A Parametric-Typological Tool

More Diversity for Mass Produced Single Family Homes Through Parametrized Design and Customized Mass Production

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Abstract: We present a research program in which a plug-in tool for the generation of vertically stacked single family homes is developed and implemented in the software Autodesk Revit Architecture. The parametrized typology will provide for more variety, individuality and appropriateness in the homes themselves and also in the urban structures created by them. CAAM methods furthermore drastically reduce the production costs. The research is government-funded and sponsored by the building and software industry with the aim to both extend the functionality of an existing software package and to build a prototype urban development.

Keywords: Plug-In Tool; parametrized typology; CAAM methods; design tool development; new design concepts and strategies; mass customization.

Overview

There should be as many types of houses as there are different types of people, and for every individual within a type there should be an equivalent within the housing type. Frank Lloyd Wright, 1896 (Kauffmann, 1995)

We present and discuss a research program in which a parametrized typology is developed for single family homes (Figure 1). This typology will provide for more variety, individuality and appropriateness in the homes themselves and also in the urban structures created by them. The parametrized typology will also be much more cost-efficient to build because of its employment of CAAM methods.

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The typology will allow to overcome the monotonous dullness of many residential quarters that is the result of postwar serialized mass production where all building parts, and with them most buildings and therefore whole urban quarters, are created from endlessly multiplied identical parts (Figure 2).

The typology will become applicable via a software tool using Autodesk Revit Architecture as a platform. This tool creates complexes of single
family homes on the basis of a given set of parameters, most importantly site and user characteristics. The resulting digital models incorporate and employ the requirements and possibilities of several CAAM technologies (Figure 3).

Our research is conducted in close collaboration with a housing company that has several decades of experience in building and managing housing complexes and is looking for ways to utilize new design and fabrication methods and technologies to increase the quality of their homes through individualization. Another partner is Autodesk who are interested in expanding and enhancing the functionality of their Revit Architecture software.

**Research aim: digital plug-in tool**

The aim of our research is a digital tool that plugs into Autodesk Revit Architecture. It creates digital models of assemblies of single family homes according to a range of parameters: site and urban context, orientation, future residents’ profiles.

The functioning of the tool does not include but presupposes the distillation of user profiles from demographic, socio-political and economic data. The digital models produced by the tool constitute a proto-architecture and not complete buildings. They include constellations of spaces that make up a single family home complete with functional zoning and internal circulation. The residential units may also be stacked; external circulation will then automatically become part of the model.

**Research structure**

We carried out four parallel surveys: existing typologies for single family homes, current developments and future trends in the development of
The results from the CAD and CAAM research were integrated into the generative diagram. The generative diagrams were translated into programs that created custom commands within Autodesk Revit Architecture which could be used to create 3d digital models of single family home complexes. In a series of iterative refinements and concisions, the set of custom commands was fused into one single command.

The individual mass production is defined by a material strategy for different building parts and the construction of the houses. A parametric structure for the supply circulation is designed to create typologies that can be used in varying scenarios of living.

**Strategy for parametrized typology**

A compositional rule system is (...) a technology for erasing arbitrariness. It restricts itself to the space of the possible. (Georg and Dorothea Franck, 2008)

When developing typologies, even in conventional design methods, there are repetitive patterns of design approaches. Besides the creative and intuitive process of concept-finding, there are two main actions:

- Definition of internal factors, i.e. programme, user requirements etc., and external factors, i.e. size requirements for single family homes, software tools for developing parametrized building models and fabrication processes for producing buildings from the digital models.

We collected data on a wide range of existing typologies and also the urban structures they correlate with, looking at a wide range of urban situations, from loosely sprawled suburban contexts to dense innercity ones. In addition, the current and projected developments and trends for single family homes were surveyed to ensure that the developed typology would correlate with future requirements.

From a synthesis of the data we distilled a generative diagram that described a desirable typology.

In parallel we looked at various CAD packages that allowed parametric modelling and compared their different properties to see which would be most suited to the development of our intended tool. We selected Autodesk Revit Architecture because of the powerful parametric 3d modeling application on the user interface and the programming possibilities on the application programming interface that Autodesk opens up for research projects.

Additionally, a range of CAAM processes were reviewed and analyzed to gather information about the properties that would make the digital building model most suitable for CAAM.
and direction of site, infrastructure requirements, distance to neighbour etc.

Developing a set of varying designs from the internal and external factors which is followed by checking and optimizing and, if necessary, developing more variations.

Random results of time-consuming trial and error proceedings can be improved and overcome by introducing a rule-based description for the typology based on the analyzed design process.

William Mitchell (1990) develops a system for the design process of Palladio’s house typologies based on Stiny’s and Gips’ shape grammar description (1971). With the aid of a very exact set of geometric rules and dependencies, Mitchell can not only reconstruct palladian houses, but also generate new variations. The rules follow an additive system: starting from a single axis point the geometry and the arrangement of rooms are added. The result constitutes the phaenotype (of the original palladian genotype) in the proportion and arrangement of rooms.

Similarly, José Duarte (2000) examines an existing building type, the “Malagueira houses” by Alvaro Siza to subsequently set up the incorporated rules. Duarte hereby combines shape grammar with a description grammar which make it possible to fully

Figure 4
Algorithm for plan layout with spatial division and transposition into the parametric 3d model
describe the building type. With the established instrument, existing house types can be reconstructed and new types in the “Malagueira style” can be generated. In addition to parameters of space and geometry, functional dependencies and calculation of costs are integrated. In contrast to Mitchell’s system, Duarte’s is not adding spaces, but dividing up the overall geometry into smaller units.

Our research project builds on these findings of design processes and consolidates them in a parametric system, that is not linear, but an interrelated network of parameters with dependencies and hierarchies.

The parametrized typology was developed in consecutive steps containing as a programming guideline all relevant information for the plug-in tool: Basic conditions of the typology were set up by means of the criteria diversity, flexibility, energy efficiency, fabrication methods and cost-effectiveness. Due to the arising complexity when integrating all
different criteria, the typology itself was developed in parts - via planning elements like plan layout (Figure 4), section layout, shape of roof, facade etc. - as parametric rule-based elements with connections and dependencies between each other and translated into parametric 3d models (Figure 5). The diagram of parameters (Figure 6) shows the relatedness of the parameters; the direction of the arrow indicates the hierarchy.

The functioning of the CAAD extension

The plug-in tool is programmed in the application programming interface of Revit Architecture in C#. The tool is implemented as an external tool.

The functioning of the tool is started by the building site conditions of size and orientation. In the next step the user can choose and specify building and user requirements, i.e. size of the apartment, slope of roof, use of solar energy. Using all this information the plug-in tool starts placing 3d model houses on the site. The 3d model houses that are placed by the tool are modelled in Revit Architecture as so called „family“ instances with specific characteristics defined with the aid of parameters of the building elements. Through these parameters constraints and dependencies can be defined and controlled via introduced formulas of different complexity.

The functioning of the tool was tested on exemplary sites of the cooperation partner. It generates assemblies of stacked row houses that are optimized according to the typology’s criteria (Figure 7 and 8). Time-efficient generation of diverse constellations of housing arrangements could be shown.

Complementary tools for optimizing and evaluating were defined, but not programmed as part of the research project. Using the BIM tools and tables within Revit Architecture, all defined parameters can be utilized and exported for further use.

Conclusion

We are convinced that methods of parametric design and customized mass production can not only
enhance design creativity and extend design and production capacities but also enhance the final product by optimizing it for user and location.

Using the described digital parametric tools, generally demands a different approach in the application than conventional CAD software. Since these tools are much more complex with integrated parametric modeling and offer the definition of associations, dependencies and constraints, the handling is more complex and the introduction of formulas might require the participation of an expert in this field or program, i.e. computer scientist or mechanical engineer.

The advantages of customizing software are already widely used in mechanical engineering and product design, but hardly known in most areas of architecture.

Similarly, the potential of production methods changing from manual to digital production are yet to be fully appreciated and applied to realize customized production at the price of serial production.

**Outlook**

From the result of this research project we plan to extend our investigations:

We intend to select one of the case study designs, develop it in detail and actually build it to demonstrate the capacities of the new tool and typology in creating urban structures and family homes that offer diversity, individuality and richness that reflect the individual characteristics of their residents - without creating higher costs but instead being slightly cheaper than current standards due to the use of CAAM methods.

Another investigation will be into the possible transfer of the planning methods using parametric modeling to other typologies beyond housing, i.e. kindergartens or supermarkets. We plan to examine and compare the specific characteristics of different typologies of varied uses, the possibility of parametric rule definition and its application in planning processes.

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