An exploration in teaching architectural design for construction and fabrication

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Abstract. The intent of this paper is to examine experimental design methods in the field of architecture and their implementation in academic settings. The projects emerged during design research studio at the institute of digital design techniques at the university of Kassel and collaborative workshops with several institutes. The starting point of the teaching concept was a divergence from the usual methods and ways of thinking, allowing for new, innovative solutions to emergence during the design process. The main point was a development of novel spatial modules in coherence with material and structural considerations. The question of materiality becomes a crucial consideration. The characteristics of different materials used for models development did not just influenced geometrical possibilities but also intensify, explore and organize spatial and structural qualities of the projects.

Keywords: Research; Education and Practise; Generative and Parametric Digital Design Aids, Tools for Construction and Production

INTRODUCTION

The first project I would like to present is emerged during the workshop in Digital Design & Fabrication in Architecture which took place in Tampere Technical University. For ten days, participants from different cities and positions gathered in Tampere. The aim of this workshop is to equip students with a basic knowledge of parametric / generative modeling with Grasshopper. The work is divided into three different phases. At each phase the number of teams shrinks throughout elections of best ideas. Initial team members operate as project architects in coordinating their teams throughout the construction phase. Construction is done in three steps: drawing, CNC milling and constructing. At the end two projects are realized. One of them is discussed here.

THE CROSSBREADER

The crossbreader xpores spatial potentials of series of interlocking, self-simikar components that gradually change their properties according to site-specific influences.
Phase 1: Rhino-Grasshopper Tutorials
In the first 3 days of the workshop, students are given a general tutorial in using grasshopper. Afterwards they are able to apply it in realizing personal ideas. The use of Grasshopper plug-in made possible for students creation ideas from scratch by enabling a variety of options throughout the process.

Phase 2: Design Competition
At first, ten teams of three are formed. Each team is given two days to come up with an idea of joining different parts together without any help of alien materials. Researching and brainstorming are the main scheme of this stage. Participants are supposed to inspire themselves from nature, previous workshops and similar constructions.

By experiments with cardboard, they developed their own ideas. At this stage, each team presents its joints. Afterwards students are asked to vote for their three favorite ideas. When elections are made, five joints are chosen and the others are eliminated. New teams are now built to improve the joints according to the constructing material. After the testing, another election takes part to decide which two ideas will be realized.

Phase 3: Construction
Transforming the handmade models into digital data 16 variations of shapes and sizes are created to form the final construction (Figure 3).
Diagramming

The students were experimenting different ways into creating the final form. A specific volume is chosen to fit in the given hall. Building this form is only realizable by dividing it into layers. At this point, the idea was to build the layers in a diagonal direction. The project is designed as a parametric array of modules, each of which transforms based on its position in the overall wall geometry (Figure 4 and Figure 5). This geometry is governed by a set of points that attach to the modules at its vertices to create this system. In this case, the design revolves around a sophisticated module defined by its end vertices and connective internal splines.

The repetitive nature of the components allowed for a fast and time-efficient water-jet cutting. The double nozzles of the water-jet could process two identical sheets in one go, moreover, up to 7 sheets could be cut simultaneously by stacking them on top of each other. A slightly excessive amount of components was quickly produced to give the montage the flexibility it needed.

The nested data was later used at the water-cut-jet to cut the parts precisely as shown (Figure 6). The digital design process used included outputting scaled models, in the form of three dimensional points, to assess overall form and test the relationship of modules to one another and to the whole. Due to the flexibility and open-ended nature of the system the assembly became both site and time specific. The final result became a dynamic sculpture with varying optical effects and views (Figure 7).
THE CURTAIN

The research for this installation was done in collaboration with the Center for Interdisciplinary Nanostructures Science and Technology (CINSaT). Combined investigations influenced the original idea of form finding as a generative tool to design and produce the form. In CINSaT collaboration, relations between growth and form could be considered at different spatial scales and levels of abstraction (Figure 8). For example, the growing thin tissue of an organ could be viewed as an assembly of individual cells or approximated as a continuous surface. A variety of analytical drawings and experiments were presented by the students which include regular arrays and random patterns.

Scripting

The design of the installation wall began with analysis of the drawings and images done in CINSaT collaboration creating a catalogues of rules for structural transformation. The base cell unit was parametrically simplified into the polygonal geometry defining the rules of transformation using Grasshopper (RhinoPlug-in) as a scripting tool (Figure 9 and Figure 10). Any changes made to the geometry of the cell regenerates the shape of the system (Figure 11 and Figure 12).
The main thing we need for a parametric model was a point cloud on the surface (the global design system boundary representation). Since one of the constraints was to enable people to see through the structure, we construct system of rails.

This spatial system was translated into an arrangement of modules and their resulting surfaces. Geometrical events such as interweaving, stretching cross-connecting were deployed to create spatial complexity and structural stability.

**Material and Fabrication**

The cells were fabricated in high-density foam on three axis CNC mill. That also manipulates the technical limitations of CNC milling to produces such “organic modules” (Figure 13). These were milled both-sided and in packages of 3 rows to simplify the process. A set of four rows were fabricated and then staggered in an overlapping pattern (Figure 14). The fabrication technique carefully managed size of the router bit with corresponding network.
cells. At the end the panels were surfaced with several layers of fiberglass composite and varnished.

The question of materials and fabrications are followed through and studied with great attention. Physical milling tests were the main factor judging the pattern and various scales.

Figure 13
Geometry studies (a) wire-frame model (b) shaded preview

Figure 14
Rhino Cam preview milling steps preview
CONCLUSION
A brief overview of these results can show that one of the outcomes of this experimental teaching method was the augmented understanding that students achieved about designing on the computer, as well as dealing with materialization and fabrication techniques.

The greatest challenge was to develop a system of element definition in space and controlling practically every single element if we want to. All the variations in form and type of an element as well as the constant changes and evolution of the structure led us to it.

It also exposes the process of working to critique and refine feedback loops in light of complex tools, methods, materials site, and performance considerations.

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Figure 15
Final impressions