Math Objects

An Origin of Architecture

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Abstract. The paper discusses mathematical form generation as an academic methodology to develop new approaches to architectural design. The academic design studio ‘Math objects’ investigates the relationship between complex 3d-surfaces and mathematics in order to expand the formal repertoire of architecture. It claims that the process of form generation can be seen as an autonomous entity, which is independent from an overall strategy or any a priori meaning. Architecture has always originated from a concept, eventually progressing towards a certain form. This methodology has been reversed. The paper discusses two studios undertaken in the last year, led by Daniel Baerlecken and Olaf Kobiella at the TU Braunschweig, Germany.

Keywords: Generative design; design methodology: architectural design teaching; parametric form generation; NURBS-modelling.

Research Setup:

‘Math objects’ is generated out of a digital research framework as shown above. It integrates research work into the students education curriculum on the base of a digital design studio. This process can be seen as a program loop, with a continuous feedback: Theoretical and technical results (part of output) of each iteration directly inform the input of the next design studio. The design studio ‘Math objects’ has been executed by two iterations of research and design work as presented below.
Mathematical Form:

There has always been a deep connection between geometrical, mathematical principles and architecture – from the great pyramid of Giza, over Brunelleschi, Palladio, to Le Corbusier up to today’s architecture. Often these abstract and invisible, numeric machines have served as an architectural fountain of youth. “Moreover, the perfection of mathematical form is such (as Colin Maclaurin learned of the bee), that whatsoever is most beautiful and regular is also found to be the most useful and excellent”. (On Growth and Form, D’Arcy Wentworth Thompson, P.1097)

Mathematical principles can inform architecture in three different scales: massing, structure and texture. This relationship has been explored in a series of academic design studios and professional work using a specific methodology, which is not just research and also not just design, but both. The studios always focus on one or more of the three scales (massing, structure or texture), although they are interdependent and inform themselves vertically. The specific research ranges from mathematical form structure and texture) to tessellation like Penrose Til- ing, Danzer, Kite etc. (texture).

In order to guide the students through the experimental design process, a gradual work flow has been developed. The elaboration of the mathematical model proceeds in four phases:

1. Research on complex, mathematical forms.
2. Creation of a form catalogue that explores the mathematical prototype by its deviates
3. Transference of the models and principles to the context of a given project scenario (program and site).
4. Exploration of interior spaces (massing) and systems (structure and texture) in the scenario of a model (ranging from large scale CNC-milled models over Z-CORP models to analogue models).

This sequence of design techniques and computing skills fosters the student’s ability to question, shape and interrogate space: The studio interrogates the computer as an advanced design tool of form generation and experimentation. The continuous integration of analogue and digital modelling techniques gives a substantial feedback to this design approach.

In the following paragraphs the design works of the studio are presented, discussed and evaluated from four different perspectives:

1. Variables, formulas and geometries: An analysis of specific mathematics and its ability to control and shape complex form (Moebius-, Henneberg-, Klein-surfaces, etc.)
2. Subjective choice and individual manipulation: an introduction and analysis of the rules, by which the mathematical shapes can be transformed to fit an architectural scenario (contextual alteration of variables, object scaling and morphing, non-parametric and manual interventions (dirty-ism), integration of architectural detail)
3. Rapid prototyping and physical models: an analysis and critique of the cross-media work flow, with a focus on its ability to evaluate space and to inform the design process.

4. Design pedagogic: an evaluation of the Math-objects studio as an approach to academic teaching of architectural design. This aspect focuses on the transformative role of such digital techniques for architecture - versus digital techniques/practices with a purely auxiliary approach.

Math Objects 01 - waterscape:

The design studio math objects 01 is based on modelling with Rhinoceros and the usage of the Math plug-in developed by Jess Maertterer which allows for the creation of complex geometry without time-consuming rhino scripting.

Starting point of the process is an initial phase of abstract form generation using the Math plug-in to create a catalogue of form variation. As a second step the students are confronted with a building site and a program and the resulting transformation of the prototype, which then has to be further developed in the third phase by investigating the internal properties of the building and finalized in the last phase by creating a large-scale model.

On a programmatic level the studio is dealing with the typology of a wellness spa – located in Heiligendamm, Germany in a decisive natural environment. The side is marked by three different situations: grove, beach and sea.

The design methodology aims at formal innovation. This formal research is based on the assumption that formally enriched architecture also has a higher degree of functional complexity. In that sense formal research is directly linked to programmatic research.

Project 01 - Julian Hartwig and Andre Stossun:

Variables, formulas and geometries:

The project from Julian Hartwig and Andre Stossun is based on the exploration of sine and cosine waves as deformative tools on a structural level.

Starting with a stacked system of planar planes each plane deforms into a three-dimensional surface creating grotto-like spaces with pockets of intersecting geometry. From this mathematical approach a system of open and closed spatial configurations emerges which has inherent structural properties.

Subjective choice and individual manipulation:

The transformation of the mathematical model follows a multi-performative approach. By precise manipulation of the surface – using transitions with curvature continuity and clear defined moments of curvature discontinuity - the surfaces allow to be used as spatial division, as structure, as circulation, as furniture, as technical equipment etc.

The mathematical model also informs the programmatic organisation of the building: By following
the logic of a stacked and then deformed system the building becomes vertically organized and aims for a new type of a vertical spa in contrast to the traditionally dominating, horizontally organised typology.

By re-inventing the ground surface as a new topography and by manipulating that surface in such a way that it forms protruding outward peaks the building connects itself with the terrain in a highly articulated manner and creates a smooth transition between the surrounding terrain and the new artificial landscape.

The main peak of this ground surface serves as fast access whereas a system of a slow diagonal, almost topographical circulation is employed in between the different functional areas of the building. Other peaks provide structural support for the building.

**Rapid prototyping and physical models:**

By re-inventing the ground surface as a new topography and by manipulating that surface in such a way that it forms protruding outward peaks the building connects itself with the terrain in a highly articulated manner and creates a smooth transition between the surrounding terrain and the new artificial landscape.

The selection of CNC technology is actually directly resulting from the sine and cosine function which creates geometry without undercuts.

**Design pedagogic:**

The project demonstrates how a methodological computational approach can develop into architecture almost on its own - just using a systemacy that informs every phase of the design process.
Math Objects 2- Skin-deep:

“Textile techniques become computing techniques, surface becomes structure, and structure becomes geometry. It goes beyond the pure transformation of textile techniques into design techniques: it is… a completely textile way of thinking.”
The central idea is what Lars Spuybroek calls the “Semperian Reversal”:
“I call it a reversal, but it is a reversal of the order of the four elements, where the tectonic proceeds the textile. I want the textile to become the tectonic itself. In that case the soft elements become rigid through collaboration, by teaming up…” (Lars Spuybroek: 2006, Textile Tectonics).

The studio follows this approach and researches textile techniques in different scales.

The design method is not based on a specific tool like the math plug-in of the first studio, but on diagramming of textile techniques that then inform architecture. The textile is regarded as closely related to rule based processes of mathematics.

Also - in contrast to the first studio - the second studio is dealing with an urban terrain, with the East Harbour in Berlin which is about to developed into a centre of Berlin’s young fashion and design industry.

Project 02 – Julian Busch

Variables, formulas and geometries:

Based on studies of different weaving techniques Julian Busch creates an ubi-directional prototype that merges those studies by changing its informative system: weaving is used to inform micro-deformations on the surface level, slim mid-scale filament-like transitions and buckling pockets on a massing level.

Subjective choice and individual manipulation:

Rapid prototyping and physical models:
The final model is produced by mixing digital and analogue techniques: Z-Corp model parts are combined with cast resin parts.

Design pedagogic:
Julian Busch’s project is highly artistic, but still based on the initial diagramming process, even though it is hidden and almost unrecognisable because of its artistic nature. The design is marked by a certain amount of ‘dirty-ism’, which is resulting from the combination of digital and analogue techniques, from research and artistic thinking, from systemacy and intuition.
Project 03 - Juliane Demel:

Variables, formulas and geometries:
Juliane Demel focuses in her initial studies on weaving techniques on a structural and textural level. By creating a catalogue of varying weaving techniques the studies develop different spatial systems linked to the applied technique. The catalogue explores rigid, tight conditions and loosened conditions. Essentially structure and texture generate massing by loosening and tightening of strands.
Subjective choice and individual manipulation:
In phase 2 the project addresses and invents multi-linear urban conditions: the transformation of the prototype succeeds by incorporating multiple linear trajectories of the urban fabric. To some extend the transformation of the prototype is generated by using the weaving technique on a massing level (weaving of pedestrian paths and its resulting negative volume) instead of the former component level (structure and texture).

On a programmatic level the crossbred of internal design parameters and external constraints create a series of multifunctional, fluid spatial arrangements that can be re-configured temporally.

Rapid prototyping and physical models:
Z-Corp technology is used to produce the model. A sectional technique has been used to join the parts together.

Design pedagogic:
From a pedagogic point of view the project demonstrates how applying a diagramming technique to two different reference systems can transform a project without re-designing.

Conclusion
Comparing the two studios it becomes evident that the research of the first studio is more focussed on a mathematical aspect, which is automatically
implanted by the use of the Math plug-in. The second studio is more open, because the starting point is a diagramming technique, which allows for greater variety of individual approaches.

In general the combination of research and artistic work and also the experimentation with a given project scenario has proven to be highly productive, because research and design can interact during different design stages. Also it links the research closer to the profession by making the output assessable. The production of models and imagery becomes in that sense essential.

Both studios clearly reject the sole use of rational arguments. Instead, they define an experimental area of architecture between pure rational processes and highly intuitive decisions.

In future studio the research will be deepened by extending the first phase in a more instructive way. This allows both: more research on techniques and more integration of time-consuming techniques such as scripting. Also other programs such as Mathematica and Generative Components are going to support a deeper understanding of the underlying mathematical operations.

But still the context of project scenario and the production of models and imagery will be essential to evaluate the results in an architectural context.

References: