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Rule based design processes

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Abstract: The paper explores MEL scripting as a design methodology and reports on the findings of its implementation as an introduction course in design computing for undergraduate and graduate students at the Architecture School at Georgia Institute of Technology. The course is structured into two parts: In the first part different variations of scripts are developed to generate three-dimensional patterns. In the second part these patterns are classified, interpreted and tested towards architecture.

Keywords. Generative Design; MEL Scripting; Design Methodology; Biological Computation.

1. Introduction

If Computational Design aims to provide means for harnessing design models, we might just introduce it at the very beginning of a design process: let the computer start and interpret later. Using an abstract set of operations or a “script” as a starting point of a design process will require a rethinking of the structure of existing design models. The design process suggested here starts out as a branching system from a “root script”. When the first feedback loops occurs, the branching system transforms into a “design network”. Based on its output that can occur at multiple nodes within it, the design network is “trained” in order to redirect the output and satisfy the results. The outcome of the network is grouped into families of different architectural applications and interpreted and evaluated as such. The network, that can be continuously developed further over time, is a structure for that serves as a resource for courses of design investigations.
2. Nano Architecture

“When all is said and done, the fact is that buildings, machines and implements are inert physical objects and not organisms; and the relevance of biological ideas can only remain in the end an analogical and metaphorical nature.” Steadman (1979).

As Steadman points out there is a long history of architects studying biotechniques in order to invent new architecture, but there is also a risk of confusing two totally different fields of science: the organic matter and the physical objects. The following research does not aim to mimic the organic, but to explore a design methodology, which originates from a biological science approach.

Steadman (1979) following Aristotle divides analogies between architecture and the organic in two categories: the aesthetic analogy and the functional analogy. The presented research originates from the first category and works mainly within the realm of aesthetics. This is not resulting from a disesteem towards functionalism, but the research project suggests a starting point, that is characterized by the generation of variation and a design process that is a process of selection, investigation and feedback loops.

The intension of the presented research is not to mimic specific biological systems and to use them for architectural applications, but to utilize a setup for form experimentation that uses a methodology common in sciences such as biochemistry. To understand forms in nature helps to have an understanding of the mechanisms that are behind the generation of forms. Pattern formations in nature for instance are based on processes that are defined by rules - algorithms, established boundary conditions - phase space and external influences. In nanotechnology for instance rules are defined at a microscopic level. Executing the rules on thousands of atoms new patterns emerge. Based on the data that is produced the rules are adjusted and the process repeated.

We know for instance that we can convert the bonding of carbon by changing conditions such as temperature in order to create very different materials: graphite, diamond or fullerene for example. These materials are built from the same atoms, but perform very differently caused by a different bonding organization. In graphite the carbon atoms are organized in parallel layers of hexagonal patterns, in a diamond the atoms are organized in a three dimensional tetragonal pattern or in a fullerene the atoms are organized in a pattern of pentagons and hexagons. These relationships can be manipulated in order to create new materials. The sphere of a fullerene for example can be changed into a tube by changing the bonding pattern of its atoms. If pentagons and hexagons alternate in two directions, three-dimensional curvature generates spheres. If the pentagons and hexagons alternate only in one direction, a two dimensional curvature generates patterns of tubes. One of the discovered
properties of nano-tubes is the transmission of electrons, which enables their application in LCD displays.

The design process that is suggested through this example is made up of two parts: First, the experimentation of generating possible variations of a system by manipulating its rules on a very small scale and second the analysis of the performance of the new system variations and speculation of possible new applications.

Applying this design model to architecture might challenge the structure of existing design models and open up the possibility of a new design process enabled by computation. Different to the prime research in CAD that is concerned in converting design ideas into digital models concepts of computation are used to invent and provoke the new. Using the potential of the computer to perform operations too complex for the human mind the computer becomes a designer that processes information differently than humans and is therefore capable to provide different feedback. The design process is seen as a feedback loop between the architect and the computer: The architect formulates the question, watches the computer execute the process, interprets the result and based on the interpretation formulates a new question. Figure 1 shows how such a process might be deviated from the given example from nanotechnology.

![Design process in architecture](Diagram) ![Design process in nano technology](Diagram)

*Figure 1. Nanotechnology’s design process.*

3. Methodology

The suggested process is applied at an introduction course in design computing for undergraduate and graduate students at the Architecture School of Georgia Institute of Technology, which introduces different tools such as Rhinoceros or Maya, 3-D modeling tools and computational design techniques and methods in scripting, modelling, visualization, optimization, fabrication and prototyping. The students of this class have no knowledge in computation prior to this class. Therefore the main target of this class is to introduce basic knowledge in each of these different fields of computation. The class in that way prepares students
for more specialised courses in one of the topics mentioned above and for design studios with a digital agenda.

The methodology of an introduction course in Design Computing is used an approach which is similar to biological computation networks. Biological computation networks do not use a given step-by-step procedure to perform some desired task. Instead, the network is taught to do the task. Transferred to design we don’t regard the design process as a linear process starting with diagrams, ideas or some kind of pre-construct and using the computer as a representation of an idea or an afterthought, but as a process that on every level informs other processes and that changes the design constantly by changing and adding parameters within this network of processes in figure 2.

Figure 2. Comparison of a linear and nonlinear design process.

3. Script modifications

The course starts with the so-called root script, a set of abstract operations: move, rotate and scale. By plugging in numbers of steps or inserting functions or random factors and applying these at different base geometries the script is used to produce three dimensional patterns of different characteristics. See figure 3. In the second part of the course these abstract patterns that emerge from executing the different script modifications are interpreted and developed into architectural prototypes of different scales.

Figure 3. Script modifications.

Without any specific goal students generate a script library by documenting each script with renderings, diagrams, descriptions and the scripts used. This documentation of scripts allows all students to regenerate each pattern that has been developed in the entire course, see applications below.
3.1 APPLICATION 1

The first script generates an undulating field of circles. The undulation in x-direction is caused by $x += \sin(i*0.2)$ and the undulation in y-direction by $y += \sin(i*0.4)$. A third wave is created in y-direction by the second loop $y2 += \sin(i*0.5)$. The second script performs a loft operation and adds variation by scaling and rotating the module. The manipulation of parameters allows creating an almost biological system that reminds of sponges in its aesthetics (Figure 4). Biological form is not used as a metaphor to create something that just looks like a sponge, but biological form is a result of mathematical operations and was not intended a priori.

![Figure 4. Illustration for application 1.](image)

3.2 APPLICATION 2

In the first script a transformed circle is randomly rotated and organized in a field. In a second script the circles are moved, scaled, rotated and lofted in space. (Figure 5).
3.3. APPLICATION 3

In the first script a random point field is generated. In a second script a regular pattern is generated by duplicating and offsetting a spline. At each point of the first script the pattern of the second script is pushed in the vertical axes. (Figures 6)
3.4. APPLICATION 4

A script is used to move and rotate a spline in space. The script is executed 10 times to generate a string. The string is grouped and the script is repeated with modified coordinates. (Figure 7)

```
string $name[] = 'ls - si';
int $size = 'size $name';
for ($i = 0; $i < $size; $i++)
{
    string $duplicate[] = 'duplicate $name[$i]';
    move -0 0 0 $name[$i];
    float $random = 'rand 2.2';
    move $random $random 0 $name[$i];
    select -r $name;
}
// change: move -0 0 0 4.5 $name[$i];
```

*Figure 7.* Illustration for application 4.

3.5. APPLICATION 5

The script is based on a rational system, which utilizes a scale and move operation to create a spiraling system. The intricacy and the interference of these layers are creating a moiré effect on the surface level. (Figure 8)
4. Interpretations and Investigations

In the second phase of the project the scripted models are interpreted towards architectural applications. Whereas the scripted geometry has no direct scale, the patterns are sorted out and classified based on their potential to match specific functions and catalogued in families of possible applications in three different scales:

1. Parametric System (S): The algorithmic pattern informs a system of a building component such as a screen, wall or louver system.
2. Parametric Space (M): The modules of the algorithmic pattern are transferred into spatial units that together with other units inform spatial systems of field-like inhabitable structures.
3. Parametric Urbanism (L): The principles of algorithmic patterns are used to operate on an urban scale. The module that informs a single room in the building scale is interpreted at the scale of a building block.

Each interpretation requires an exploration of different 3d modelling techniques and an exploration of different geometries such as NURBS, subdivisions and polygons. These interpretations also trigger constant feedback loops between the interpretation, different modelling techniques and the original scripts. Through these constant feedback loops a design network emerges. The goal of the network is to generate a script for specific architectural applications.

Since the network is always open for new parameters different networks from different students could be combined. Patterns can be also nested within other patterns, which require adjustments to the original scripts.

In a further investigation digital fabrication is used to develop the interpretations towards functional, structural and material performances. In
order to get a physical, three-dimensional understanding of their project students are first asked to generate 3d prints from interpreted patterns or details of different patterns. The selected 3d printer is a Z-Corp printer, which binds powder with a liquid binding material. The parameters of the printer such as a minimum required thickness create further feedback loops for design considerations of the model. (Figure 11)

In a second step laser cutting is used in order to create a rib structure, which might be interpreted as a representation of a structural system. To meet the new set of constraints of the laser cutter students have to break down the complexity of the 3d print. A double curved surface for instance that is possible to 3d print has to be broken down into single curvature surfaces and planar faces. This process triggers another feedback loop and a rethinking and optimizing of the original design.

In both fabrication modes the virtual and the physical reality are directly linked: virtual information is used to fabricate an analogue system. Using a variety of fabrication methods helps to clarify the characteristic and behaviour of the project, but also optimize the original pattern on multiple levels by
optimizing the geometry for the fabrication process or optimizing the amount of material used to fabricate the project.

The intention of these investigations is to provide ideas and possible new starting points for further investigations of specific interpretations. The architectural application operates on the level of an open system that will receive external information from a specific program and urban context that hasn’t been introduced as design factors to a full extend jet. Such explorations might be the context of future design studios, but are not fully explored within this introduction course.

5. Conclusion

The presented research has to be evaluated in two different ways: first in the context of an introduction course in Design Computing as a pedagogic concept and secondly in the realm of pattern research.

The pedagogy, which starts with scripting as a driving stimulant for the generation of ideas allows to apply rigor to the digital world where the computer is able to create a myriad of form variations. The limitation on basic commands has proven to be highly productive.

Future research though has to focus on the analysis of properties of these three dimensional patterns such as structural performance for instance as well as further investigation in these systems, testing them against a context of a specific architectural project. All these investigations would always take place within a design network that is characterized by multiple feedback loops between all levels, which would naturally lead to the introduction of performative aspects in the scripts.

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References