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# DIGITAL DESIGN STRATEGIES

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## 1. Introduction

Technological development surpasses conscious and reflexive decision-making, since it advances more rapidly than the corresponding understanding of its effects. Research in digital design is founded on the imperative to understand, evaluate and consciously decide about the use of digital media in architecture.
Since complex curvilinear geometries seem to be as feasible as planar geometries [Kolarevich, 2003], there seem to be almost no constraints in form generation. Beyond formal exuberance form-finding processes require re-direction and meaning. Well-founded design concepts rely on rules, laws, which are applied to generate specific designs in response to requirements. Rules underlying digital design are embedded in computational concepts and processes.
An experimental approach to digital design has been implemented in a workshop, involving architecture students from the universities of Innsbruck and Karlsruhe. It reflects critical analysis and assessment of 3D modeling programs as design tools.

## 2. Digital Design

As a field of studies in architecture, Digital Design introduces the use of computer to students not only pragmatic, but also conceptual, as an instrument to explore more complex systems of organization. A

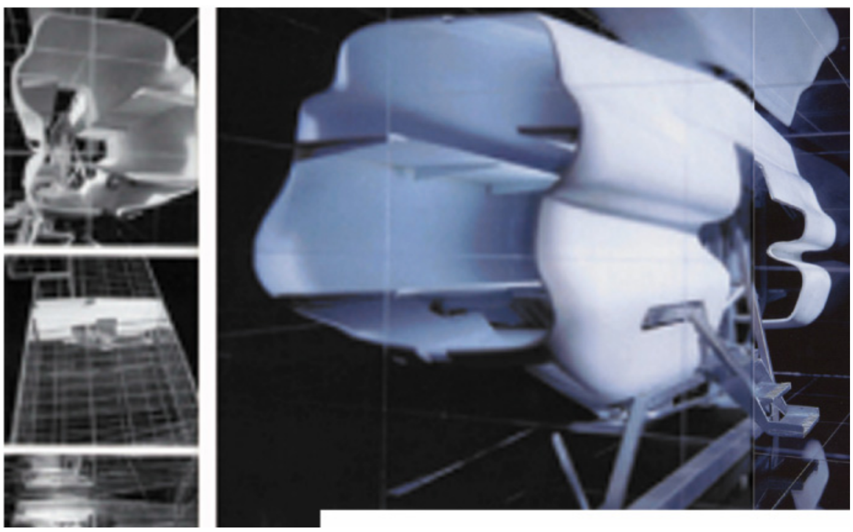

**Figure 1. The Wall [Denari, 1999]**

case study - N. Denari‘s project The Wall - serves as a framework for a 3D modeling survey with emphasis on implementation of 3D constructions and editing operations as well as examination, interpretation and evaluation of 3D modeling tools and their intrinsic morphogenetic features.

### 2.1 Program-intrinsic morphogenetic features

Attributes and software characteristics related to generation and control of geometries pre-determining design are program-intrinsic morphogenetic features. A surface modeler‘s morphogenetic features are based on the geometry of continuous curves and surfaces, mathematically described as NURBS: Non-Uniform Rational BSplines. The ability to control effortlessly their shape by manipulating control points implies rigorousity in understanding and applying methods to generate space, methods to subdivision, manipulate and transform space.
In contrast to a surface modeler a solid modeler [such as FormZ] operates with volumes, allowing a wide range of additive and substractive operations. A solid modeler‘s shape-generating features rely on boolean operations - union, intersection, difference - applied to free-form solids. Questions of how computer programs are determining and influencing the design become relevant on the level of computer based experimentation.
Therefore, students were asked to implement the acquired software knowledge in the actual design process, which implied the development of a concept of transformation for the Denari-object. The transformation process is defined by operations such as repetition, segmentation, differentiation, diversification, deformation and rules such as symmetry-asymmetry, regular-irregular, repetitive-nonrepetitive. It relates not only to software-determined geometric properties such as curvilinear-angular but also to qualities of space such as soft-sharp.
In this context, the transformation of a NURBS surface into a polygon mesh, as illustrated in Figure 2, represents a transformation from curvilinear to facetted, whereas a polygon mesh is defined as a set of connected planar surfaces. Polygon meshes can be used not only to represent polygonal objects but also curved surfaces: by increasing the number of polygons to create smooth transitions. Decreasing the number of polygons creates angular discontinuities in the surface accentuating its angular, facetted character in opposition to the continuous curvilinear condition of the NURBS surface. The transformation of a NURBS surface into a polygon mesh is not only important because of the implemented design methodology but also because of the corresponding construction strategy called polygonal tessellation. It implies the transformation of the surface from curved to facetted enabling subsequent extraction of 2D, planar surfaces from double-curved surfaces.

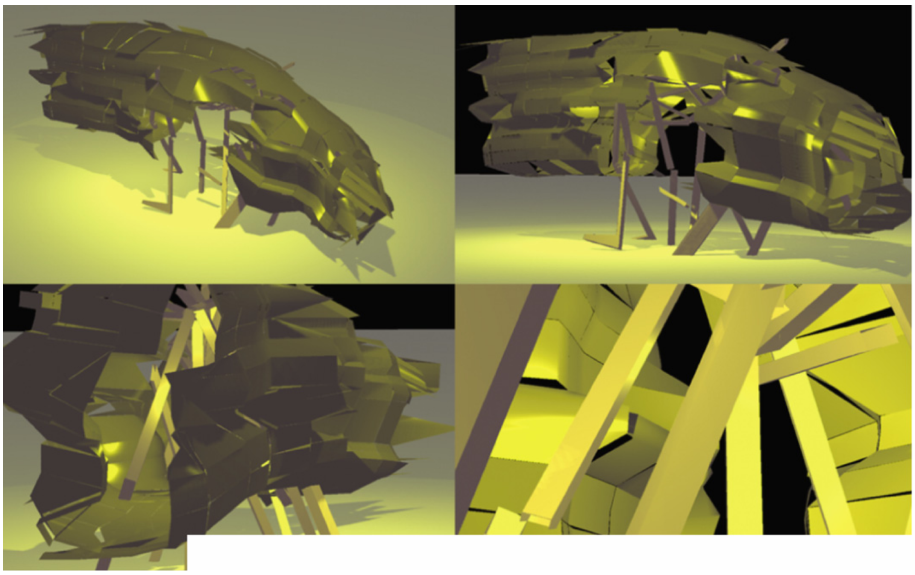

**Figure 2. Polygon Mesh from NURBS Surface**

Considering the transformation process as a series of evolving spatial configurations, choosing a stadium in accordance with targeted formal and programmatic conditions establishes a methodology of design development and evaluation, whereas shape grammars provide a systematic approach to the generation of designs.

### 2.2 Grammar Shape

According to Stiny [1980] shape grammar is defined as a set of rules based on shape. It is used to generate designs by applying rules. Rules take the form of a->b where a and b denote shapes. A rule is applicable if shape a is part of shape b.

In terms of shape grammar, the vocabulary used in the workshop contained one initial shape: a cylindrical object [Figure 3/1a]. The spatial transformations applied to this object were: multiplication, translation, reflection, rotation, whereas the rules represented a selection of spatial transformations chosen in accordance to the constraint that shape a is part of shape b, which in turn is part of shape c. The rules consist of three consecutive operations involving two spatial transformations: multiplication and translation.

Figure 3 shows the primitive [1a] and its duplicate [2a] in an axonometric view, whereas the extended duplicate is translated and positioned adjacent to the primitive [3a]. Parallel translation of the front-face is illustrated in 3b and 4b in side and front views. Front face translation and rotation of primitive and duplicate finalizes this process and is shown in 3c and 4c as side and front view.

Basically, the grammar development starts with shapes as basic components and spatial relations between these shapes. The definition of a rule involving a spatial transformation a->b->c, as described above, leads to the development of a series of shapes.

Derivations of the rule defined as a sequence of designs where each design is generated from the previous design by applying a rule implies an ordering of the shapes into a hierarchy, which provides an efficient design generating method.

Decomposing Denari's object into a hierarchy of subshapes allows for any parts of the shape to be transformed within a system of rules, which defines a design strategy based on the concept of learning from practicing architects, in this case of learning from their design. Denari's object offers a template to study curvilinear geometries in architecture. Learning from the design process of practicing architects - on the other side - involves a more different approach illustrated in the following section.

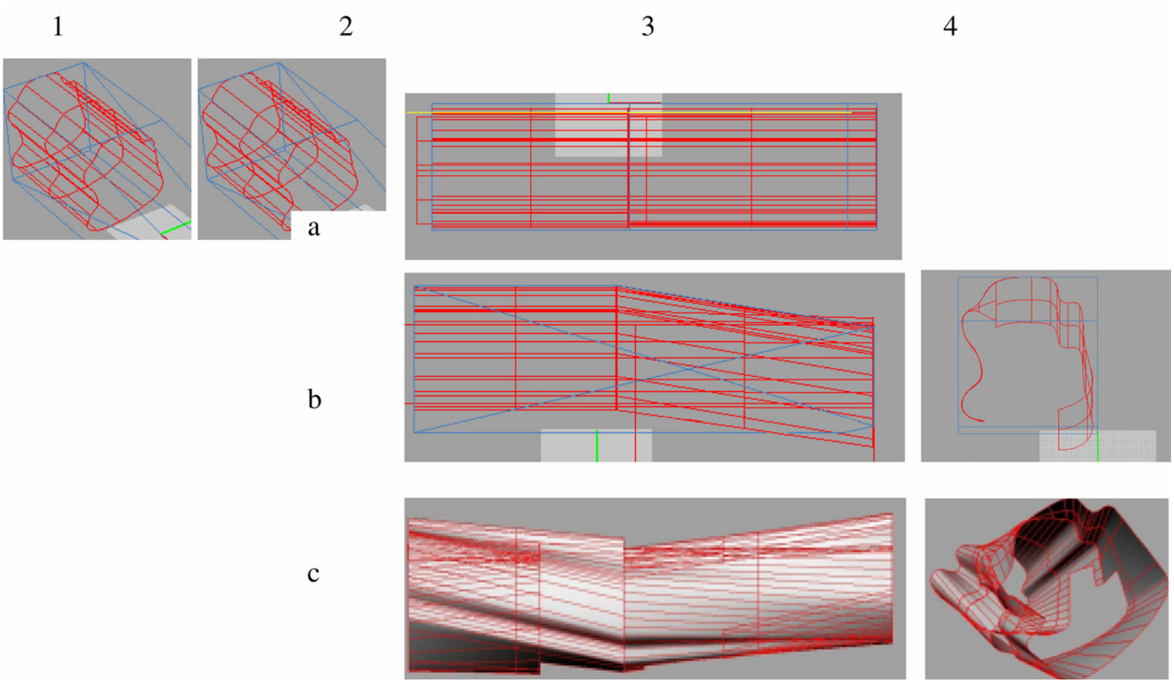


**Figure 3. Transformation process a->b->c**

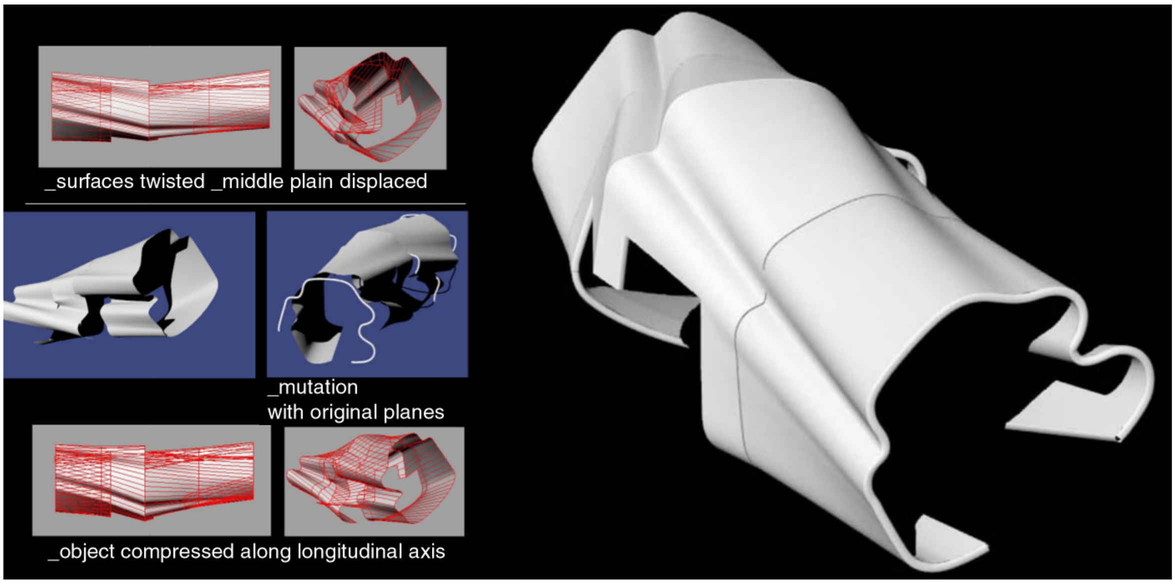


**Figure 4. Transformed Denari-object**

## 3. Learning from Practicing Architects

The work-process at Morphosis incorporates computer technology on the level of pre-schematics, design development and construction documents by means of digital design, representation, visualization and communication in a process of transferring data from a 3D modeling to a 2D drafting software and to a Rapid Prototyping [RP] machine, respectively. Digital fabrication techniques such as RP allow to generate and control complex geometries - establishing a feedback mechanism between conception and production. Morphosis uses 3D Printing, where the physical model is generated directly from digital data in a process of layer-by-layer adding of material. It allows not only to efficiently iterate on design concepts but also to identify problems.

A case study - Morphosis' project Hypo Alpe Adria Center, I worked on in the 3rd construction phase - serves as a framework for a design and building construction survey: The 3D FormZ model of the project defines the geometry of the building. The roof, for example, is a fragment of a sphere [Figure 5]. It determines the geometry of the walls and columns: every single column having a specific height. Every single wall elevation requiring an elaborate process of intersecting the vertical planar walls with the curved roof surface. In a two-step-procedure, elevations and sections are first generated in FormZ to be then transferred to the 2D software for further elaboration and detailing.

The steel construction of the roof required a different procedure employing exclusively a 3D model. It allowed to skip iterations such as generation of 2D drawings - so called construction documents. For that purpose Morphosis established a platform for collaborative production with the steel manufacturer by means of computer supported systems of communication such as FTP. Although physically remote the participants in the collaborative process worked simultaneously [on the project], while the up-to-date design was available from a common database on the Internet.

In response to requirements of the double curved surface Morphosis employs specific construction strategies such as polygonal tesselation, which refers to the transformation of the surface from curved to facetted enabeling subsequent extraction of 2D, planar surfaces from double-curved surfaces. The transformation of a nurbs surface into a facetted surface is an automated tesselation processes based on surface subdivision algorithms providing several computer generated tessellation alternatives. It is based in the concept of transformation of a NURBS surface into a polygon mesh [2.2]

The use of computers in different phases of the design process - starting with spatial experimentation involving 3D modeling in Pre-Schematics, through detailing by means of 2D drawing in Construction Documents - reflects the need to discern which tool to use in a certain phase of the design process.

Students were first asked to analyze the Morphosis design strategy subsequently implementing the

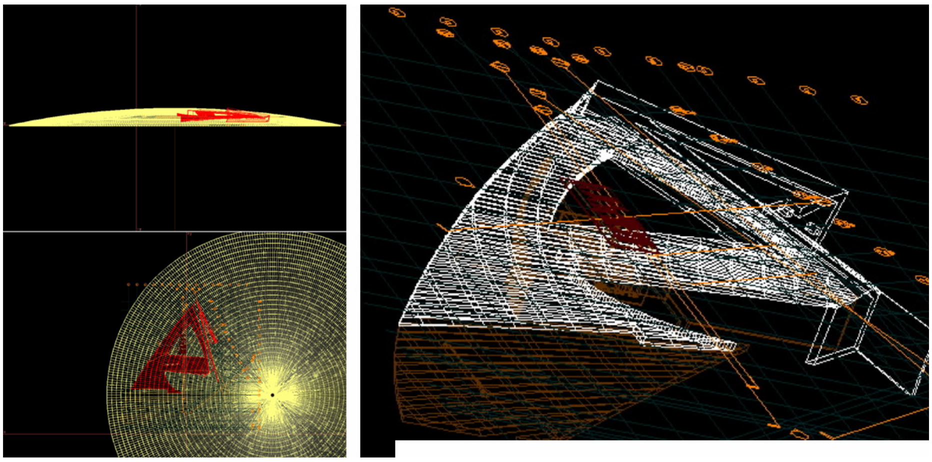

**Figure 5. Roof: Fragment of a sphere**

knowledge gained on digital design processes in their own design process by following a procedure similar to Morphosis': [1] design: 3D modeling, rendering, visualizing, image processing, presenting, [2] construction: transferring 3D data to 2D program, building a physical model using sections from the digital model, [3] communication: exchanging files through internet by using a file transfer utility.
Learning from practicing architects involves not only analysis of architectural design and design methodology but also establishes a relationship between architectural practice and education, informing about new technologies, offering clues about digital design strategies and their influence on design thinking. Visiting the construction site establishes a sense of built architecture - defines a relationship between virtual and real.

## 4. Conclusion

The concept of a new post-industrial paradigm based on digital design and digital fabrication informs about new design strategies established by gaining expertise in the creative use of software through experiments. Based on experiments in computer, new teaching concepts introduce students to digital design, offering them clues to evaluate, compare and consciously decide about the use of software in the design process: The experimental approach to digital design implemented in a workshop implied 3 pre-defined conditions: [1] the students had no preliminary knowledge of the 3D modeling computer programs, [2] the design task was restricted to the transformation of an object designed by Denari, [3] the workshop established a link between design and software on the geometrical-formal level and explored how shape grammar relates to software.
Students implemented 3D modeling experiments revealing intrinsic morphogenetic features of computer programs and their influence on design. The experiments referred to generation and control of complex geometries whereas geometrical intersections of simple geometrical objects resulting in complex, composite-objects were developed in a sequence of designs based on shape grammar. Aside from 3D modeling experiments, transpositioning digital design strategies from practicing architects in the academic environment of a studio ensured exploration of methods and techniques, which recently found implementation in leading architectural practices.

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