Parametric possibilities: Designing with Parametric Modelling

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We describe several projects in our ongoing research and teaching activities in the field of parametric design. The work is based on the premise that using parametric modelling and customized mass production for designing, planning and realisation, the creation of a spatially rich and varied architecture which is specific for individual programs, users and contexts is being made possible.
We demonstrate this design approach by explaining three different design methodologies of various projects. The specifics and the experience of the use of various CAD software tools will be described: scriptable CAD programs like VectorWorks and CAD software with integrated parametric modelling like Unigraphics.

Keywords: *Parametric design; Generative design; Mass Customisation; CAAD curriculum; Digital aids to design creativity.*

Introduction

We use parametric modelling and customised mass production to design architectures where variety, spatial richness and a sensitivity to specific programmes, users and contexts go along with the economics of mass production and the easy adaptability and changeability of architectural designs at all stages of the design process.

The specific conditions of each new building task, each new group of inhabitants and users and each new site has in the past century rarely found a place in an architecture that through the use of serial mass production had limited itself to a small formal repertoire and the repetition of equal or similar buildings and building elements. Customised mass production provides possibilities to economically produce many elements which are not identical like twins but similar like related family members (figure 01).

In order to employ customised mass production, rules have to be established that relate the family members to one another. Through the variability of their parameters, parametric CAD models provide such a prerequisite for customised mass production.

Every building is designed for a specific set of parameters, i.e. use, size, material. Traditionally, this set of parameters is frozen at the start of the design process. Every later change results in labour-intensive redesign. Parametic modelling introduces changeability of the parameters into the ongoing design process. This leads to much more dynamic and adaptable designs where a 'late change' like for example the addition of another hall to a cinema

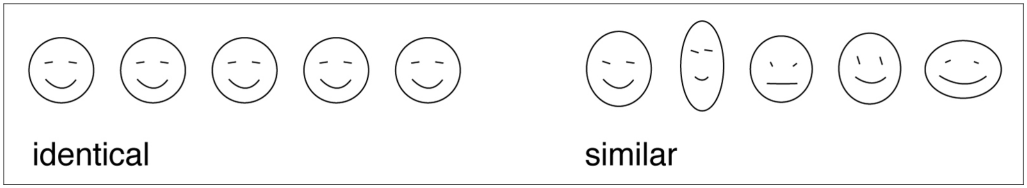

Figure 01
Faces: Identical and similar

complex does not result in the labourous manual integration of a new element into an existing design but merely to the re-calculation of a parametric object with a new set of values for the parameters.

Specifics of context and users can inform the mass-produced object or building and thereby create a balance between regularity and variety. Monotonous repetition can be overcome and superceded by varied similarity.

Parametric design

Parametric modelling CAD programs are widely used in automobile, naval, aeronautical and product-design industries, where the process of planning is characterised by further developing and optimising an existing product or its components. Rarely, a completely new design "from scratch" is being introduced as it is most often the case in architecture.

Therefore, in these industries tools for easy handling of changes on an existing object have been initially introduced with CAD systems.

Even though in architecture the process of planning is different, there are innumerous changes to a building over the course of developing it. And not only would the utilisation of parametric models make changes easier to handle, it would also offer the possibility to easily produce variations of the design object and provide adaptability to user and location (figure 02).

To employ this alternative design method, the object must first be described by a set of rules of geometric dependencies and constraints that are then "translated" into a digital parametric model. The definition of dependencies facilitates the variation of complex systems rather than the mere change in scale as in non-parametric systems. Defining constraints is part of the definition of rules and incorporates aspects such as material specification, sizes of parts and spaces, planning regulations etc.

Parametric design methodologies

During the course of several design projects, various

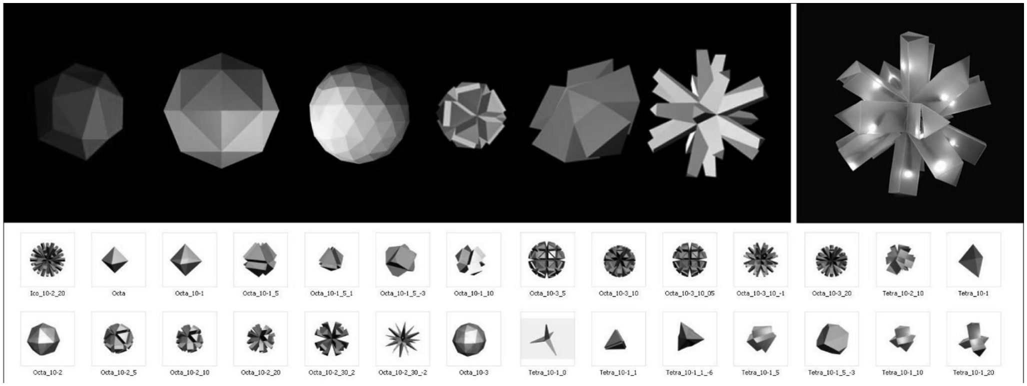

Figure 02
"Geometric variations of parametric lighting object", student design project, winter 04/05, Mohan Zeng, Technical University of Braunschweig

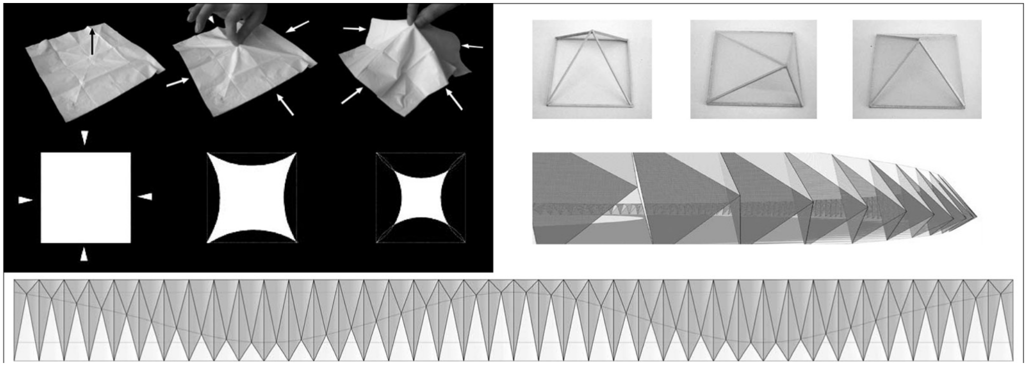

Figure 03
"Parametric facade system", student design project, winter 06/07, Islam Adel, Ji Choi, Egon Hedrich, Christian Keil, Rainer Schmidt, Technical University of Darmstadt

methods of teaching parametric design and using different parametric design tools have been employed depending on the given subject. This paper will present three different approaches:

- Parametric systems defined by individual or climate factors [a]
- Complex shapes in nature translated into parametric objects / buildings [b]
- Geometric structures in nature translated into parametric objects / buildings [c]

Parametric systems defined by individual or climate factors [a]

Designing parametric objects and buildings requires an understanding of geometrical dependencies and constraints and their application in defined rules. Several small consecutive design projects will show experiments of parametric design of increasing complexity.

A demonstrative introduction to the subject

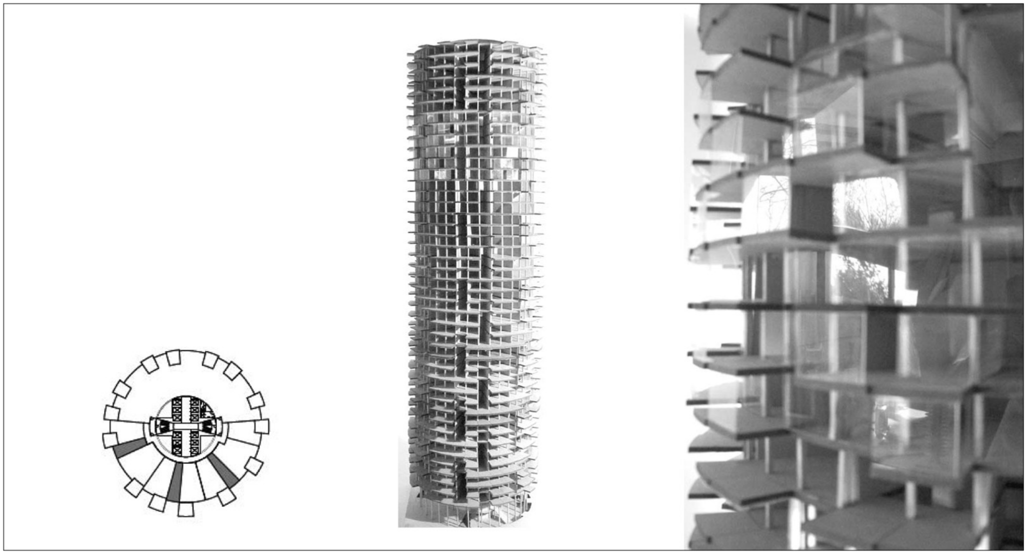

Figure 04
"Highrise in Moscow with parametric facade elements", student design project, winter 06/07, Pascal Kuhn, Technical University of Darmstadt

is the analysis of an object of one's environment. A piece of furniture is chosen and described with variable parameters, i.e. height, width, depth, angle, material etc. Changing the value of the defined parameters on one hand offers an infinite number of variations, on the other hand enables the creation of the "perfect" piece that is adapted to the specific user and differs from the other pieces in the way that the user differs from the other users.

In the following step of increased complexity the topic of parametric systems is being extended from the indiviual user to climate conditions. factors are now sun, heat, air, water etc. in different climatic locations (figure 03).

With these factors and the awareness of how these are differently apparent in different climates, a building or building element is designed that can be created - due to its parametric adaptability - to an optimum on various levels and aspects: to climate on the macro level and to orientation of the site and internal use on the local level.

The developed parametric system allows the creation of buildings that are conceived ideally for the specific climate, site and usage.

Our design project creates a parametric system for a highrise building with office, residential use, recreational services and open communal spaces in three locations with widely varying climates: Hamburg / Germany, Moscow / Russia, Doha / Qatar.

The main emphasis of this design project was to deal and experiment with similarity and variation and to develop a rule-based parametric system for a building that is designed as regards content and geometry. For the creation of continuously adjustable variations film features tools of the CAD programm Cinema4D were used (figure 04).

Complex shapes in nature translated into parametric objects / buildings [b]

Another methodology experimenting with rule definition and creation of variations started with the analysis of a nature object as source of geometry definition.

Here a chosen fruit is analysed as to its complex shape and structure. The polygonal segmentation of the shape shows a variation where not two polygons are ever identical but merely similar (figure 05).

From this analysis parametric systems are developed on increasing levels of complexity: from an object to a piece of furniture to a building.

First, the object is designed to be a lighting object that can satisfy all different requirements of a user: shape, size, material, luminance etc. These characteristics are defined as rules of a parametric system with parametric expressions and constraints and are scripted in the programming background VectorScript of the CAD software VectorWorks (figure 06).

Secondly, for the piece of furniture a coffeebar is designed as a parametric system. In the project

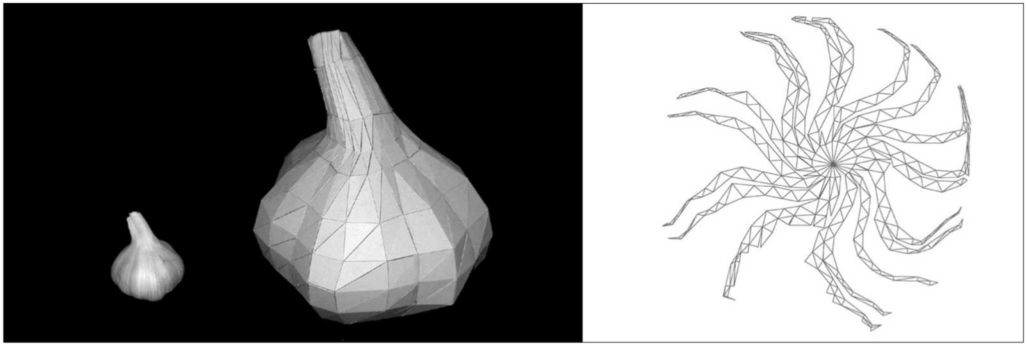

Figure 05
"Study of three-dimensional shapes in nature on the example of garlic", student design project, winter 04/05, Mohan Zeng, Technical University of Braunschweig

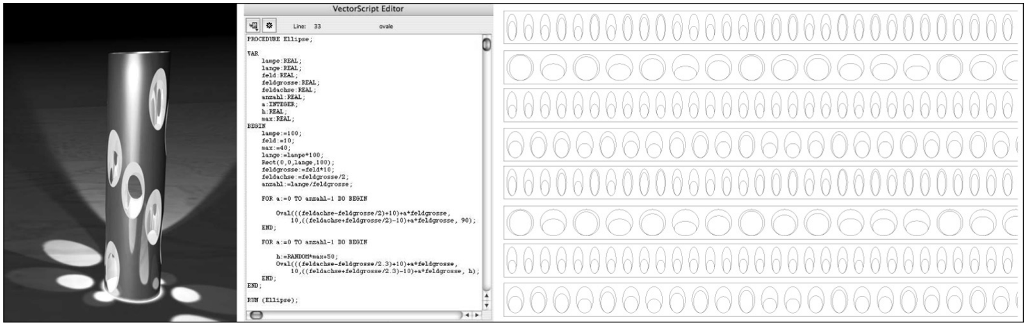

Figure 06
"Lighting object with opening shape scripted in VectorScript ", student design project, winter 04/05, Christoph Jeßnitz, Technical University of Braunschweig

shown below, several modules related in geometry are designed in a way that they can be added by a defined rule. The different shapes and sizes of the modules result from different tasks they fulfill, i.e. containing coffee machine, sink, fridge or storage for cups and glasses (figure 07).

The geometry of the modules' shape in relation to the position of its bar elements was scripted in VectorScript.

Thirdly, the design of a parametric building consisted of developing a new 'architectural identity' for a German discounter expanding to countries in East Europe and hereby developing a parametric system for the building's internal organisation, its construction and facade system that will be created according to varying conditions and requirement of site and use (figure 08).

Geometric structures in nature translated into parametric objects / buildings [c]

The third design methodology experiments with geometric principles from nature, their analysis, abstraction and transposition into objects and buildings.

Here, as before, a fruit is being analysed, but this time not only by its complex shape, but by its geometric construction principle. The established principles are then abstracted and classified according to principles like spiraling, packing, cracking, tiling etc.

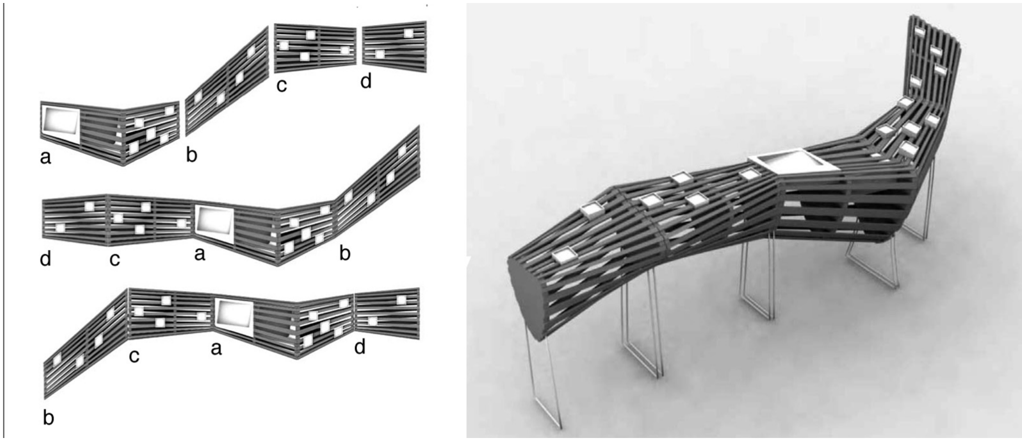

Figure 07
"Coffeebar with parametric modules with shapes differing according to contents", student design project, summer 05, Mohan Zeng, Technical University of Braunschweig

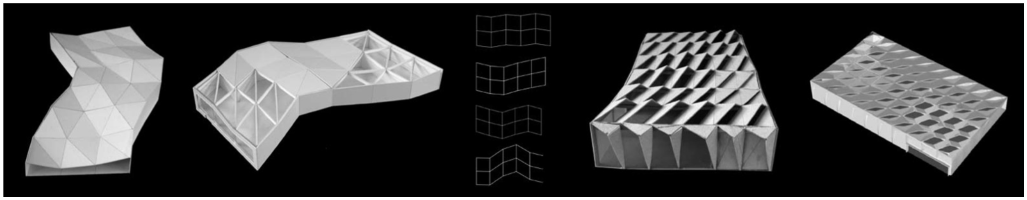

Figure 08
"Supermarket with parametric organisation, structure and facade system", student design project, winter 04/05, Mohan Zeng, Christian Behnke, Technical University of Braunschweig

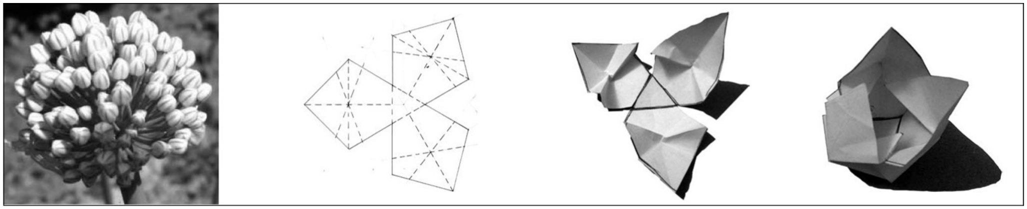

Figure 09
"Study of structure and geometry principles in nature", student design project, winter 06/07, Edda Gaudier, Susann Zimmermann, Technical University of Darmstadt

[Aranda, Lasch: 2006]

These construction principles are transposed into a parametric object. At the beginning lies here the construction principle from which structure, shape and use evolve - a reverse approach from design methods where design evolves from the predefined use (figures 09-10).

The object's construction principles are then further developed into a building's parametric facade system (figures 11-13).

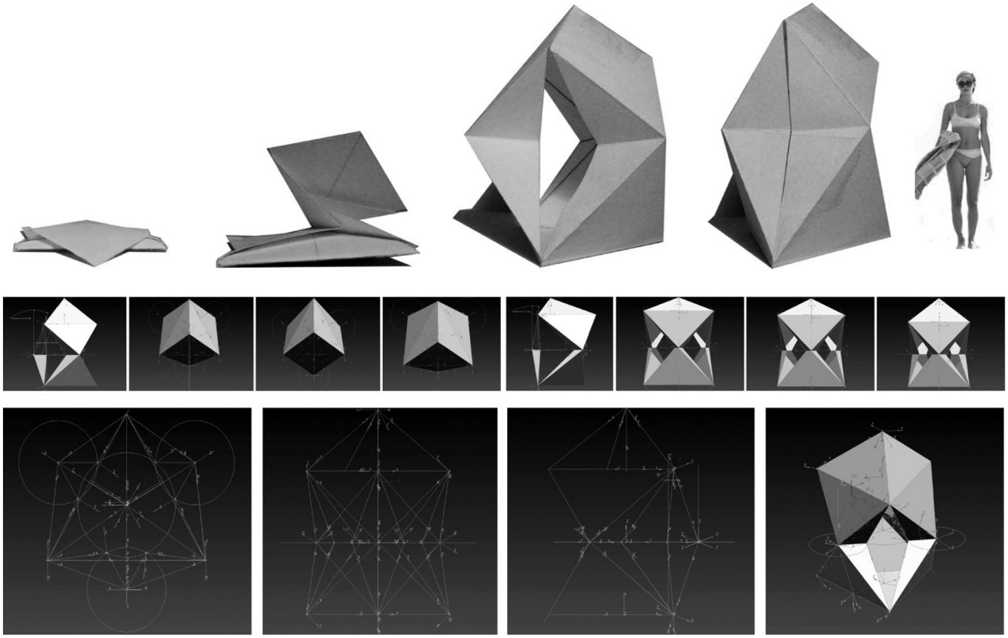

Figure 10
"Folding beachcabin and parametric model in Unigraphics", student design project, winter 06/07, Edda Gaudier, Stephan Mehlhorn, Susann Zimmermann, Technical University of Darmstadt

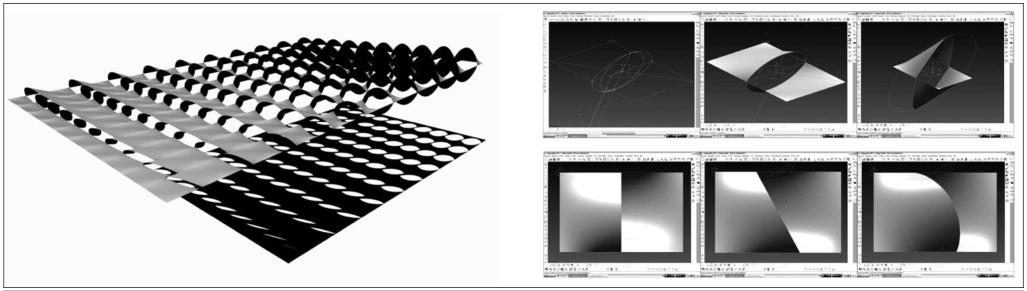

Figure 11
"Parametric roof light system and parametric model in Unigraphics", student design project, winter 06/07, Edda Gaudier, Stephan Mehlhorn, Susann Zimmermann, Technical University of Darmstadt

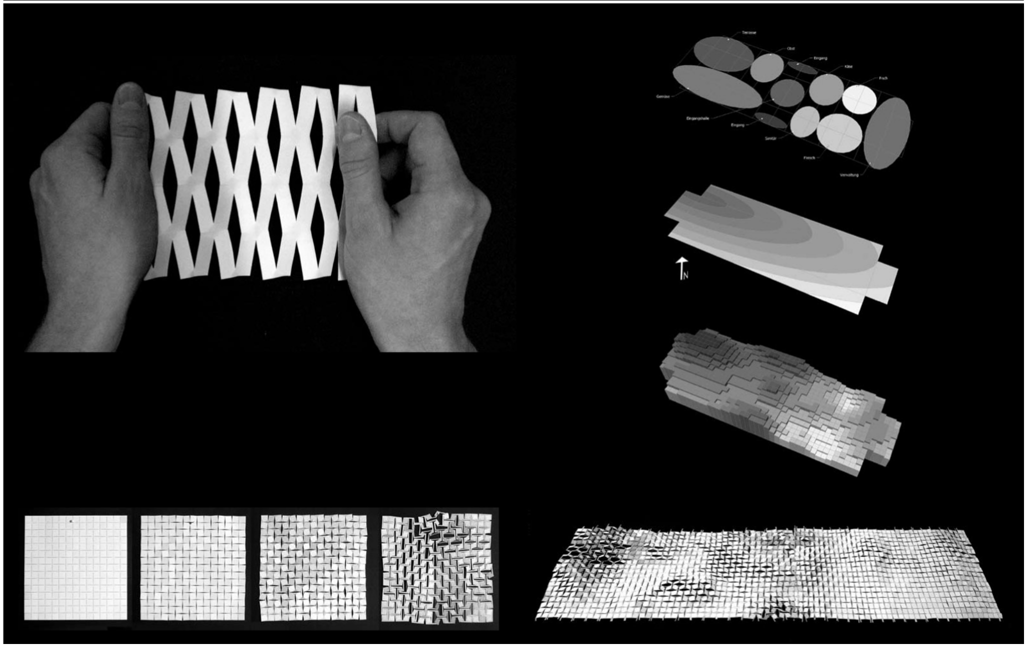

Figure 12
"The principle of expanded metal is used to create a parametric sunshade system. The size of the openings are controlled by the position and length of the incisions", student design project, winter 06/07, Fabio Fichter, Saskia Mayer, Technical University of Darmstadt

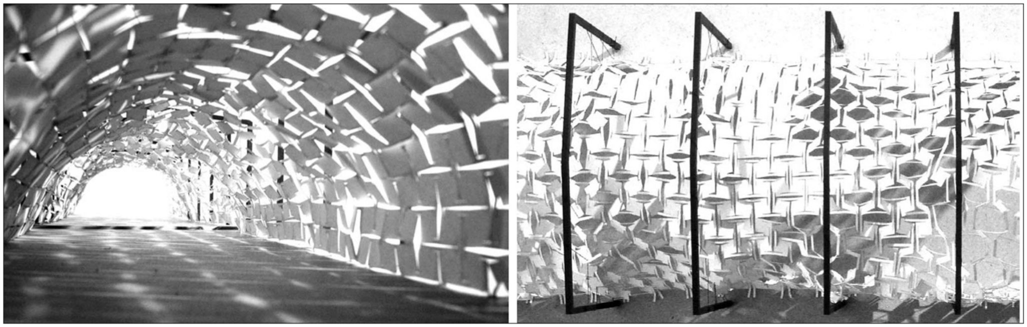

Figure 13
"Sunshade structure with parametric openings according to site orientation and internal usage", student design project, winter 06/07, Fabio Fichter, Saskia Mayer, Technical University of Darmstadt

Comments and Outlook

We are convinced that parametric design methods can not only extend design capacities but also enhance the final product by optimising it for user and location.

During the course of the presented projects we have experienced various grades of success in the application of scripting programmes and the use of parametric modelling tools.

In German universities the existence of these digital tools is rarely known or thought of as too specialist to be used in architecture. Therefore CAD is mostly understood and tought as "computer aided drawing" instead of "computer aided design", not making use of the inherent intelligence of a lot of digital tools.

Using these "advanced" digital tools generally demands the participation of an expert in this field or program, i.e. informatics or mechanical engineer. This has so far been done in collaborations with other departments within universities.

The application of the scripting background of VectorScript within the CAD programme VectorWorks meant an introduction into basic programming skills. For the majority of participants it was feasible - even without any previous knowledge - to understand amd experiment with given scripts and transforming and adapting them to a student's own design project.

VectorScript proved to be well applicable for two-dimensional elements or ornaments, not so much though for more complex design objects in three dimensions.

The CAD programme VectorWorks offered an easy access for three-dimensional modelling and rendering to all students having basic knowledge of CAD modelling programmes.

The CAD software Unigraphics proved a comparably difficult introduction in the basic use of its drawing tools. Compared to VectorWorks it offers much more complex tools with integrated parametric modelling and facilitates the creation of parametric models through the use of parametric expressions and constraints without any scripting as it is necessary in VectorWorks.

Our experience of teaching and researching the possibilities of parametric design so far is that the awareness and appreciation of the subject is not very widespread in the field of architecture, apart from a small number of large firms using the technology of parametric modelling for handling the complex geometries of their buildings.

The capabilities of parametric tools are far beyond that and we will further explore this field in various research projects on subjects like flexibility and variability of residential buildings and the transposition of digital planning into digital production.

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References

Aranda, Lasch: 2006, Tooling, Pamphlet Architecture 27, Princeton Architectural Press