Digital Chains in Modern Architecture

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The "digital chain" is a continuous digital organization process, from the draft right into the manufacturing. Now one of these chains is applied on a mountain shelter. The individual steps are programmed and connected by universal interfaces. The computer is used not as passive digital drawing board, but as self-dependent tool that exerts influence on. Rules, dependence and aims, are formulated by the architect the computer can optimize due to its computing power. The role of the architect shifts thereby from the form designer to the role of a process designer. The aesthetics of the results is exciting and unusually, organically and self-evident - it is however always the result of given parameters. One topic is the complexity. The constructional modeling of the computers is a substantial support and easement. With programming techniques and parameterized construction, a high degree of individualizing becomes possible. A further point is efficiency. Construction with individual units, which former on was just realizable with high time and cost, become economically in this manner today. Furthermore computer-controlled machines work with precision and a detailing, which would be by workmanship neither temporally nor technically obtainable.

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Preamble: The digital chain

The "digital chain" is a continuous digital organization process, from the draft right into the machines. The chair for CAAD, computer aided architectural Design at the ETH Zurich develops, under the direction of Professor Dr. Ludger Hovestadt for six years now prototypical "digital production chains".

The project new Monte Rosa Mountain shelter is based on a student draft under the direction of Professor Andrea Deplazes. Originally it was neither technically nor financially realizable. In a research and a development project the Chairs of architecture and construction, CAAD and building process were united, in order to make this project construction ally, organizational and financially realizable.

Aim of this project was to prove that by the conditions of the "digital chain", excellent architecture becomes possible to usual market prices. However

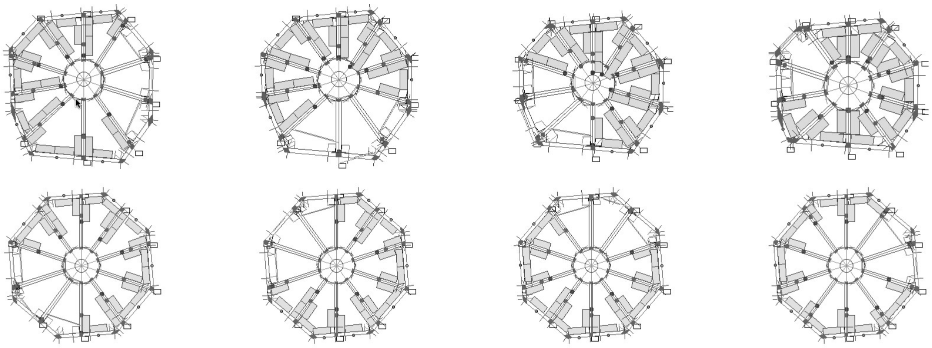

Figure 1
Screenshot of different versions of the "rubber band model"

a condition is a fundamental paradigm change: Not the system determines the building, but the building generates its own system.

In the case of the new Monte Rosa Mountain shelter, different circumstances made the conversion more difficult and required innovative solutions. Because of the exposed situation only transportation by air was possible. It was an aim to develop a light construction as possible. As a given fact of the high mountain situation there is an extremely short construction period of only three months. And at least there was also the formative challenge of an unusual architecture, in which appearance no construction unit should repeat itself.

1.0 Draft

The focus during the revision and optimization of the student's draft, which had been developed according to traditional architectural methods, was on the feasibility with the help of the digital chain. A characteristic of these chains are the independence of the individual links. Naturally they can out-play their full efficiency only in a consistent conversion. To start working with it, the Chair for CAAD developed a so-called "rubber band model". With it is possible to control and optimize all relevant design parameters.

1.1 Assumption of the form and the input into a data model

The form of the building pretended strict geometrical requirements, for example the solar front of 10° inclination and 80 square meter surface to the south. This and other draft-constituent parameters were transferred into the rubber band model. Within this model achievement parameters, for example number of beds, and constructional parameters, like wall thicknesses, could be also entered and changed.

From these specifications a model was created, which one can change and see the effects by changing directly.

1.2 Developing a specific system

After importing the draft a parametric building model is existent, which can be optimized according to different goal criteria with the help of the computer. In the project of the new Monte Rosa Mountain shelter the aim was a high utilization of beds. Compared to other SAC huts at the beginning this percentage was below average.

Within a Java based program the beds try to negotiate "independently" a minimum place, without falling below the minimum movement areas. The architect of course can intervene at any time.

2.0 Construction unit optimization

The first rough static dimensioning was based on a very much reduced and highly simplified geometrical model. Construction units were chosen on the acceptance of a maximum load, which would have in far parts surely led to over sizing. An over sizing affects however also directly into another part of this project: increased expenditure for material and supplies, more material costs, higher weight, higher transportation costs!

The compact figure and the crystalline appearance of the draft had to lead to a general constructional survey of the whole building. A consequence of this view is to understand the static as a folded plate. A special meaning is hereby attached to these edges. The building becomes light and stiff.

3.0 Construction optimization

With the import of geometry from the "rubber band model" in a Java applet all surfaces are present three-dimensional. To transfer such a description in a conventional CAD program is very error-prone and time-consuming. Owing to our program there is access to all staffs, surfaces and areas. It can also be imported into usual CAD software, without mistakes.

3.1 Heuristic optimization

The entire construction was improved by a heuristic optimization procedure. The simulation in the computer is used for optimization problems, while the search for a simple mathematical solution is impossible by the high complexity. With a genetic algorithm for many generations, the positive characteristics are developed and the bad are rejected.

Generally the original question for the best solution is not answered by this procedure. However in practice usually a good solution is still better than none. In the case of the Monte Rosa shelter is a good solution an optimized middle between a light and an efficient structure.

4.0 Evaluation

In the first place by this way allowed us to develop a light and efficient construction, now the software makes an improvement possible, which no human can compute. Also trying out different profiles and showing oversized construction units is possible now.

To this control additional data was supplemented for profiles and resistance values. The requirements at each individual Point were specified. The specification of the static is now a basic element of the realization. These results were given to the executor, which could convert it in constructional details.

Thereby the detailing is not dictated, but a minimum described. There is a managerial decision, since we describe only the accurate geometry and the requirements. The conversion of the individual implementing is however incumbent on the executor.

5.0 The smooth interface into production

The result of the computation is beside the static service catalog but also the description of geometry. An export in Cadwork, standard software for timber construction, made it possible to deliver all static requirements and a complete described of the building in this software.

5.1 The interface problems

Direct heading of production machines is an established and usual method. Exporting the data that is available is still poorly conceived. So far CAD plans will be printed out, transported, distances will be measured in with yardstick and manually put again into software.

The problem is not the machines in detail, but rather the interfaces between the individual involved programs in the building process. Main problem is thereby the lack of compatibility on the exchange formats between the different software solutions.

Frequently this problem is solved with breaking down on a low complexity degree, (e.g. -DXF) whereby much information is lost. Besides the settings, which must be made for import and export, make high demands against the users. The absence of platform-spreading defaults for identifying designations of layers and classes makes interaction more difficult.

Another problem results from the requirements for clean handling the data. While two lines lying on another is not a problem for a plotter, it will lead in a static computation inevitably to an error message. In the minority of cases one works three-dimensional, which is one of the basic conditions for the conversion to the reality.

The individual components of the digital chain are present and are successfully used. The achievement of this project is finally in the successful connection of the individual links to a functioning chain. Universal validity also is proved to be true in this project: a chain is only as stable as the weakest member.

Up to now the chink was always the integration of production into planning. Most architects hardly argued so far with production software. These steps are implemented in this project. The software Cadwork makes an implementation to machine codes possible.

Finally these are instructions for the control of the milling and drilling heads. This handling of machines offers two advantages: Control and precision. On factory conditions now matching construction units are provided. They contain all necessary things, from the facade up to the building services. The precision is high so that rectification work is void.

Compared to former times a wall with the window cutout does not have to be build before the windows can be manufactured. In the consequence, control will become more important. It will be possible to make changes without affecting the costs. The linkage of price will make extremely exact cost estimation possible. Changes will be evaluated in real time. In last consequence the responsibility for the correctness of the construction units is determined by the correct data.

6.0 Conclusion

The consistent digital chain uses machines, which can produce just as favorably homogeneous as different parts. By skillful handling, interface problems while connecting the individual steps are nowadays no problem anymore.

An additional aspect is the implementation of a static plausibility check. It delivers exact evaluation of complex structures and as in this project makes a static optimization by genetic algorithms possible. Starting point of this process is a data model in which individual steps are improved until a buildable output is produced. Advantages are precision and time gained and from the start on a greatest possible control. Current architecture combined with up-to-date building methods makes this project a showcase for a modern way to build.

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