Abstract. This paper can be viewed as the continued development of a research project presented at last year’s eCAADe. The project focused on the potential and possibilities of cooperation among architects, investors with concrete building projects, and researchers at the university level working on generative design and parametric construction. After having spent several years of research on design techniques in a purely academic setting at the university we see, contrary to our fears, that reality and the integration of concrete factors such as budget, time management, etc. does not diminish but rather improves the quality of our work. This work is not primarily concerned with the development of a new architectural language but the intelligent use of modern computer technology based on digitized planning processes defined as ‘complex building design’. Designs developed in this manner can be distinguished by certain characteristics, the evaluation of which is a point critically discussed in the following paper.

Keywords: Generative Design; Collaborative Design; Parametric Design; User Participation in Design; Case Study; Strategic Design.
kinds of solutions.

The method we have developed for this context, ‘Statistical Design’ allows for a basic evaluation and preliminary planning of complex construction jobs. As opposed to typical procedures, it distinguishes itself with a significantly higher resolution of detail (more parameters), faster planning iterations, and consistent, comparative evaluations of planning alternatives. Here we were able to fall back on experience we had acquired in the context of various urban design projects (i.e. Kaisersrot and Heerhugoowaard in cooperation with KCAP, a Rotterdam-based architecture and urban design firm headed by Prof. Kees Christiaanse).

A significant advantage of this method is that the program, which is based on a set of defined rules, can automatically generate different solutions according to the problem or setting of parameters.

The ability to compare extreme variations increases planning quality, diminishes risks, and provides the foundation for qualitative revision in collaboration with architects.

**Generative Planning Process**

The unique challenge to this research work is rooted in the project’s origins. After the client had already concluded all of the usual steps of preliminary planning, including a use analysis as well as a time-intensive urban design competition, he was forced to conclude that it had led to no convincing result. Instead, the preliminary planning had only generated high costs and all of the designs could be regarded as being inconclusive and insufficient.

This frustration led the client to invite our chair to take part in a research project to develop concepts and various solution possibilities at the level of urban planning, as well as more detailed designs and strategies for their execution. Within this framework, several building phases were to be determined to
realize an office complex of approx. 120,000 m² for around 2800 employees.

The difficulties our client had experienced from the start strengthened our theory that this task could not be solved through conventional methods, but rather new technologies and design procedures had to be introduced to adequately address the complexity involved.

The resulting concept is based on three separate planning phases with different programs and technologies:

- 1st Phase: ‘The 50-Year Structure’ – 1:1000 urban scale
- 2nd Phase: ‘The 5-Year Structure’ – 1:200 building scale
- 3rd Phase: ‘The 5-Day Structure – 1:50 construction document scale

Each individual phase generates a series of solution possibilities and gives feedback to neighbouring phases, through which conclusions and evaluations can be made. In order to allow the smooth transfer of individual data formats from various planning phases, a special transfer format in XML was described in order to pass on geometric, topologic and semantic information.

A previous research project had shown us that this kind of strategy poses significant advantages over traditional planning practice. The possibility to demonstrate the program live to the client allows the user to spontaneously react to the client’s wishes as well as helps illustrate the individual steps of the design process in a comprehensible manner.

The main advantages of generative planning over conventional methods are the great degree of planning freedom, the controllability of the process, and the direct verifiability of changes. Any stage of the planning can be given out immediately in the form of tables, which facilitates the evaluation of quantitative qualities. However, the programming of the individual phases does not primarily make a concrete statement on the architecture. This is an essential characteristic of this research work and allows collaborations with external architects at several different levels. The developed software, on the one hand, can function as a ‘decision-supporter’ in that the architect’s designs can be entered into the program in order to gain an objective evaluation. Collaboration can also occur at the level of the development of style sheets determining different design options. These style sheets can subsequently be integrated into the programming language of the different levels.

**The 1st Phase: ‘The 50-Year Structure’**

In the ‘50-Year Structure’, urban planning is generated that takes into account factors such as topography, noise, daylighting, use allocation concepts, length of façades, circulation, and individual client wishes. These factors make up the software parameters, or so-called rulebook. Next to these given parameters, the design parameters, such as interlocked structure, compact volume, etc., play a decisive role in the architectural language that is generated. In addition, the fixed points, for example circulation and infrastructure are positioned.
The program developed for this purpose is a Java program, which is able to generate a building from a given space allocation list and set it on an existing site. The spatial distribution can be optimized according to different quality criteria in real-time, in order to generate a building custom fit to the user’s needs.

The basis for this procedure is a differentiated description of the building site in question. This is made up of various levels of information, including legal framework conditions (i.e. construction boundaries, max. floor height), infrastructure (i.e. streets, existing buildings, green areas), and project-specific details.

The program is based on an optimizing strategy following a genetic algorithm. The building site is divided into areas of the same size. The three-dimensional distribution of the space allocation list onto these areas subsequently generates the code (or genotype), which is to be optimized. The final building geometry is calculated using simple form grammars.

The building and path network that are generated form the phenotype, which is evaluated according to various criteria. Using these criteria, one is able to evaluate the ‘fitness’ of this building generation. If one is satisfied with the results, one can generate a 3D model with a click of the mouse, where the internal spatial distribution and precise listing of the most important building characteristics are saved. The resulting concepts are passed on in the form of an envelope, the details of which will be discussed later in the ‘5-Year Structure’ section.

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The three-dimensional real-time program interface constitutes an important programming development. This visual evaluation component is important especially when in direct contact with the client, in order to avoid misunderstandings and enable the user to directly intervene in the optimization process.

**The 2nd Phase: ‘The 5-Year Structure’**

The ‘5-Year Structure’ allows for zoning according to defined use profiles. It uses the generated envelope of the 50-Year Structure and distributes the different use units over the floors.

The first step is to separate the different units into groups with similar requirements based on the space allocation list. **The operation mode of the system to be optimized can be essentially divided into three areas:**

- Analysis of the 50-Year Structure
- Distribution of the units
- Generation of geometric spaces

The 50-Year Structure analysis evaluates interior qualities, e.g. the geometric appraisal of room depth, as well as exterior factors, i.e. views or daylighting.

In a second step, the units previously defined by
the space allocation plan are distributed according to the results of the analysis. This step roughly positions the units, while the optimization of the spaces occurs in a successive step. Afterwards, individual spatial units are generated according to their requirements. This results in different zoning concepts based on room depth, which constitutes an additional level of complexity of the programming in comparison to previous projects, where circulation concepts were static.

**The 3rd Phase: ‘The 5-Day Structure’**

In addition to the focuses described in this paper, the concept developed for this concrete task also addresses aspects of implementation in the construction process. In order for the building to attain maximal flexibility of use, a decentralised networked building services system was developed in collaboration with Prof. Dr. Leibundgut, Chair of Building Services at ETH Zurich. In this system, the services modules are integrated into the façade or floor construction and can be individually controlled. The advantage of this strategy is that the internal use structure is independent of the building geometry and can be varied to a large extent.

Since uses can often vary, especially in office buildings, a 5-Day Structure was developed, which takes the generated floor plan typology and automatically generates furnishing proposals. In a next step, the distribution of uses will be evaluated to reveal strategies for optimizing building use.

**Outlook**

The various research projects of the last years have allowed us to gain expertise in the programming of complex structures. In the meantime, our challenge lies no longer in creating these programs, but rather establishing and investigating a new manner of applying computer technology within the field of architecture.

In addition to the function mechanisms we have described, this project places great emphasis on the integration of the client as well as the user. A key issue is how programmed or generated planning structures can simultaneously achieve greater security with greater planning freedom.

By separating structure, e.g. the generated design, from the specific architectural language, or style sheet, a professional dialogue with architects can be maintained. In time, this can help denounce the preconception that programs can automatically generate architecture and therefore pose a threat to architects. However, it is still easy to assume that the generated structure already suggests a certain architectural language, a point that has to be critically examined on the one hand, but on the other hand can also be seen as a new point of departure for design.
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