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Computer Generated Architectural Design: 160 custom-made

Architectural data flow from schematic design into Computer Aided Manufacturing

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The paper constitutes the introduction of a new approach into architectural design methods at the Institute for Architectural Design and CAD. It describes the experience with regard to the learning process and explains the design studio experiment '160 custom-made'. The design method has been developed from different actual building procedures.
'160 custom-made' provokes the contradiction between a modernistic architectural approach (industrialized parts and series manufacturing) and computer based design and manufacturing processes which promise the realization of almost every imaginable architectural shape at no extra cost. The students visited several Companies in Germany, Switzerland and Austria, who demonstrated state-of-the-art-technology-manufacturing methods on various materials. This Computer Aided Manufacturing (CAM) process then became the basis for discovering a new way to speculate about solutions to a design problem. The project was described into computer aided modeling starting early in the design. In the beginning participants were asked to design an object using terms, images and ideas, entirely detached from architectural thinking and without the knowledge of the actual architectural goal. 'Maya', a three-dimensional modeling software, was introduced at the same time, which allowed participants to translate the analog data of their models into a digital model description. In the last project phase this knowledge was used to visualize the models with the computer; a programmatic task was added to the design as the students proceeded with the further development stages of the project.
The group searched for ways to translate the produced data structures and to drive the Computer Aided Manufacturing (CAM) process. The easy building of quick models with this technology proved to be more difficult than expected. '160 custom-made' participants were confronted with an entirely new method of designing due to the unusual procedures needed to handle digital data information in order to receive the desired output.
Keywords: *Computer Aided Manufacturing, Rapid Prototyping, Design Education, Digital Design Development, Data Structures*

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Introduction

The design Studio “160 custom-made” provokes the contradiction between a modernistic architectural approach with its industrialized parts and series manufacturing and computer based design and manufacturing processes that promise the realization of almost every imaginable architectural shape at no extra cost.

The introduction and public discussion of computer based design and production methods in different architectural firms such as Frank O. Gehry & Associates, Peter Eisenman, Greg Lynn, NOX architects etc. indicates that today we are able to produce a comprehensive range of formal shapes. This is made possible, also in the economic sense, through the use of complex hard- and software components. Unlike other industries such as the aerospace or automobile industry, it is impracticable to build a first realistic prototype in building design, due to the fact that most of our buildings are unique. Therefore the aspect of using industrialized parts and series manufacturing components seems to be mandatory for the economic and quick building process.

The thesis that the author pursued with the design studio ‘160 custom-made’ is to trace possibilities to plan and build individual shaped architecture, using today’s state-of-the-art computer driven process chains and considering economic factors. Similar to today’s prefabricated and mass produced elements, the author believed that with the possible future development of complex computer driven production methods, an individually designed element might be producible at no extra cost. The studio group expected a synergy effect concerning the developed data structure, which was to be used from early design into the finished product, refining the structure step by step. Furthermore it seemed to make no difference to the studio participants if a computer-manufactured component is automatically produced one time or a thousand times.

The Design Studio 160 custom-made

The design studio ‘160 custom-made’ was set up by the department for architectural and computer aided design and the department for design, building science and spatial organization at the University of Cottbus. The studio settings’ goal was the exploration of above-mentioned aspects under consideration of possible constant data flows from early design development stages into the model production. Besides the author was interested in producing the individual prototype with equal expenditure to the mass product.

Considering the design process, the studio group wanted to work free from an analytical interpretation. Instead, participants were asked to approach the projects with an open and intuitive strategy, acting as a reader, able to unravel and interpret the emerged objects rather that occupying themselves as authors of their forms. During this procedure of reading, participants were to discover forms by chance that could be added or subtracted to the vocabulary of the developed objects. Inconsistencies should be accepted or denied, as long as they seemed to be a challenge for the project. To support this process, the analog and digital modeling was the studios chosen process for translating the conceptual ideas into visual, tangible forms. ‘Maya’, a three-dimensional modeling software, was used for the digital modeling process.

In the beginning, candidates had to approach their object designs by terms, pictures and imaginations, entirely detached from architectural and therefore formal-functional thinking. On the basis of four partly given, partly self-chosen terms, participants had to pick images of analogues. These analogues built the basis for the entire project. They got analyzed for building structures, details and several features, which were used for the shape of the objects in the further design process.

In the early stage neither architectural program or design task were given to the group. After six weeks of project development, using classical models, sketches, and computer studies, the participants were able to transfer their shaped objects into a digital 3D-

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model. Due to the lack of 3D-scanners or computer-tomographic devices, as they are used for the transferal of physical model data into digital 3D-model structures, the group had to use conventional techniques for the “data transfer”. Built models were cut into thin sections, those were measured, scanned, and got digitized to define a virtual 3D-model in ‘Maya’. That way the analog data structures were translated into digital descriptions of the projects. At the end of the first phase all participants had produced a physical work model that represented their interpretations of the chosen terms, related to their personal background and history. Regarding the unfamiliar design process, only few students were able to handle such an open minded, unstructured, rather sculptural process without difficulties. Most of the candidates found it very complex to approach an architectural project without given perimeters and to learn a new software at the same time; they experienced the freedom of the project rather disturbing than challenging.

The described model building and data handling process was a chosen part of the didactic concept, since the author knew, appropriate technical opportunities and software knowledge of the participants presumed, that the group would have picked the opposite way of designing the projects. Instead of producing analog, hand-made models, participants would have designed and explored the projects immediately in the digital computer model. Subsequently they would have employed the rapid prototyping method to check and examine the desired shapes. Due to the lack of financial funds the studio was forced to the practiced process, which finally did not change the group’s desired output for the first phase: a physical, tangible representation of the design idea and a precise copy as a digital data structure in the computer.

Thereafter the studio visited several Companies in Germany, Switzerland and Austria who demonstrated state-of-the-art technology manufacturing methods on various materials. Two issues were important for the participants: this computer aided manufacturing process became the basis for discovering new ways to speculate about solutions to a design problem. Secondly the group got confronted with actual architectural programs and sites for their projects.

Regarding materials and manufacturing procedures, the studio acquired following facts about processes and materials:

Desired shapes for concrete and equal ‘formable’ material depends on the material that is used for casing. In Frank O. Gehry’s ‘Zollhof’ project in Düsseldorf, Germany, huge styrofoam blocks were hollowed out as negative forms by computer numeric code (CNC) mills, subsequently filled with rebars and concrete. There is literally no limit in producing such free forms. That manufacturing procedure is in fact suitable to produce more than just a building ‘prototype’ since it is comparable to a mass product process. Unfortunately, in the ‘Zollhof’ case this did not apply, because, among other things, the styrofoam forms had to be destroyed in order to uncover the concrete structures. Admittedly the manufacturer developed a recycling process for the material, but the problem to re-use a form wasn’t solved.

The deformation process of glass, which is basically produced in endless sheets of a certain width, is similar to the concrete shaping process, but comparably very cost intensive. Heat resistant casing has to be produced and a huge amount of energy is necessary to shape the glass sheets. Besides, it is a complex process to produce insulated, layered sheets of glass.

Wood and steel constructions can be produced economically in nearly every shape by dismantle a desired building mass into fins and ribs or frames, similar to aircraft or ship constructions. These elements can be cut, laminated and connected with a high degree of automation, finally covered up by layers of a desired material that defines the final shape. In many cases those production processes represent the status quo in today’s building industry. The studio group was able to find several built examples, of which one, the conference space of the German Genossenschaftsbank in Berlin by Frank O. Gehry, was visited.

Finally, materials like natural stone can be CNC-milled into shape, limited mostly by the size of the material or the machines. This procedure is similar to the production of styrofoam blocks, only the milled material represents the final shape.

In the succeeding phase, students were asked to use their newly gained knowledge and face the confrontation with the projects' utilization and detailed program. This was the time to begin to organize and design the projects in an architectural manner and to redefine the designs with the computer. To simulate the very expensive process of using rapid prototyping methods, the studio produced the objects by cutting the computer model into appropriate layers, printing out the information and laminating the prints onto material with proper thickness. By doing so, each participant finally produced a detailed digital model in 'Maya' and a precise twin as a working model. That was the base for the rapid prototyping modeling process that followed.

Regarding the design process, participants had difficulties to work on their ideas, to develop programmatic aspects, and to learn a new computer program, all at the same time. Later in the proceeding this attitude changed step by step due to the gained trust regarding the usage of the computer tools. What remained was a psychological barrier that can be overcome by experience and practice only.

After presenting the final projects, the closing challenge for all participants had been the transferal of the developed 'Maya' data structures into the computer aided manufacturing process. The studio authors chose the Stereolithopgrahic (STL) file format, a standard that is used to drive selective laser sintering (SLS) processes, CNC-mills, laser cut machines etc. It is based on the stereolithography process of 3D Systems. Since 'Maya' can't produce such files, a data exchange format (DXF) transfer from Maya into 3D Studio was necessary to finally generate STL-file formats.

At this point the studio authors had to realize that the data structures, developed by the group, were not at once usable for the accurate CAM-process. The students worked exact enough to produce good-looking screen visualization, in terms of accuracy and finished volumes the precision was insufficient. What followed was a discussion about the sense of using computer tools in early design stages. In order to design a project and to work on a building shape, architects commonly work vague and intuitive. This working method is contrary to the development of a digital model that demands a high degree of perfection. Looking at the models in an STL-viewing software, the projects had unexpected openings, some of them as many as thousands, due to the loose working precision. The chosen output devices weren't able to produce the models since the machines demanded perfect and closed volumes and skins.

To get at least some of the objects build, we were urged to remodel several digital models. This happened partly through closure of the openings by Boolean operations, partly through rebuilding parts of the object. This process was very time-consuming since no automatic program routine was available.

Looking for a better data exchange process, the studio authors decided, also by arrangement with the model manufacturer, to use the Initial Graphics Exchange Specification (IGES) file format this time. IGES is a common format for the exchange of geometrical information. Besides it is possible to write IGES-files directly out of 'Maya'; furthermore non-uniform rational b-spline (nurbs) primitives and nurbs-volumes are supported.

Conclusion

Despite the studio was not able to produce computer driven rapid prototypes of all digital data models, the group learned some very important facts about the transport of data structures from early design stages into a simulated computer aided manufacturing process. Available 3D-modeling software is a highly complex tool that demands excellent knowledge about the handling by the user in order to use it creative in an early design process. One more time the studio participants realized that in a design process the physical, tangible model is not replaceable by a 3D

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virtual model that is in fact represented visually on a flat, two-dimensional computer screen. Therefore the possibility to produce rapid prototypes in an early phase must be absolutely given.

Furthermore it seems necessary to stop the data transport at a certain point of the development process (possibly after each design phase or jump in scale), to produce a clean data structure of the prior phase to avoid the addition of errors and inaccuracies in the virtual model.

The conditions demanded by the very complex computer software distracted participants in some cases from the actual design work. To gain specific software skills is time- and energy consuming, sometimes at the expense of the design quality of the project itself.

In conclusion the group was content that a precise arranged chain of coordinated software and hardware products enables a very economical process in terms of developing architectural projects, model prototypes and finally computer driven manufacturing processes. If a process of such kind can really fulfill the promise of the computer based design and manufacturing process, to allow the realization of very complex architectural shapes at no extra cost compared to the series productions of building parts, was not answered by the experiment. The author believes that both computer and production technologies have to develop further, especially in the field of user-friendliness and interfaces, in order to redeem that promise.

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Links:

160 customized project archive:
http://www.archinf.tu-cottbus.de/160_massgeschneidert/de/

Chair for Architectural design and CAD:
http://www.archinf.tu-cottbus.de/

Rapid prototyping technologies, overviews:
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