

# From Digital to Real

## **Theoretical-digital architectural concepts and the realization of complex spatial forms**

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*To summarize former experiences of design seminars of the past years, the paper describes how new thinking and development structures within a design process, in conjunction with digital design media, requires new approaches to the design process itself. Also required are new solutions in adequate, three-dimensional, haptic presentation methods (model making), in order to secure the physical control of the computer-generated data structures.*

*Points of origin have been several student projects whose conception was based on the idea of the contradiction of a modern architectural approach with its inclination to industrialized parts and series. The promise of the computer based design and manufacturing process seemed to allow the realization of almost every imaginable architectural shape for the same costs as those in regular planning and manufacturing processes. The different projects explored both static modeling methods and dynamic computer-driven development and presentation techniques. The latest project touches the field of an algorithm-based design process.*

*Finally a possible process chain from early design stage into a three-dimensional, physical model is described. Considering the resources and financial budgets at universities, the development of an efficient manufacturing process with effective interfaces will summarize the method and finalize the study process.*

**Keywords:** *Digital Interfaces, Computer Aided Manufacturing, Design Education, Dynamic Design Development, Algorithm Driven Design Process*

### **Project approach**

#### **Initial projects**

The series of digital design experiments began with the design studio of *160 custom-made*, in which the authors pursued to trace possibilities to plan and build individual architectural shapes by

using today's state-of-the-art computer driven design and production chains. The studio group worked free from analytical interpretations and approached the design process by using different terms and images of analogies that built the basis for the entire project. Those were analyzed for

building structures, details and several features and were used for the shape of the objects in the further design process. In most cases, the arising formal statement was described in a hand-made, physical model. This model was cut into slices, measured, scanned and digitized to define a precise, virtual 3D digital description of the project itself. At the end of the design phase all participants had produced a physical working model that represented their interpretations of the chosen terms, related to their personal background and history. Regarding the usage of the applied software *Maya* with respect to the design process, the tool more or less was utilized as a resource in order to translate an analog and complex design shape into a digital image.

The logic development for the next step was the introduction of semi-dynamic aspects into the design procedure. The *Maya* software enables the user to add dynamic components in order to generate forms and shapes. In the project *urbicles*, student groups studied the dynamics of moving pedestrians within a highly frequented milieu in the city of Berlin. These dynamics were used to drive a digital design process that specified the design of their architecture. Movement patterns produced by the urban actors within a defined area were analyzed to describe certain procedures, depending on time, day, location and event. These parameters were read into the *Maya* software in order to produce a design that was based on the special occurrences at the location.

#### **Algorithm driven design process**

The final project in the series of described design experiments used the computers superiority to process an immense number of calculations and operations within a short period of time. That enables the designer of the algorithm based design method to analyze and structure very complex contexts. A relatively large number of different variants for a desired design topic, driven by deliberate variables and/or accidental

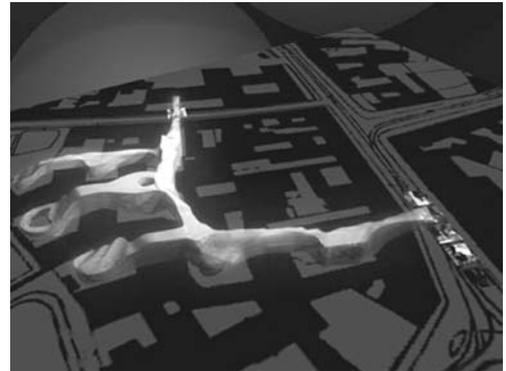


Figure 1. *Urbicles*, 3-dimensional movement scheme

parameters, can be created, studied and valued. The algorithm admits a multifaceted number of affected factors that allows the generation of an individual object, designed for its specific design task and location. The designer actively influences and directs this process through adoption of the algorithm (s) and the choice and assignment of the different parameters and the selection of the variants. In order to influence the design process or to force the design development into a desired direction, the designer can make interventions and/or supplementary changes of the design, structure, and shell at every point of the process (god-mode).

Although the result sometimes might appear arbitrary or unusual, it fulfills the defined conditions precisely and strictly. Compared to the regular design process, where certain steps are not always re-enactable, the algorithm based development steps itself are precisely re-enactable and therefore describable, even in a scientific manner.

#### **The Algodes-Project**

The task of the *Algodes-project* is the development of a specific algorithm that is based on the chosen situation of Mies van der Rohe's Farnsworth-House. The algorithm shall describe an architectural shape in a useful scale, based on geometric, structural and functional parameters.

The final result shall not only display the aspects of a possible quality of the generated architecture, space and shape, but also point out negative valued steps and results.

**Step one**, tool definition. The software of the choice is *3D Studio Max* for the reason of an included script language (Max Script). The script language offers the opportunity of recursive programming (to operate files, analyze bitmaps etc.). By reading out text data, it is possible to use a wide range of mainstream software to generate data structures that can be read by *3D Studio Max*. The .dxf export function provides an interface to common CAD software.

**Step two**, the fence experiment. A virtual worker is simulated to build a fence on a rectangular site. He picks up poles at a certain position, carries them to the site and erects the poles. During this activity he gets tired. Depending on the pre-defined power and work-day-length of the worker, the diameter of the fence on the site varies. In addition to Max Script, *Java* is used to program the simulation. As a data generator *Java* offers an object-orientated programming language. The *Java* data gets read into *3D Studio Max* and generates the different experiments.

**Step three**, object matrix and object processing. Four objects (space, mass, function, and dynam-

ic objects) and several processes for a simulation (curved, linear, binary, punctual processes) are defined. On the simulation area a number of static function and mass objects are placed. All objects have a defined function and configuration (parameters). Dynamic objects with differences in speed, turning angle etc. move through the simulation area, getting influenced by the static objects and their pre-defined parameters, leaving behind traces of their movement. The complex traces can be processed as a mathematic average for better graphic readability. By generating different mathematic representations of the result, it can be viewed in a desired visualization.

**Step four**, adoption onto the Farnsworth House Project. The Farnsworth House was chosen as an experimental building configuration for the above described object matrix. The building is well known by the architectural community, its structure is fairly simple and all functions are established on one level. The object matrix is applied as described:

The functional areas (static and mass objects) are analyzed (entry, decks, living room, kitchen etc.); a certain object type is applied to each area, describing it in parameters. The starting point for the dynamic object (s) is the staircase of the main entry. The specific parameters for the different

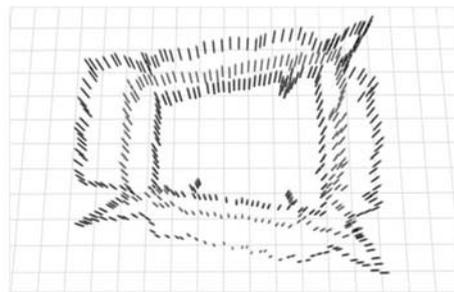
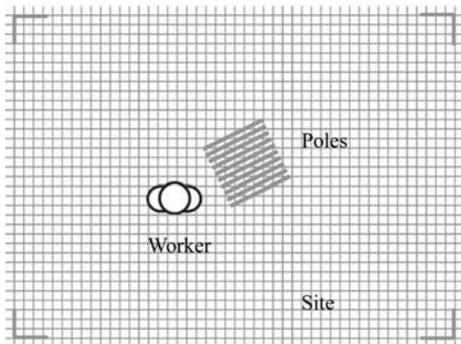


Figure 2. The fence experiment

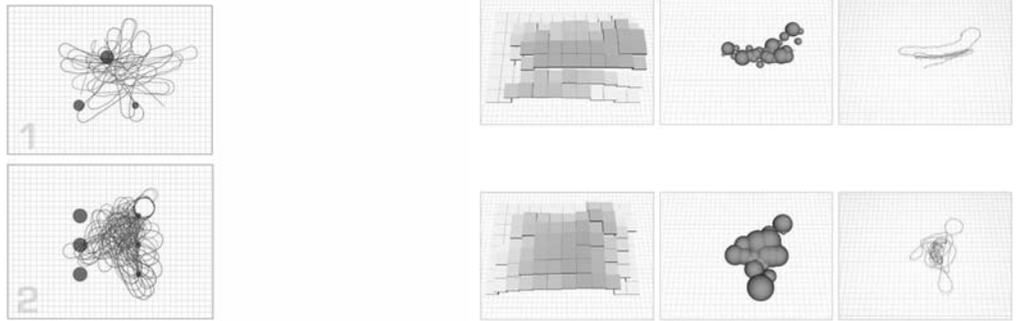


Figure 3. Simulation process and graphic representation

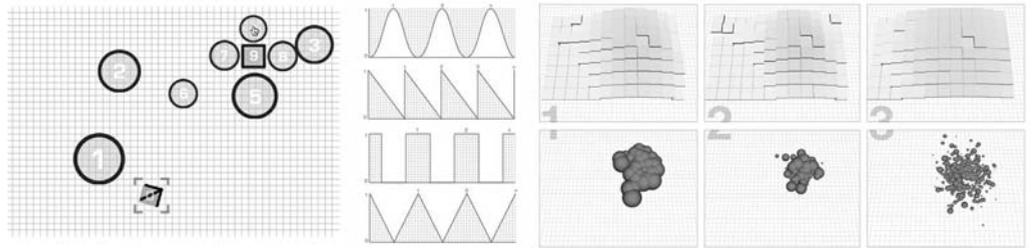


Figure 4. Simulation process and graphic representation of the Farnsworth House

areas are chosen partly in conjunction with their function, partly arbitrary. Finally a number of different dynamic objects (each could, for example, stand for a different person) start to move through the setting. The dynamics draw a path onto the floor plan, influenced by the forces of the different object parameters. Depending on the given setting, some static objects are too weak to effect the movement of the dynamics. Like in a planetary system, the 'gravity forces' not only influence the direction of movement, but also the speed of the dynamics. The graphic analyzing tool allows looking at the result in a more explicit representation.

**Step five**, visualization of the so far generated data structures. By using a self-developed tool, the so far generated data structures are visualized into architectural shapes. The parameters for the used visualization algorithm are defined spontaneously. By changing the algorithm during the

ongoing process, some new ideas were born that might lead to new forms of architecture. The produced shapes turned out to be very complex. In order to handle the shapes for a form generation, they got simplified in a next step. Out of the wide range of produced results one scheme was chosen by the project authors to finish it up as an understandable architecture. To do so, the project authors had to add some manual work on the project in order to reach the desired goal. During the described process the computer inherited a good part of the design work; anyhow the main design decision was still made by the authors.

### Modeling process

For the realization and production of physical models of the designed schemes several computer aided manufacturing methods were investigated, of which two were considered for reasons of

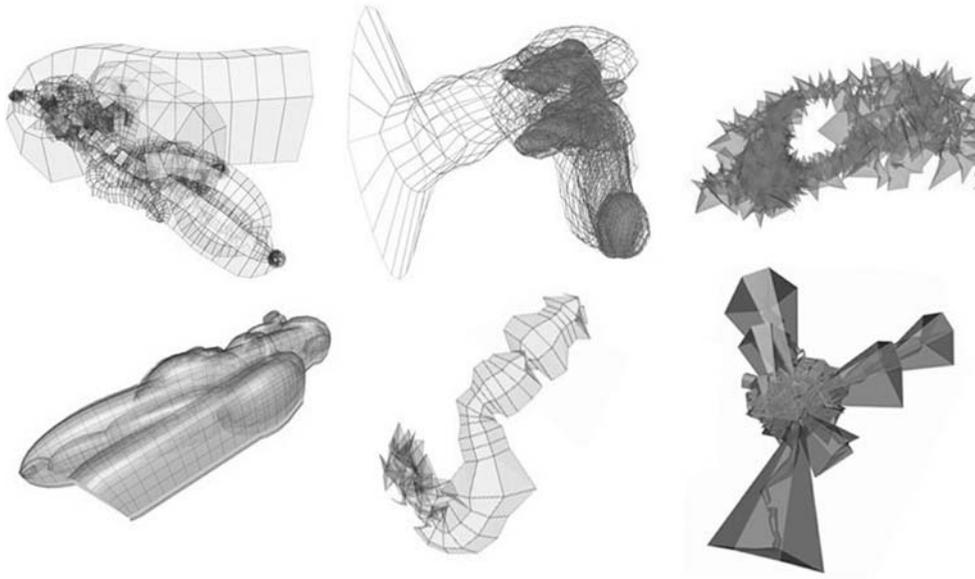


Figure 5. Examples for generated shapes

possible production and reasonable production costs.

### 3D printing process

As described in a previous paper, the data structures of the projects of the early design experiments were not at once usable for the accurate CAM-process. The precision was satisfying to display the shapes on a screen without any visible imperfection but in terms of accuracy and finished volumes for the production machines the precision was insufficient. The chosen output devices demand mathematically perfect volumes and closed skins. Part of the production process is therefore the (partly manual) controlling of the generated volume, before it gets produced automatically. Exchange formats were the STereo Lithographic (STL) or Initial Graphics Exchange Specification (IGES) file format. In case of one of the 160 custom-made projects, the 3D printing method was chosen. Thin layers of wax-like material are applied by a printer that uses wax instead

of ink, building up a model out of thin layers of material. Comparable to the stereo lithographic method, the 3D printing method seems to be more affordable. The process depicts every detail very precisely but uses extra material in order to stiffen the model during the production process. This extra material has to be removed manually for the final outcome. In the case of interior spaces this process sometimes turns out to be

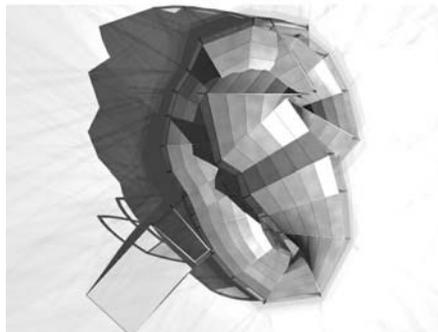


Figure 6. Final scheme



Figure 7. Virtual and physical model of the project 160 custom-made

very complex. The main advantage of the method is the preciseness of the mass model; disadvantageous is the non-transparency of the material and its sensibility to heat.

#### **Laser-cutting method**

The laser cutting process chain gets developed for the Algodes project. In order to receive a physical model, each three-dimensional structure is cut into two-dimensional sections; the three-dimensional character is obtained through the overall-structure of slices in the final model. Although the final model is only an abstract representation of the desired shape, it produces a perfect impression of both exterior and interior space. Since the described Farnsworth House Project turned out to be too complex for a test run, a simplified volume is used for the manufacturing process. The volume was generated with *Rhino 3D* software, a product design modeler that allows the easy extraction of two-dimensional slices of a three-dimensional object. The extracted. dxf data can be read without any conversion

by the output device. Another advantage is the simple manual remodeling possibility. As soon as the volume is transferred into 2D-slices, these single files are easy to control and manipulate; the third dimension of the single part is given through the thickness of the used material. As in similar processes, the final pieces are cut from a chosen material by laser (wood, steel, plexiglas etc.). To construct the final model, the pieces have to be arranged manually.

#### **Conclusion**

The goal to use the computer and its certain software as a tool to influence and specify a design process was reached successfully in the sequence of several design studios. It shows that the digital machine cannot replace the designer in his function to come to a formal and functional decision within the design process. But the computer can support the designer in his work to approach new design methods and explore new possibilities to use context-based parameters to

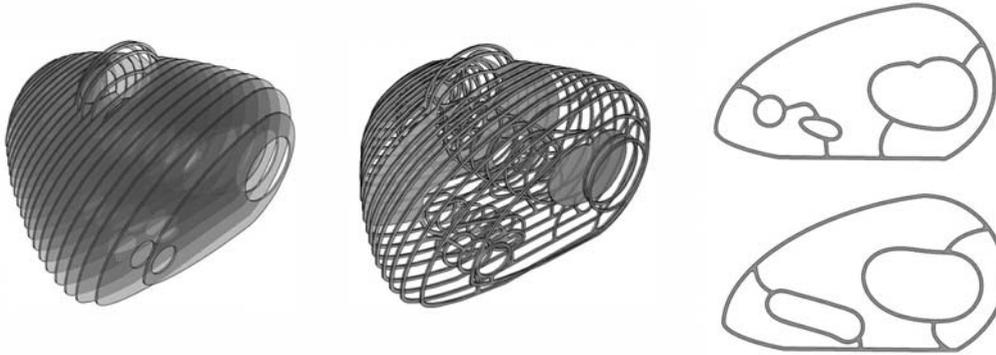


Figure 8. Virtual model; model piece ready for the laser cutting process

drive the design process and development. Anyhow, the designer remains to be the person who keeps the control and responsibility over the whole process.

### Acknowledgements

Jörg Rügemer, Markus Bader and Peter Oemichen organized and taught the urbicles project; Barbara Kellers and Stefan Schneider designed the urbicle. Daniel Dörr and Patrick Gerdtsmeier programmed the algorithms for their Algodes project. Peter Oemichen organized the 3D printing process; Daniel Dörr worked on the process chain to develop the laser-cutting model within the university. Lesley Morris revised the text.

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