Sculptor - A Tool for Intuitive Architectural Design

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To manage the complexity in three-dimensional modelling and design in architecture, new approaches and methods are needed in computer based design tools. This paper identifies key factors in designing with computers and presents a computer program called 'Sculptor' for intuitive and direct virtual modelling in architecture. The program focuses on new methods for design in the early stages such as conceptual and abstract designs for massing studies.

Keywords: architectural design, user interface, virtual reality, distributed modelling, intelligent agents.

1 Introduction

What do designers in general and architects in particular need to design on the computer? How do they interact with it and in which stage of the design do they need it? These and similar questions arise when working on a computer tool for design.

There exist a variety of different approaches for designing with a computer, each supporting or based on different perspectives. Some solutions are based on the methods of how designers used to work before there were computers. Others are limited because of the limitation of computer power at the time of their development.

In this paper, yet another approach is described using the ideas and implementation of a computer tool called 'Sculptor'. But this might be slightly different than where the mainstream development of computer tools for architects has been carried. We take a look at the most crucial elements of a design tool especially important in an early stage of design: human machine interaction, user interface, interaction with other designers working on the same model and also how to support intuition and creativity in the interaction with a modelling tool. It emphasises the intuition and spontaneous discovery that is not based on analytical reflection, as one important principle in computer based modelling.

Sculptor has been developed with a natural, intuitive and direct user interface for three dimensional modelling that uses the newest technology in graphics computer. It is a non-commercial, experimental tool used in an academic environment to show a possible future of modelling tools in architecture.

2 Historical development

The development of using computers for architectural design happened very rapidly. It actually started in 1963, then 'Sketchpad', the first system that was able to generate line drawings on the computer, was created by Ivan Sutherland [19]. This was the beginning of many inventions and developments that used a computer as a system for representation of graphical information in various techniques, level of detail and realism. This includes the work in the development of a wide range of display and interaction techniques. [14, 15]

During their initial introduction in architecture, computer tools allowed an architect to draft two dimensional layouts. The producers of such software were talking of

CAD, meaning Computer Aided Drafting. This approach for two-dimensional (2D) drafting systems appears to have matured better with the two-dimensional look-and-feel interfaces. Monitor screen, mouse input, program menus reflect this paradigm of twodimensional space.

In the early eighties, three-dimensional (3D) tools started to be used more frequently. They are mainly used for numerically precise construction of models and for generating drafting's in 3D - i.e. in the final stage of a design - and were called CAD meaning Computer Aided Design tools. But most of these programs have encountered- beside the already existing - some crucial new problems:

(1) The tools sold now in a big quantity cover the construction documentation phase in architectural design. The conceptual design aspect is not covered yet.

(2) The paper based paradigm can not be translated for modelling in three dimensions. Totally new and different approaches are needed to solve these problems.

(3) The complexity of 3D models is enormously higher than the ones of 2D and 3D drafting. The difficulties are to understand 3D scenes and to construct and navigate in them. Better support by computer programs is needed.

(4) Sketching with a computer means a lot more than just using a drafting tool. The concept of fuzziness, roughness and non-precision could be useful when using computers.

3 New design approach

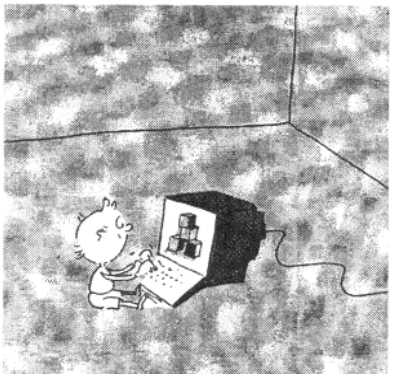

Figure 1: The idea of the cartoonist Hanspeter Wyss, a possible way for a modelling tool?

Since there exist very fast graphics computers and the computational power is getting more and more inexpensive, it is time now to think about new approaches both in the interaction with digital models and the way designers are using the computers for design. Also the question has to be asked: what is needed to use the computer already in an earlier stage of the design process?. In this respect, still a lot has to be done.

To enable this, one of the possible approaches is to use some developments in the human-machine interaction like Virtual Reality (VR) [8]. Even though VR is a catchword and used by everybody, still a common definition is not in sight. In this paper, the term VR is used to mean "a very realistic, computer generated environment that allows a user to sense and immersively interact with a three-dimensional model. This may or may not be with a data-glove or a head-mount display. More important for the work of architects is the immersive interaction with a model. Installations like CAVE [http://www.ncsa.uiuc.edu/evl/html/CAVE.html] that use a room where on all six sides images of the generated model and the environment are projected represents a step in this direction. This allows more than one person to be in an artificial room.

One of the key factors in interaction with a computer is the visual appearance of the interface. The rising complexity of 3d models also increased the complexity of the interface. The mainstream CAD interfaces therefore use windows, buttons and sliders to interact with the user and to make the parameters changeable. Why does a tool for 3D

modelling need dialogue boxes to appear on screen so that the user can enter the scaling of an object by 0.35 cm in the positive x direction? Shouldn't the user just be able to see it and do it, as directly and intuitively as possible - pick it and grab it? This leads to a more intuitive and direct approach. Actually a better modelling paradigm if design in 3D could rather be a foam model than precise 31) construction. [18]

An important issue in design is creativity - especially in the early stages. Like an architect that uses a large pencil and makes a rough sketch on a piece of paper, a computer tool should also be able to serve this or similar functionalities.

And we are living in a networked world, and we use more and more information from all over the world. The amount of electronic traffic on the internet using World Wide Web tools like Mosaic or Netscape® has grown and shown the enormous need of information. This reflects also on the profession of an architect. There is a increasing need to support networked models, information or images. Models of future design could have sensitive zones where more information would be available. Also a very important task in the future will be the collaboration with other people like other architects or engineers. Therefore much research is going on in the field of Computer Supported Collaborative Design (CSCW) [4,17]

There is no way to standardise the design process. It is as individual as human beings exist on earth. For some user certain functions of a tool might be an possible source of inspiration, for others an annoying and useless thing.

4 Sculptor

4.1 The Tool

Having identified key factors in design, Sculptor was developed basically to appear as a tool with wooden blocks, or more precisely with foam to generate real models. A possible approach was a system that behaves like a computer based tool for generating block models and extend it with possibilities wooden block models can never fulfil. The directness and intuitive operations are to be implemented in the computer tool to make it handy to use, especially for abstract design and massing studies. It is a tool that can be used where other construction based tools fail - the early design stage.

The development of Sculptor focuses on the implementation of a human-machine interface that is simple, direct and intuitive. Sculptor allows the manipulation of 3D object in a 3D scene. It allows this in real-time rendered 3D scenes and models, including the specification of attributes like form, geometry, colour, material, texture in a very rapid and powerful way.

Figure 2: Entering Virtual Reality with Sculptor

A very direct approach is chosen and all the specifications of an object happen instantaneously. Whether it is a change of the point of view or of objects that can be changed in size, position, rotation and colour etc. - everything that a user would expect from a 3D modelling tool - happens by just clicking and dragging it. It should actually feel

like grabbing it by hand and stretching it or moving it. So the user does not change objects by numbers but by changing them directly and getting visual and numerical feedback.

Compared to other 3D interfaces, Sculptor has a deliberately simplistic interface. There are no slider, buttons or windows on the screen. No complex dialogue boxes that fill the rendered area. One menu contains the functionality. Things change by moving them and not by typing in parameters.

The objects in the scenes act as natural as possible. This is supported by some physical behaviour [2]. Certain degree of intelligence can be attached to every object [17]. This means that the objects start to respond on gravity for example. If the user lets it go in the air, it falls down to the ground when not supported by another object. This function is enhanced by the collision detection. Objects that are being moved around in the scene collide with others. This make a scene much easier to understand.

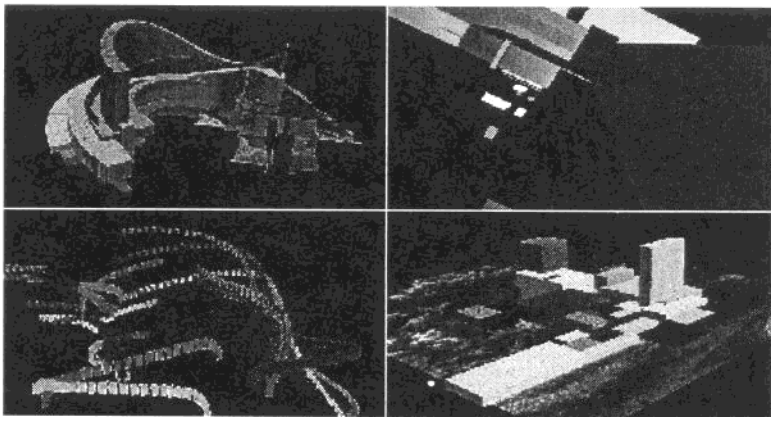

Figure 3: A compilation of scenes created with Sculptor

Design is viewed as a non-linear process. Especially in the sketching phase of a design, new techniques are to be found. One could bring some life into the machine, for example, using a method implemented called Autonomous Motion. Objects could be given a constant and autonomous changing of size, position, shape, colour or texture. All these parameters of the dynamic objects like frequency, speed, size, motion type can be specified interactively. One can define slow creeping objects as well as fast blinking and warning elements. This can also be applied to entire scenes of constantly changing virtual architectural models that define a whole space of different solutions [9]. The user can stop this constantly changing scene at any moment and continue to model with the current scene. This principle called 'I like it' reflects the non-linear way human beings are designing. A liquid architecture [3] can be defined which for some user might be a possible source of inspiration, for others an annoying and useless thing. It might be a part of creativity, a principle very hard to support in computer tools [13].

Since the tool concentrates on the first design stages, there is a need to be able to export generated data and use them in other programs. The data can then be transfered to more construction based CAD tool for further development, simulation or animation.

The importance of the global network is significant. More and more tools are required that allow global exchange of data and communication with people all over the world. Sculptor addresses this aspect in two ways. First, it is possible to generate sensitive field and elements. These elements are connected to other models or to hypertext data that are located on the WWW (World Wide Web), using the standard VRML (Virtual Reality Modelling Language) [http://vrml.wired.com]. When selecting or entering these elements, the corresponding data is loaded over the net and external models and information are presented in Mosaic or Netscape®.

The generated models can be stored locally distributed, but also distributed modelling is supported by Sculptor. The possibility that people in different places work together on the same model is offered in Sculptor. The field of Computer Supported Collaborative Work (CSCW) is very active at this moment. The basic functionality in

Sculptor to support the one-owner-one-machine design operation is expanded so that more than one user on more than one machine can work together. To make this possible, tools and functions in a library called DTM [http://xtc.ncsa.uiuc.edu/DTM / Documentation/DTM2.4/dtm.tp.html], developed at the NCSA in Illinois, are used.

4.2 Autonomous agents

In an other parallel project, Sculptor is used as the 3D interface for encapsulating different intelligent agents for the human machine interaction. The agents work in a virtual environment for a given design task. We are trying to develop very dynamic and constantly changing design worlds. We envisage that human designers in such design worlds will be assisted by various, kinds of software agents. Until now, three prototypical agents have been conceptualised 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 [10, 12].

The navigator acts like a guide in the virtual world - a taxi driver. 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. 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' [1, 11, 19].

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 of available sounds that are described using weighted attributes 16] 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.

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 [5, 7]. Each of them needs to see the project in a different way to be able to make decisions.

4.3 Sculptor in us': an example

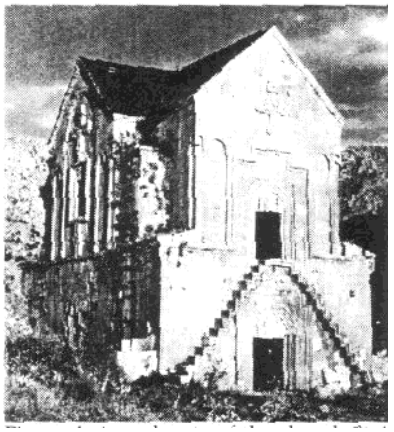

Figure 4: Actual state of the church St Astvatzatzin

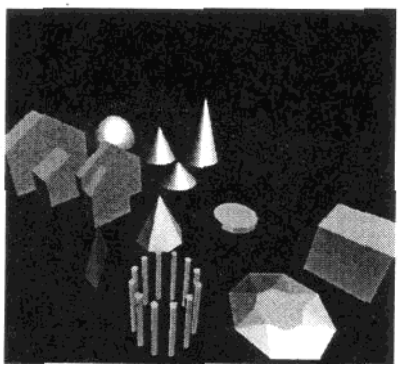

Figure 5: Extract of object library

In the following is described how Sculptor was used for studies in reconstructing St. Astvatzatzin in Noranvank, a gothic church in Armenia. The building is in a very bad state right now (figure 4) and needs to be restored. For our specific case, we created a library of basic topological elements of sacred Armenian buildings. The user can select the objects from a menu and insert them in the specific scene (some of these elements are shown in figure 5).

The actual state of the church St. Astvatzatzin and different studies were modelled using these pre-defined elements (figure 6). The underlying functionality of Sculptor, especially the direct approach, gravity and collision, helped us to understand the typological structure while modelling (e.g. by simulating the existing building and extending it while allowing it to change the size of the elements interactively). The interaction of the user with the model was of paramount importance as supported in Sculptor. Everything 'happens' instantly and is displayed on the screen.

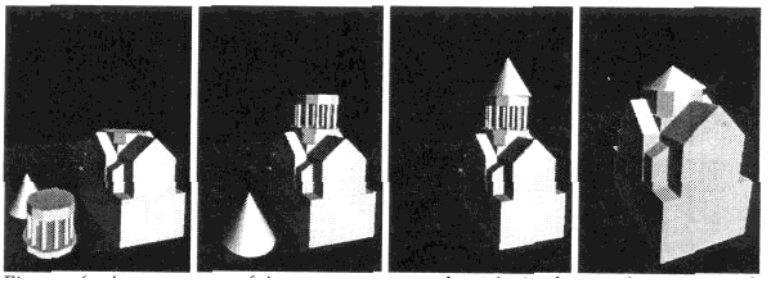

Figure 6: A sequence of images, generated with Sculptor, that shows the compilation and creation of possible variations for St. Astvatzatzin

For the further use for another typology or for more detailed simulations the element catalogue can be easily extended with other, more elaborate objects. The definition of grammars - valid combinations of elements - can be introduced to restrict combinations of elements.

4.4 Technical Details

Sculptor is written in C/C++ on Silicon Graphics Computers (SGI). It makes extensive use of the Graphics Library GL/OpenGL implemented by SGI. It runs on all recent SGI machines. The minimal hardware requirement regarding speed is an Indy/R4000.

A RGB projector with wall-size display demonstrates the ideas of the program the best. A nice and impressive option is the stereo projection. We use shutter glasses for this instead of the head mounted displays to obtain better impression of space and to make communication of people possible. Although the program is adapted to many 3D-input devices, they can be used optionally for interaction.

5 Conclusion

Traditional design methods and historical development of using computers in the architectural design process have consolidated specific tools that mainly concern the construction aspects. As described in this paper, we believe that more direct and intuitive approaches could lead to new and more natural design tools that are especially useful in the early stages of design. This is still an experimental research project developed within an academic environment. It will take some time before we can comment on the real impact of this new approach. First experiments by students and demonstrations to other designers have evoked encouraging feedback.

6 Acknowledgements

The development of Sculptor has been going on for three years now and originated within two projects: The research project Working Group in Model-Based Design and Reasoning is a collaboration between a number of research institutes and private manufacturing firms. This project is funded under the Priority Program on Computer Science by the Swiss National Science Foundation. It involves researchers from the Swiss Federal Institute of Technology: Artificial Intelligence Lab (Lausanne), Steel Structures (Lausanne), Architecture and CAAD (Zurich), and Logic and Computer Science (Zurich).

The project on Multi-agent Interaction in a Complex Virtual Design is funded the Swiss National Science Foundation. The project involves M. Engeli, D. Kurmann and researchers from the Swiss Federal Institute of Technology, Lausanne.

The author wants to thank Prof. Dr. Gerhard Schmitt, Dean of the architecture department ETH Zurich, and head of the chair for Architecture and CAAD, for the opportunity to work in this chair and to have all the exciting resources for personal development. Thanks also to Dr. Bharat Dave for his technical and linguistic advice.

Additional on-line pictures, videos and descriptions of Sculptor and the projects are available on the World Wide Web page: 'http: / /caad.arch.ethz.ch/ -kurmann/sculptor.html".

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