

SCULPTOR - HOW TO DESIGN SPACE?

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Abstract: Architects face a significant lack of computer tools that truly support them in the early, conceptual stages of design. In this paper, we take a look at the reasons for that and propose some solutions. We introduce new human-machine interaction methods that do differ from construction based approaches. We define new spatial interface paradigms as well as new objects and their behavior. Finally we present their implementation in »Sculptor« - a modeling prototype to enable designing *in space* with *space*.

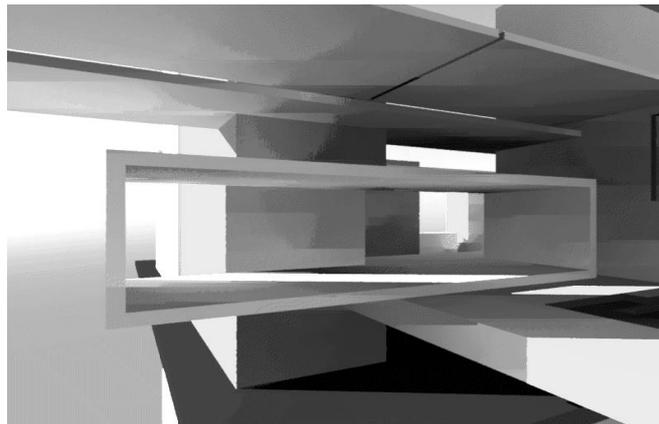


Figure 1. Interactive Sculptor model (R. Probst, phase X)

1. Introduction

One can observe that architects are not completely satisfied with the tools offered even though they use computers more frequently today. Looking more closely at the existing commercial programs we can see two major shortcomings: Computer Aided Design (CAD) tools are not designed for architects specifically but primarily for engineers reflecting a wide area of



engineering knowledge. Furthermore, one can observe the lack of conceptual possibilities of design tools to use in an early stage of design (Van Vries and Wager, 1990). CAD tools do support the construction of buildings, but they hardly support the design. In order to overcome this situation we started to develop Sculptor - a prototype that demonstrates new approaches for the design with computers.

There are three tightly connected questions regarding design with the computer: *how*, *what* and *when (in which stage)* to design. We claim that different interfaces are needed in the construction and the design phase of a project. Our approach therefore is to build interfaces that are more direct and much more intuitive than construction tools, supported by fast graphics possibilities.

Especially the importance of space is neglected by most CAD tools. Space is not only a result of composing walls, roofs and floors. It is a key element and major principle with an overwhelming amount of inherent functions and implications. An architectural design tool has to offer both the ability to build space and to experience it. Within several research projects, we are working on ways to design and manipulate space.

This paper will demonstrate the newest principles, possibilities and ideas developed with Sculptor in supporting spatial design. Results and experiences in teaching architecture students using this tool will be presented, especially from a collaborative global design studio held in November 1997 in Zurich, Hong Kong, Vancouver and Seattle simultaneously.

2. Design and Tools

CAD tools today have to server multiple disciplines - general programs are written and refined afterwards to fit for one or the other profession. This helps to reduce cost of development but produces bigger and therefore slower programs. Fundamental principles tend to be forgotten with this kind of development process. The architecture discipline especially suffers from this process as CAD tools are being developed for civil engineers and therefore concentrate on the construction part of the design process.

Designing fundamentally differs from construction. We can agree on conceptual - early stage - design as being more complex, more intuition based and for sure far more non-mathematical than the construction aspect of CAD. There are literally millions of different approaches to *how* to design in architecture. Individualism and uniqueness are two of the attitudes associated with architectural design why defining strategies for architectural design is complex and implementing them is difficult.

Different approaches were taken to master this situation. Some try to design by analyzing sketches on the screen to define three dimensional objects

(Gross, 1994). Others are exploring emerging shapes out of existing ones (Edmonds and Soufi, 1992). Early approaches defined grammars rules about how design has to be and were creating one or hundred solutions to choose from (Shih and Schmitt, 1993). Yet another approach is the analysis of existing designs to derive new solutions similar to the ones in the data base (Flemming, 1994). Most of these artificial intelligence based proposals do support the architect in one way or the an other. But there is the principle problem of interaction not addressed by these proposals.

3. Design and Interface

What has to be offered to a designer is the possibility of interacting with a computer model in a convincing way. It is the dance on a rope to provide full control on the design, analysis of the actual model and offer certain inspiration while using the computer. A large portion of the solution to this is *interface design*.

Without making the mistake of copying traditional design methods we still have to look at the way architects are used to design conceptually and analyze paradigms of traditional design. What is in common to paper and pencil, cardboard, foam and wood used for sketches and physical working models is the *transformation of ideas*. They are representations of ideas and every re-presentation is a transformation. This reflection of an idea while modifying a sketch or a model is an aspect of great importance. It offers inspiration through the objects that are being created. They help to form ideas and concept both obvious to or hidden from an external spectator. This is the part of inspiration that must be supported by the medium in which design happens. Typical parts of the design process have to be supported like: storing ideas, possibility of elaborate on different aspect, get back to the old sketch, copy parts, change others and look at the changes from all sides.

We consider supporting this transformation of the designers' ideas though the medium to the designer back again to be essential. A design tool for architects must support this by providing an interface between model, computer and human and has to combine it with the advantage of computer capabilities. The more hurdles there are between the model and the designer the less intuitive the interaction process is. And the slower a presentation of a model on the screen is, the more one has to wait for a change to get calculated and displayed, the less intuitive a modeling package is. Instantaneous representations of changes in the design combined with real-time interaction therefore is a base for every design tool. Directness and intuition are keys for successful design tools, not numbers. Architect do think graphically (Laseau, 1989). A design tool mainly has to support this though direct graphical representations and feedback.



Figure 2. The outside is always an inside (Le Corbusier, 1923), Villa Savoye, Paris

4. Space and Material

Beside the *how* and *when* we should look at the *what* to design. Construction tools enable the modeling of material. In architecture however space might be even more important (Van de Ven, 1987) - a concept not supported by CAD tools. Many architects were and still are proclaiming the importance of space (Boudon, 1977). »Through Frank Lloyd Wright, many architects have been influenced by Lao-tzu's teaching that reality of a hollow object is in the void not in the walls that define it.« (Pelli, 1997).

One has to talk about a Duality in Architecture:

Material	-	Space
Solid	-	Void
Walls + Roofs	-	Room
Boundary	-	Volume
Buildable	-	Usable
Additive	-	Subtractive

A design tool obviously has to reflect this duality. We therefore proposed to define two types of objects - space elements and material elements. They have to be treated identically and should behave dually. The void element always carves out space, the solid element adds material. Actually only an attribute of every object defines whether it is a space object or a material object which helps enormously to understand spatial compositions.

A room object is simply a group of a larger solid with a smaller void inside. The difference of size defines the thickness of the wall. Moving rooms to intersect with each other automatically creates the more complex void shape of the inside. Even hierarchical structures are possible to build rooms inside of rooms.

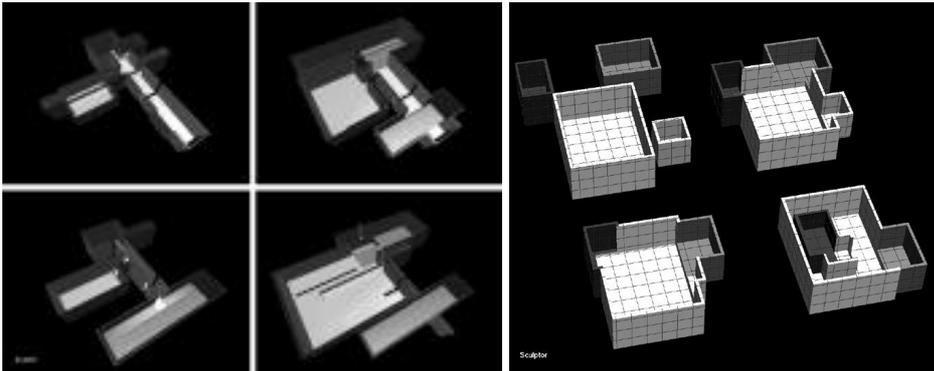


Figure 3. Complex voids with composed rooms. Rooms inside rooms on the right.

Sculptor has these mechanisms implemented and enables real-time modeling with intersecting material, spaces and rooms (Kurmann, Elte and Engeli, 1997). As the underlying modeling technique surface modeling approach is used. Every closed volume can be used as a void form. For the reason of speed and in order not to lose direct interaction voids are implemented as cubes for now.

This approach might look similar to solid modeling (Mäntylä, 1988), but there are two fundamental differences. First one is that not the operation between objects (intersection, union, difference) is defined, but the objects behavior (how they are interacting with others). Secondly and more important is the reflection of spaces and voids and with that the direct support of architectural ideas and concepts in the design tool. This approach makes it possible to perform calculations based on spaces rather than on material. Cost estimate based on volume, spatial adjacency, path finding in connected rooms as well as sound, energy and light analysis are made possible with the space elements.

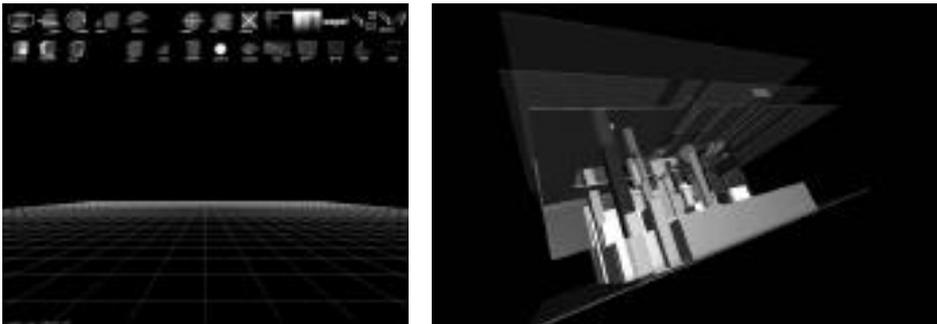
The idea of using voids for modeling was presented by other authors before. Chris I. Yessios (1987) for example presented the idea of a void modeler for the reason of computability. Yessios proposed to have operations between objects: intersection, union, difference, this in contrast to object *attributes* as presented here.

5. Sculptor

The development of Sculptor started in 1993 with the vision to demonstrate that conceptual design is possible with the computer by offering real-time manipulation of objects in space. Beside modeling primitives autonomous moving objects were a first approach to add inspiration to in the interaction with models. (Kurmann, 1995).

Recent developments involve the direct connection of Sculptor with the light simulation program »Radiance«. Material, light sources and viewing positions can be controlled directly from Sculptor which starts the rendering process interactively.

Newly developed is also the possibility of collaborative modeling over the Internet which is controlled and managed on the web. On the collaboration management site everyone can start a new or join an existing Sculptor collaboration session. The actual state of the model can be observed through both pictures and VRML models that are uploaded and presented regularly.



Figures 4. The Sculptor interface. Figure 5. View of a model in Sculptor

6. Multiplying Time

Sculptor is being used in many courses taught at »Architecture and CAAD« at ETH Zurich. It was very intensively used in the virtual design studio (VDS) in November 1997. Together with Hong Kong University, University of British Columbia, Vancouver and University of Washington, Seattle we worked on new ways of international collaboration via computer networks. By taking advantage of the time-difference between the parties involved a 7x24 hours workshop was established.

Student groups from each school participated in the project. The design task was worked on and refined in several phases by all schools in parallel. It was divided up into five distinctive phases:

- i) Duality
- ii) Solid and Void
- iii) Light and Shadow
- iv) Material and Immaterial
- v) Space and Place.

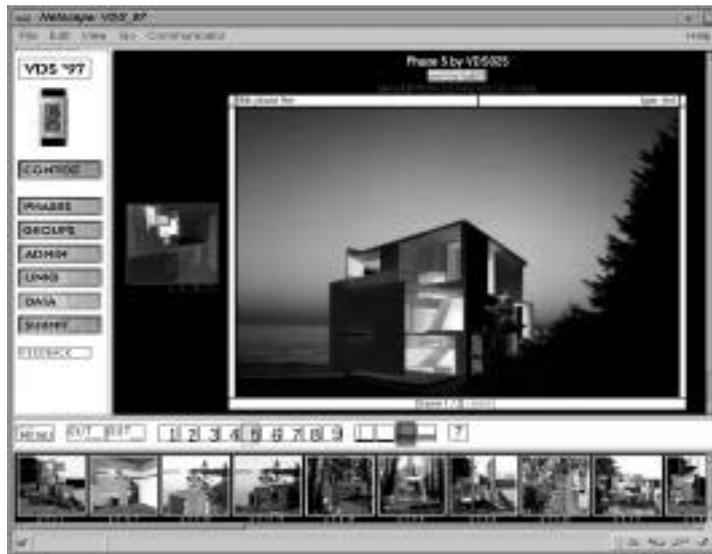


Figure 6. The »Multiplying Time« database interface.

All the increasing information was managed by a worldwide accessible Internet database - a development based on the interface phase(X) (Schmitt, 1997). At the end of every groups' working period the finished parts of the work were submitted to the database. The next student group had to select work from the previous phase by different authors. Students thereby could browse through the database and see other participants' work at all times. The exchange of information over the database was supported by email and video conferences.

Within all the groups of the VDS, Sculptor was used as the design tool for spatial modeling and for controlling the light simulation process with Radiance. The different topics of the phases therefore were defined on the capabilities of Sculptor. Looking at the final results of this test case clearly showed the capabilities of Sculptor as a design tool. Taking into account that most of the students in Zurich were in their first year of architectural study and had no computer experience at all the achieved results are extremely pleasing. The results certainly were influenced on the other hand by the medium Sculptor to quite an extent. The feedback also demonstrated that certain students being familiar with commercial design tools enjoyed the offered freedom not needing numbers and construction elements and going things visually only.

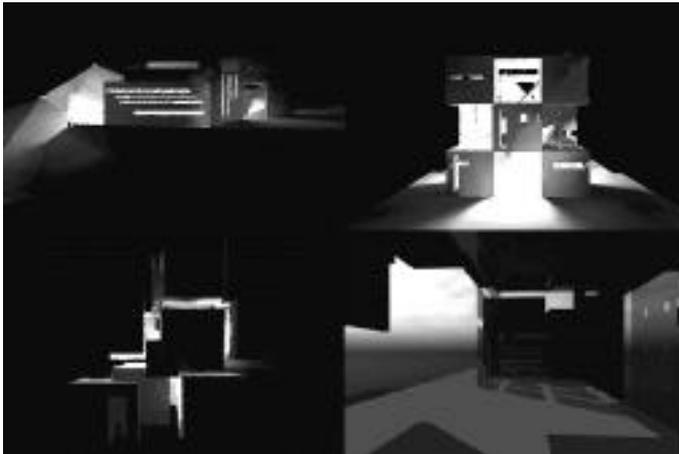


Figure 7. Sculptor models rendered by students in »Multiplying Time«

Conclusion

Sculptor adds new and hopefully controversial topics to the discussion of the how, when and what in architectural design. An implemented interface is one explicit possibility to interact with the model and therefore always very personal interpretation. Feedback from several hundreds of students using the tools has shown that the approach is very successful and helps to improve the functionality and interaction constantly.

Acknowledgments

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http://space.arch.ethz.ch/VDS_97

Sculptor runs on all Silicon Graphics Computers, a PC version is in development. Free download for non commercial purposes as well as information, models and tutorials are:

<http://caad.arch.ethz.ch/projects/sculptor>

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