The new design studio as well as the design project itself will also exhibit autonomous and intelligent behaviour. On the one hand, the interface can behave intelligently and adapt to the user. It can learn to anticipate actions, learn when comments from background processes can be shown, filter information from outside source, and learn to fulfil new tasks. On the other hand, the elements of the design could become intelligent by containing knowledge about their own properties, behaviour mechanisms to perform actions, and sensors to interact with others.

Design Process

Thinking about how the design process will change and could change is the next important step. So far features have been described that are possible due to developments on the hard- and software side. It has been explained that each one of these features will be a valuable addition to the design studio. The combination of these features will also have an impact on the process of designing. Thoughts about new approaches to designing are important to get beyond research approaches that improve existing systems with new hard- and software features. In this section we are going to fantasise about what should be done. It may sound like too many ideas impossible to combine into a working environment. To address these concerns, the following sections are aimed at presenting the implemented parts of this vision and various aspects that can be demonstrated.

To work in the new design studio should feel like playing a game, were the change of the state turns into the driving force that keeps the player involved. Once the designer enters the virtual environment, things will start to happen on different levels and the designer will get involved like in a VR game. The architect will try to influence the environment in a positive way, develop strategies, formulate goals, find solutions. The game will be rather like solving a puzzle, where there are an infinite number of solutions. What does this mean for the implementation of the new design studio? The game has to be attractive. It should not be too hard to play but just challenging enough. This means that either the designer can adjust it, change its pace and the number of simultaneously happening things interactively, or it has to be smart enough not to overwhelm the user. Recognition of both positive and negative attempts during design development are necessary.

The process of designing does *not have to start from zero* anymore. Instead of confronting the architect with an empty site and expecting him/her to get ideas by looking at a blank model, the design studio could initiate the design process on its own. Intelligent objects that try to arrange themselves to satisfy the design task as well as they can will present themselves to the designer as a dynamically changing composition. The architect will have the possibility to observe the action and get a feeling for the size of the project. The next step will be to recognise good tendencies among the ongoing transformations and favour them. This should not replace the designers own creativity, rather push it to a very intense level. Instead of spending much effort on producing the initial volumes and forms, the important work of the designer shifts more towards formulating and refining a design idea. As Mitchell points out: “Designers ... frequently recognise emergent subshapes and subsequently structure their understanding of the design and their reasoning1 about it in terms of emergent entities and relationships.” [Mitchell, 1989; Edmonds et al., 1994] For producing designs, known strategies like shape grammars or case based reasoning could be combined with other intelligent behaviour in the design environment. Artificial life approaches would be applied to keep the project dynamically transforming. Such an idea has been formulated by Peter Eisenman “... It will take various formal organisations depending on its own internal movement and growth. If there was the capacity in architecture to begin from such kind of modelling we would begin to have a kind of new architecture, an architecture that was no longer phallocentric. Now that does not mean that we could not be sheltering and containing, rather the containing would be seen as the residue of the process. In other words, the process image and its analogous meaning would come from the self-generating activity as opposed to the enclosing activity. In this sense nobody is saying that architecture would not shelter, enclose, contain, etc. but it will not necessarily make metaphors of these organisations.”[Eisenman, 1994]

The designer should be enabled to formulate *abstract design ideas* and add them to the way the composition is transforming. This can happen when patterns get recognised and characterised so that they can be reapplied. Or it could be the characterisation of transformations that should occur, for example: waves in a certain direction, or cutting and merging transformations. The designer’s intuitive capabilities should get promoted, while the machine takes over the task of precise formulation.

In the new design studio *time will be relative*. Not only for creating simulations and comparing different points in time of the project, but also for promoting the non-linear character of design thinking. With current tools the process of documenting design ideas is very slow and because of the linearity of time (of our perception of time), design becomes a linear process. With new tools that can produce and display new solutions very fast, time becomes more relative, one can jump forth and back in the design process and try out new approaches. The evolution of a design can be thought of having a tree-like or even a net-like structure, because things happen closer after each other and nodes can be remembered (and also better documented).

The architect will need and get *help from machine*. Collaborating software agents should help the designer to keep the overview of the project. Other agents should take over tedious tasks, so that the designer does not need to worry about things he/she does not like to do.

Our vision of a design studio is an *optimised human-machine collaborative environment*, where it is a joy for the human to work in. Even though research about design automation is advancing, we believe that in the near future the human experience, common sense and emotions, will still be needed to give a design its final touch, enhance its unique qualities and its expressive power.

SCULPTOR - INTELLIGENT OBJECTS

This section describes some of the ideas and techniques of Sculptor, a computer tool for virtual design in architecture that has been developed by one of the authors over the last three years. In particular, novel features and functions of Sculptor in addition to the already implemented general concepts of modelling in 3D are described. Intelligent behaviour of objects to respond to gravity and collision for intuitive feedback are explained. The ongoing work for extending Sculptor towards distributed modelling are also presented.

Modern software developments in the field of man-machine-interaction in three-dimensional (3D) space and virtual reality [Kalawsky, 1993] show important results and great potential of computer graphics technologies for modelling. But they also show some

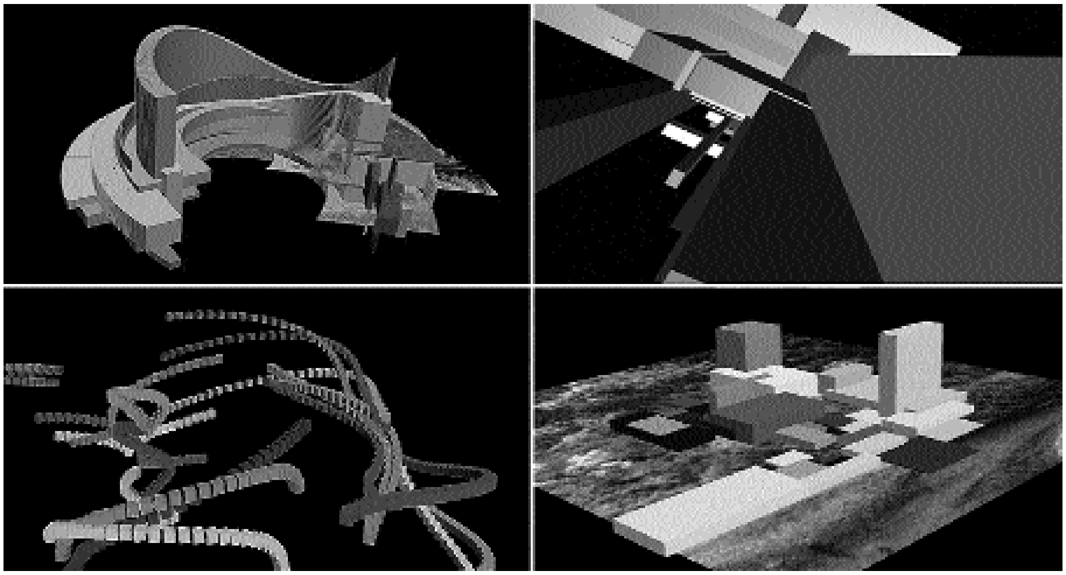


Figure 4: Various kinds of scenes produced with Sculptor: including two which show the path of dynamic object (left side) and one of urban design modelled on an image of the site

crucial points where more research is needed. For example techniques for overcoming and understanding the complexity of three-dimensional scenes require more research.

Sculptor allows very direct, intuitive and immersive access to three dimensional design models. Through interactive modelling in a virtual space, an easy way of generating and manipulating models and scenes is made possible. Interactive parameter specification of objects, models and scenes with attributes like form, geometry, colour, material, etc. are supported. Objects can be grouped together hierarchically. Objects, groups and virtual worlds can be changed in real-time by scaling, resizing, rotating, reshaping and moving them in space. Different points of view can be chosen as well as functions invoked for walk and fly through in 3D space. All the manipulations happen immediately by moving the mouse or one of the possible 3D input devices and the scenes are changed and rendered in real-time. Therefore multiple windows with complex text input and sliders or buttons are avoided: The interface is widget-less.

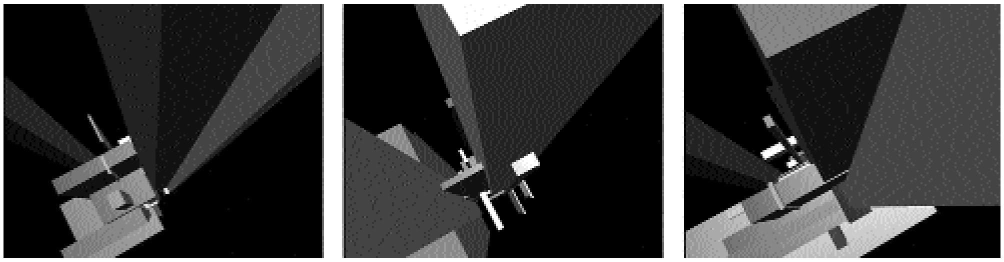
Sculptor focuses on encoding different knowledge into objects to make the interaction with them more intuitive. Intelligent objects with a certain behaviour or quality are defined [Barzel 1992, Schmitt 1994]. The objects contain knowledge about themselves and about their environment. Models may represent physical objects such as building elements or furniture, or they may represent purely functional and behavioural characteristics of objects. In practical terms, this offers new possibilities for participatory design in which all building partners can experience the designed object, its environment and make decisions.

In addition to assisting the users with realising the three dimensional geometry of objects, Sculptor also supports models of behaviour based on principles of mechanics and dynamics: Collision detection while objects are changed in size or moved in the scene provides a very intuitive way to experience a scene. Motion and modification of objects may happen only under valid conditions. Solid objects can be specified not to intersect. Instead the objects will collide and the motion or modification of objects will be inhibited.

Another functionality implemented in Sculptor supports modelling gravity. An object falls down if it is not supported by another object or the ground. Gravity is one example of a phenomenon where the inner structure is non-visual but its effect can be visually modelled. Additionally, we are currently working on modelling and testing statically (as in physics) correct object configurations based on their material and behavioural properties. Using these constraints, the interaction with objects in the virtual worlds is heightened since users find the experience of moving to valid positions or combining objects following physical principles very direct. Different sorts of feedback are an important feature of virtual reality tools to understand complex scenes in space.

Other important types of behaviour that can be attached to objects are autonomous motion and transformation. To every object a certain form, intensity and speed of motion can be attached. Objects not only have a position and colour but also a certain types of behaviour in time which makes them change constantly. The resulting behaviour adds a new complexity to a scene. Since the parameters can be defined for every object or group separately, very complex scenes that change over time can be created dynamically. This behaviour adds realism to an existing static scene and can also be used to attract the attention by vibrating objects.

Figure 5: 'Dynamic Manhattan': A sequence of images showing a scene that changes constantly (autonomous motion)



The experiments with autonomous motion to develop design solutions work very efficiently and surprisingly. A user can make certain objects change their size or move dynamically in three dimensional space. At each moment, the virtual design worlds evolve according to the forces that are active and which guide the growth of objects. A typical sequence (figure 5) shows a range of valid solutions. At any moment, the user is able to stop the motion, intervene and change the course of modelling - a mechanism we call the 'I Like It'-principle.

Recently we started using design generation systems in Sculptor. Certain functions out of the field of artificial life [Levy, 1992], animal-like objects or genetic systems [Goldberg, 1989] are being implemented to test the value of automatically generated and animated parts. We are experimenting with magnetic objects that attract others or push themselves away from them and objects that form groups attracted by a pole. There are objects that reproduce under certain conditions and with changing parameters. Cellular automata or Life Games that work in three dimensions and generate or erase objects have been added for experiments.

At present, we are working on distributed modelling with Sculptor to support locally distributed visualisation and manipulation of a shared model, an application in the field of Computer Supported Collaborative Work (CSCW) [Dave, 1995]. This will be one of the important features of Sculptor since we intend to expand the current one-user-one-machine situation. This functionality will also be required when using multiple software agents with Sculptor (see below). If one of these agents needs a lot of computing power, a distribution of computation will be necessary to have a satisfactory performance of the system.

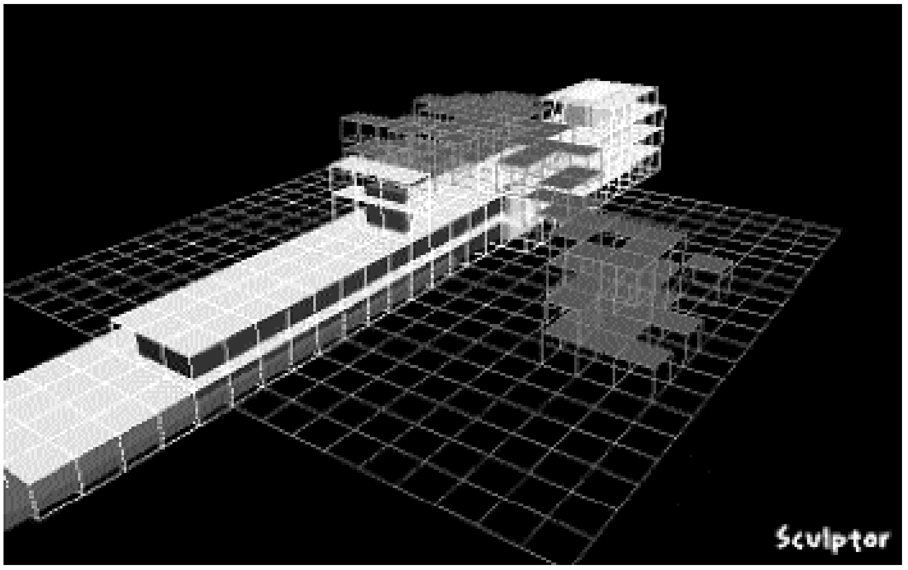


Figure 6: Artificial Life: A design enlivened by creatures simply attracted by a magnet.

Compared to commercial CAD programs, Sculptor is efficient in the early stages of design development because of the directness of its use and the realism of its results. Different approaches also serve as a source of inspiration, for example the ‘I Like It’ principle or the population of artificial objects evolving according to some rules. As one possibility, it can be used with different object models such as a set of building elements for different types of designs. One can walk around and see the scene from different points of view in real-time just like a real model out of wood or foam. These features makes it interesting for designers in general [Mitchell, 1990].

Sculptor works with the mouse and keyboard as well as with a Spacemouse® or Spaceball® for 3D input. The output can be directed to a monitor or a beamer in 3D (used with shutter glasses), a head mounted display or boom as well. Sculptor is written in C/C++ on Silicon Graphics Computers (SGI), makes extensive use of the Graphics Library GL/OpenGL implemented on SGI, and runs on all recent SGI machines. The program has been presented at several conferences including in the art and media exhibition 'artificial games' as the interactive installation 'ImPuls' [Wenz, 1993]. A video showing different scenes produced with Sculptor won an award. [Kurmann et al., 1994]

AGENTS - DESIGNER SUPPORT

The design environment also got enhanced by introducing intelligent agents to support the designer. In addition to their supportive function, agents may influence the quality of human-computer collaboration. AI engenders the great danger, that its results can look more intelligent if the user does not understand well, what is going on. Agents can be introduced to counteract this mystification, because they can have names, fulfil specific tasks, take commands, and learn how to perform best on the users behalf. This helps the user in two ways: First, the AI tasks are divided up among known entities. Second, the user has the possibility to give positive or negative feedback to customise the agents.

We had to start by *defining the term 'agent'* again, because it does not get used in a standardised way. To us it is important that agents:

- contain knowledge
- are designed to work on a specific task
- can work autonomously
- are acting on behalf of the user
- have the ability to learn.

Nicholas Negroponte had formulated the idea of *employing agents in the interface* already in 1970 in his book "The Architecture Machine: Towards a more Human Environment" [Negroponte, 1970]. It took some years for AI, behaviour based AI and agents research to mature, so that proven principles (speech recognition, planning algorithms, neural networks and learning through reinforcement) can be used for the implementation [Maes, 1993]. Our contribution to the field lies in the new way of using known principles and combining them for appropriate behaviour. A particular aspect for further research efforts, is to find ways to represent the agents themselves, make their activities visible and let the user interact with them. In this respect, we hope to make innovative contributions, specially with the new interface possibilities provided by a virtual reality set-up. We can imagine two basic kinds of agents: *design assisting* agents and *design generating* agents. For now we are limiting our work to design assisting agents, because we want to focus on improving the aesthetic qualities of the human-computer interaction.

First Agents

Three prototypical agents have been conceptualised so far and will be described more in detail now: *The navigator, the sound agent and the presenter*. They are meant to be personal assistants, trained by each user to adapt to his/her individual preferences. These three are selected because they were the most feasible ones and the most effective ones to test our idea of agents in a virtual environment.

The *navigator* acts like a guide in the virtual world. It can follow different kinds of instructions like: moving to a specified place, moving in a specific direction, or composing a tour. The navigator gets commands through a voice interface. This kind of interface is very suitable to be used in a VR environment and very natural to work with. For our implementation, we started with a simple speech recognition algorithm that works with keyword spotting. A set of keywords had to be defined in advance. The first word has to be one of the verbs: go (to), show, jump (to), that describe the action to be taken. Next comes either a noun that names a place to go to, e.g., kitchen, entrance, living room, or an adverb that tells the direction to be taken, e.g., left, right, up, down, forward, backward. To follow the instructions the navigator works with a taxi driver approach, it starts moving immediately and simultaneously plans the next steps towards the goal, this approach is based on the theory of 'situated activity' [Suchman, 1987 ; Lave, 1988; Agre, 1990]. This approach was chosen, so that the navigator has a chance to find its way even in a dynamically changing project. The planning capability is the most important artificial intelligence aspect of the navigator agent besides the speech recognition.

The *sound agent* is a companion of the navigator. It will try to enhance the visual impression of a space by adding an auditory component to it. A database with the available sounds that are described using weighted attributes [Engeli, 1993] is prepared for the agent. A neural network built into this agent has to be trained in a special set-up to select the appropriate sound from the database and to apply some effects on it. When used in the design studio, there will be a special interface provided so that the user can ask the agent to make modifications if the sound is not appropriate. The agent will follow the instructions and use them to improve itself over time by learning from these corrections.

The *presenter* agent learns about the preferences each user has for looking at the project. In a distributed environment this will be important because users with different backgrounds like, architects, engineers, clients, or HVAC planners, can get involved. Each of them needs to see the project in a different way to be able to make decisions. An architect may need floor plans to get an overview, while the client might prefer to get 3d views and tours through the building. An architect will like to look at details and see some sections, while the client is satisfied to see it as a whole, and animated if possible. An architect will be very interested in the surface materials and colours, while an engineer needs to know the material of the different building parts. The presenter learns by 'watching over the shoulder' of the user and detecting patterns and regularities in the user's behaviour [Lashkari, 1994]. Since this agent will adapt to the user over time, the improvement of performance can be measured and reported on demand, which is an important aspect to gain the confidence of the user.

Future Plans

The next set of agents will be agents that connect to information sources that are outside of the actual design studio. On the one hand, controlling agents can use outside information to check the validity of the current project, like figuring out if spaces are dimensioned reasonably or checking if building laws have been considered appropriately. On the other hand, information agents can scan through different sources and, whenever they consider it to be appropriate or when they get asked, pass relevant information to the user. Examples are:

- an information agent, that scans for information 24 hours a day.
- a cost agent, that calculates approximate costs of building.
- an HVAC agent, that calculates and controls isolation as well as energy exchange.
- an illumination agent, that can simulate different lightning situations.

These and additional agents will get improved so that they are able to *help with designing*. For example:

- the cost agent can make proposals on how to lower costs.
- the HVAC agent can help to optimise isolation and energy exchange, help to layout installations.

- the illumination agent can help to plan for an optimised light situation in the rooms considering daylight and artificial illumination.

- and last but not least design agents, that can suggest design solutions, based on a more knowledge based and holistic approach than can be built into Sculptor's intelligent objects.

conclusions

Many previous research and development projects in CAD have generally reflected the manual design reasoning and design development sequence. As described in this paper we believe that there is a need to explore other possibilities to support design, especially those that derive directly from artificial intelligence and virtual reality.

Since the project implementation has led us to challenge and question our own beliefs about architectural design, it is yet early to evaluate all the possible contributions of this project. It will take some time until we can comment on the real impact of this new environment on design. First experiments by students and demonstrations to other designers have evoked encouraging feedback.

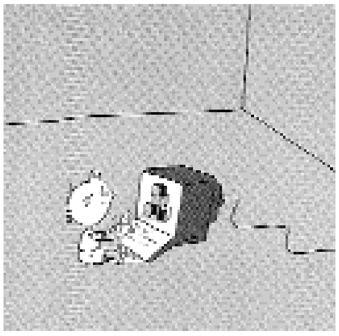


Figure 7: Little David playing with blocks, by Peter Wyss

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1 "human reasoning, outwardly logical (that is intelligent), is not meant to solve problems, but only to explain the intuitively found ... decision" from partner systems by Pereverzev-Orlov.