Cybernetic models in building fabrication. A three stage training approach to digital fabrication in architecture

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ABSTRACT
In the time since European architects first began using computers in the building design process, the digital revolution has transformed how architects use planning tools completely. Today, digital tools are an indispensable part of planning practice. Besides a wide variety of digital modeling tools, parametric tools offer architects diverse options for generating cybernetic building models as BIM-models or homeostatic parametric geometry models. Cybernetic models help us to describe the buildings as a system and can improve planning efficiency.
The aim of planning is to construct or fabricate an end result. The integration of digital fabrication methods in the digital chain is a fundamental goal if architects are to benefit from the progressive development of computer controlled machine tools. Fabrication integrated digital models can automate the planning process up to the production stage and enable the efficient fabrication of building components. The increased efficiency of planning and fabrication has facilitated a growing proliferation of buildings of increasing geometric complexity. Computers can open a door to the realization of new forms, spaces and construction systems to architects that understand the principles of fabrication-integrated cybernetic modeling.

KEYWORDS: didactic; parametric design; digital fabrication; CIM;

Teaching "Fabrication Integrated Cybernetic Modeling"

The application areas in the building planning process are practically unlimited. Our teaching programs on digital fabrication topics offer our students a three-stage specialization option. This paper describes our didactic approach and analyzes gaps and opportunities.

Stage one: Fabrication Basics

The aim of this course for bachelor students is to provide a general overview of CIM (Computer Integrated Manufacturing) and a basic understanding of cybernetic and successive modeling techniques. The course consists of a lecture series entitled "Digital Form-Finding", where we lay out a theoretical overview on fabrication topics, and a practical part comprising two small projects, in which students gain a first experience of fabrication-focused digital chains by using laser cutters to build physical models from digital models.

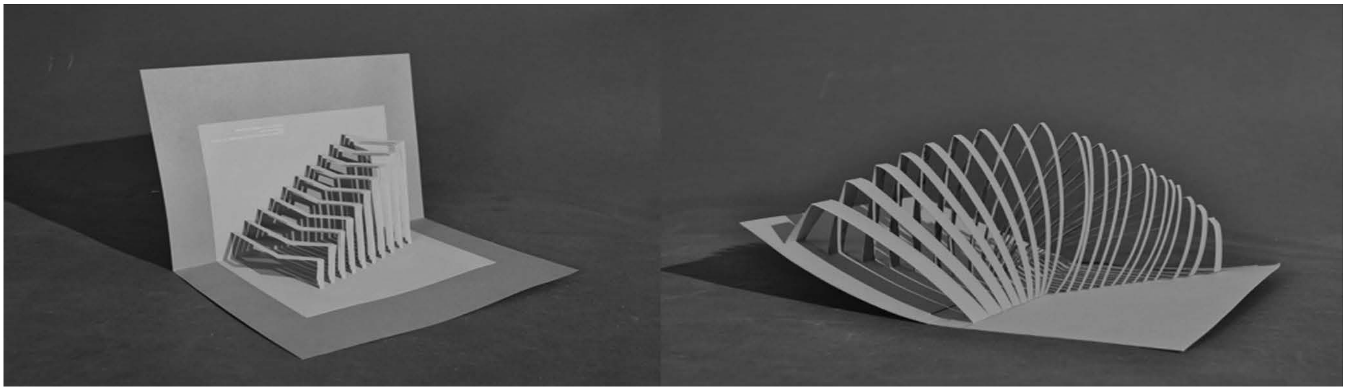

Image 1: Studentprojects Project II „Fabrication Basics"

	CAD	Production Strategy	Machine	Material
Project 1	2D Drafting	Folding	Laser-cutter 2,5 D Milling	Paper Wood
Project 2	Loft+Boolean	Developing	Laser-cutter	Cardboard

Table 1: Course syllabus „Fabrication Basics"

The course offers an experimental way of tackling the challenges of resolving freeform fabrication problems such as controlling 3D geometries, developing surfaces and using CAM interfaces (Tab. 1, Image 1).

Stage two: Digital Prototyping

In the elective course "Digital Prototyping", we offer bachelor students in-depth training in the modeling of digital prototypes and the use of digital manufacturing machines in the planning process. The aim of this course is to benefit from the efficiency of fabrication-integrated cybernetic models to rapidly improve the quality and efficiency of the planning process using digital and physical models.

The theoretical content of the course includes goal-oriented information on gathering and processing, along with the principles of the digital design and fabrication chain. On the practical side, students gain the ability to operate a wide range of digitally-controlled machines themselves. Over the course of one semester we build 4 models (Tab.2, Image 2).

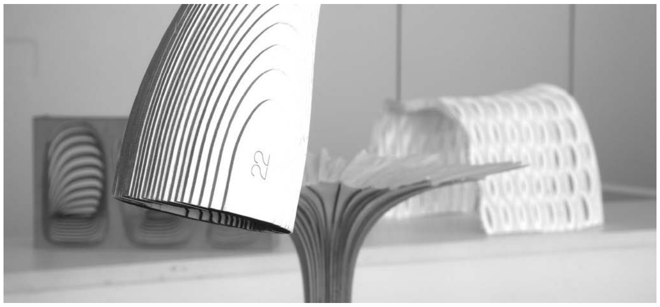

Image 2: Digital Prototyping / Student projects

Stage three: Digital Building Manufacturing

For our master students we offer a course entitled "Design and Production". The goal of this course is to help students develop a holistic design approach, from the understanding of complex geometry to the fabrication and construction of building structures.

We analyze methods of designing free-curved shapes and their boundaries, with a strong focus on feasibility. We emphasize that connection details play a key role in the construction of complex structures. In addition, we provide physical experience of the manufacturing process using large-scale computer-controlled machines.

The course ends with collaborative student project for the construction of a design prototype at 1:1 scale. An important supplementary aspect of the practical side of this course is the connection between the realm of the university and the building industry. We visit the production facilities of manufacturers of digital machining tools as KUKA, Hundegger and Voxeljet and then develop and produce our prototypes using their production tools. This collaboration is interesting and challenging for all partners (Image 3, Image 4).

Form Follows Production Resources

For an architect's education, where the primary paradigm is to provide a strong foundation in up-to-date skills and knowledge, access to technology and digital design tools is an essential building block. In response to this, we created a digital prototype lab more than ten years ago to begin integrating these tools into the education process. Since then, our digital workshop has been steadily expanded, and its continued development is firmly rooted in the growth of the Faculty of Architecture as a whole.

Today our prototype lab is open to students and researchers 7 days a week / 24 hours a day, and is equipped with the most essential digitally-controlled machines. It is located in close proximity to the well-equipped computer rooms and is situated beside the faculty's wood, metal, and plastics workshops. In weekly classes, we train our students in the operation and management of the digital manufacturing machines, although some equipment, such as our 3D input devices, are reserved for particular projects due to their high sensitivity.

	3D Modeling	Production Strategy	Machine	Material
Model 1	Boolean	Layered Manufacturing	Laser-cutter	Cardboard
Model 2	Loft	STL Tessellation	Rapid Prototyping	ABS
Model 3	Parametric m.	G-Code with 3A.-CAM	3D Milling	PU-Foam + PS
Model 4	Relaxation	Developing	Flatbed Cutter	Fabric

Table 2: Digital Prototyping / Course syllabus

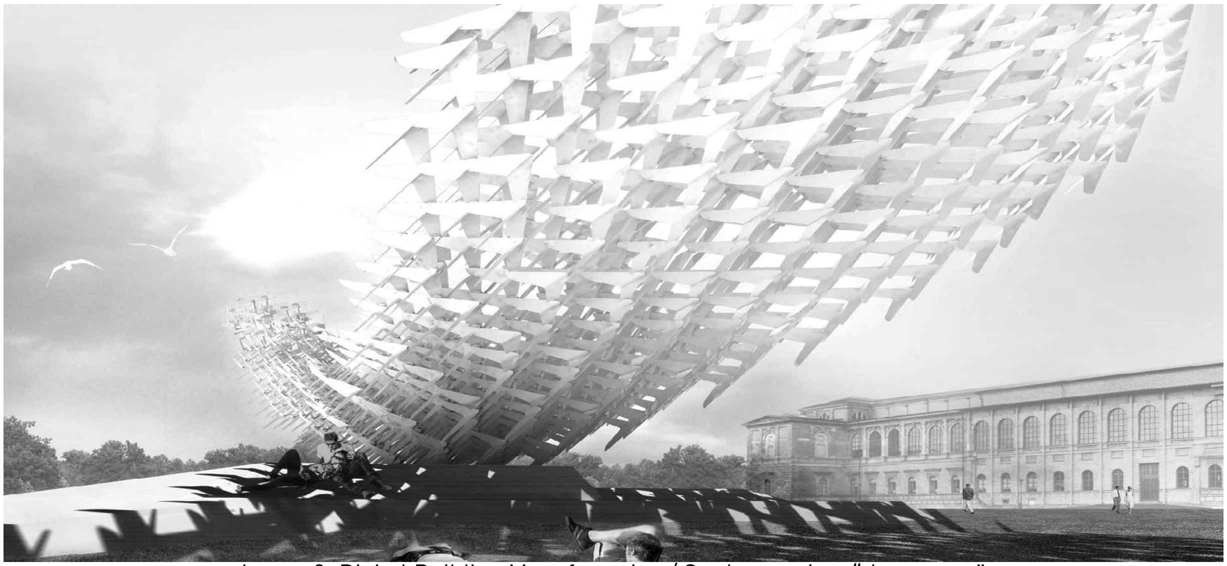

Image 3: Digital Building Manufacturing / Student project “the swarm”

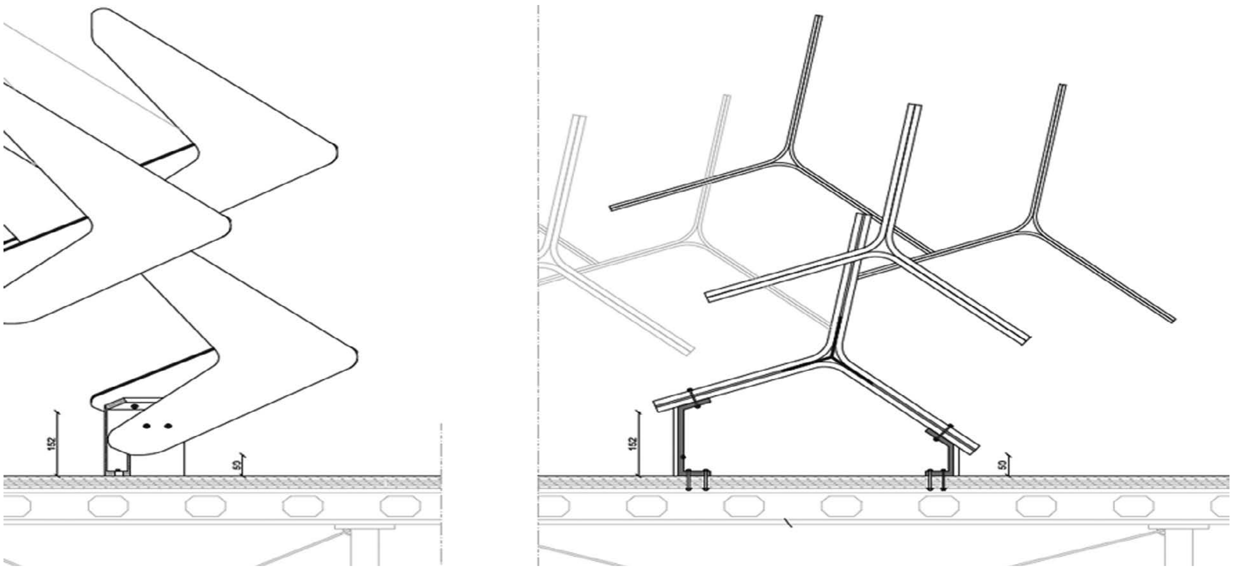

Image 4: Digital Building Manufacturing / Student project “the swarm” detailing

Conclusion

Teachers

The opportunities for using CAM-integrated cybernetic models in the building design process are virtually unlimited. By dividing the fabrication education into three stages, we are able to focus more strongly on the needs of the application areas, e.g. “design support” (stage 2) and “fabrication” (stage 3). The “Fabrication Basics” course (stage 1) allows us to establish a basic level of knowledge of fabrication topics among our bachelor students and provides a springboard for the later use of “Office CNC machines”.

Students

Setting up a cybernetic model including material, machining and detailing in one single term is a challenge not just for the teaching staff but also for our students, even when using user-friendly software. For the stage three project, we think a second term is necessary in order to adequately achieve the educational goals of the course and so that students are able to apply their knowledge to a 1:1 scale project.

Research

In all our courses we are constantly exploring the boundaries of feasibility. By analyzing gaps in the process we were able to develop a parametric component that integrates the feature-based machining steps of large-scale CNC-machines in the cybernetic model. (Beaver for Grasshopper)

This component enabled us to improve the degree of fabrication automation and to implement fabrication-related planning consequences into an interactive planning process.