A grammar-based system for the participatory design of urban structures

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Abstract. *We propose a three-step participatory design cycle for the early urban design phase that can be integrated into the digital design chain. Step one involves a visualization method that is implemented as an interactive card-based interview technique for the collaborative requirement specification of urban designs. In step two these specifications are a) translated into simplified GIS data and then b) implemented into a grammar-based system together with the corresponding design regulations. The final outcome is a generative and iterative urban model, which includes buildings, building blocks, transportation networks and open spaces that visually communicates spatial impacts of urban design proposals.*

Keywords. *City modeling; participatory design; shape grammars; urban planning.*

1. Introduction

We propose a novel method for participatory urban design workshops. It enables participants to set up requirement specifications for distinct urban design aspects in a collaborative manner. Defined specifications, e.g. the maximum building height facing a street side, are implemented in a grammar-based system, from which a 3D city model can be instantly generated. Participants can mutually agree upon the results or iteratively refine the specification since they see the results of their interventions immediately. Parties from different interdisciplinary fields can visualize and communicate their ideas more efficiently within one parametric, procedural 3D city model. The model itself works independently from traditional modeling scales that are usually fixed. The procedural modeling technique offers specific control on the granularity of the model by adding more and more details to the geometry where it is needed. Traditional virtual or physical 3D city models do not offer this flexible parameterization. Most of them are a) built manually, are b) non-parametric and therefore foreclose time and cost efficient design iterations. Beside that they do not meet the requirements for participatory design workshops in which the 3D model has to be changed interactively. Hence, this presented approach offers new insights and opportunities for practitioners as well as for urban design studios in education. The paper is organized as follows: Section 2 gives an overview of methods used for participatory design and focuses on architectural programming and 3D city modeling. Section 3 illustrates the process with a case study on the "Dubiocity" experiment where the present approach has been implemented into a regular elective course at ETH Zurich, followed by the conclusions in Section 4.

2. A Framework for participatory design

The system can be directly implemented into common urban design workshops. For example, a group of stakeholders have a design briefing held by urban planners (see figure 1).

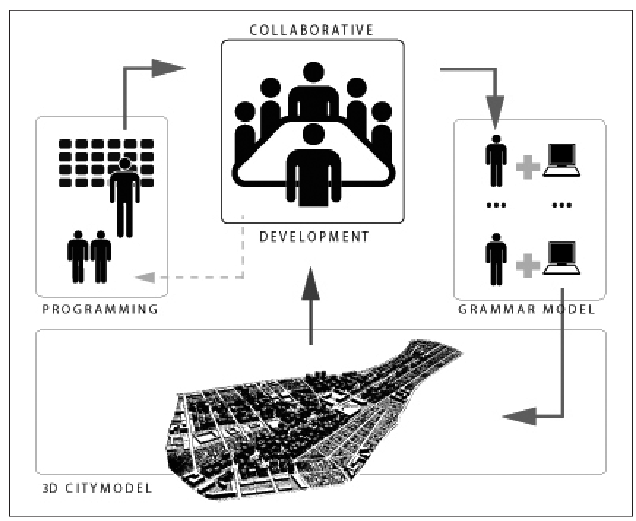

Figure 1. The participatory design cycle.

2.1 The Architectural Programming

The method 'architectural programming' (AP) had been initially introduced in the late seventies by Peña (1977) as a technique where information about a design project is gathered in form of figurative expressions and standardized ceremonies. The approach has been expanded by Preiser (1978), Palmer (1981), Duerk, 1993 and Kumlin (1995). Robinson and Weeks (1983) integrated AP inside design phases. Henn (1994) integrated AP as a quality control instrument for daily use in architectural offices. AP starts with the monitoring of planning briefings. Through the monitoring process an AP card wall is composed. Each card of the AP wall is based on a sheet of DIN A5. Strict style conventions are used to structure each cardboard into specific zones for headlines, shape attributes and one (1) abstracted drawing of a distinct geometrical configuration. Cards are discerned into (a) fact patterns – for the analysis – and (b) design concept patterns for a proposed reaction on the existing condition that had been discovered during the briefing. Pre-prepared definitions can be used as well since some conditions in urban planning are recurring (e.g. definition of land use, geographic orientation). The briefing team moderates the process. The resulting cards are evaluated by the participants and mutually accepted or neglected. Afterwards they are integrated into a matrix following a defined weighting for the main categories – horizontal subdivision – and urban scales – vertical subdivision. The resulting AP wall is visible to all participants and can be individually discussed.

2.2 The Urban Modeling

In parallel, a scripting team encodes the geometric descriptions on the AP cards into (a) CGA shape grammar and (b) into a simplified GIS data model based on color maps. Then, the GIS model and the CGA representation are used for the automatic generation of 3D city models with Procedural's CityEngine (Procedural Inc., 2009). The resulting 3D city models include parametric buildings, building blocks, transportation networks and open spaces.

Over the last decades, a number of production systems for architectural models had evolved, such as Chomsky grammars, graph grammars, shape grammars, attributed grammars, L-systems or set grammars (Vanegas et al., 2009). Shape grammars have been used for the analysis of several examples in architecture, such as the Palladian Villas (Stiny and Mitchell, 1978) and the Siza's Malagueira houses (Duarte, 2001). CGA shape was initially introduced by Müller et al. (2006) and was extended by Ulmer et al. (2007), Halatsch et al. (2008) with rule-based urban planning patterns and landscape patterns (Alexander et al., 1977). For more information on the CGA shape grammar and its potential use in urban planning we like to refer to Müller et al. (2006) and Halatsch et al. (2008). The resulting 3D models is evaluated and analyzed with regard to solar load with applications like CityZoom (Turkienicz et al., 2007) and Ecotect (http://www.autodesk.com).

3. Case study: The Dubiocity

We tested the presented participatory design cycle in an elective course during spring semester 2009 at ETH Zurich. A no more utilized military airport in the outskirts of Zurich posed an ideal example for an experimental case study. There are plans to transform this airport with a size of 2.5 km2 into an area for residential living and other uses in the course of the next twenty years. It is located next to the city of Dübendorf with 23,000 inhabitants on 13.6 km2. Starting from that situation, the assignment was to develop a 'clean tech' city for additional 30,000 inhabitants. The land use mix proposed by the students for 'Dubiocity' integrated different functions (industrial, science, living, public building, retail). The participatory design cycle took place in the ETH Value Lab – an innovative collaborative design environment (Halatsch et al 2009) (Figure 2), which consists of five multi-touch interactive displays and a sophisticated hardware and software framework for the generation and visualization of large urban environments. It is ideal for participatory design.

3.1 Analysis of the planning site

The planning site had been analyzed with the AP method, taking into account several urban scales and existing urban network connectivity. After this, a brainstorming session took place and the most important points regarding the site's potential and the new guidelines for the project were discussed. The results were translated into fact and concept sheets – the AP cards.

Figure 2. Value Lab: a collaborative design environment.

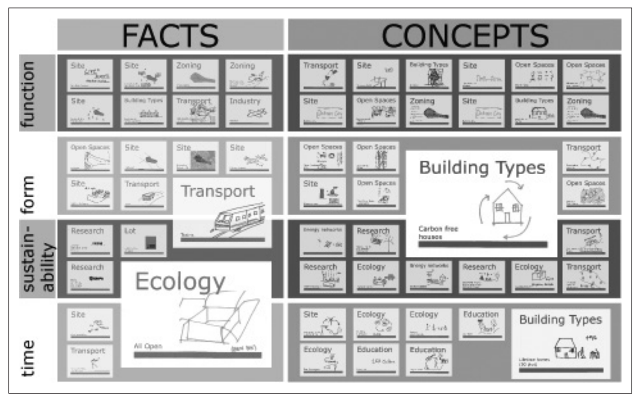

Figure 3. AP cards arranged in matrix layout.

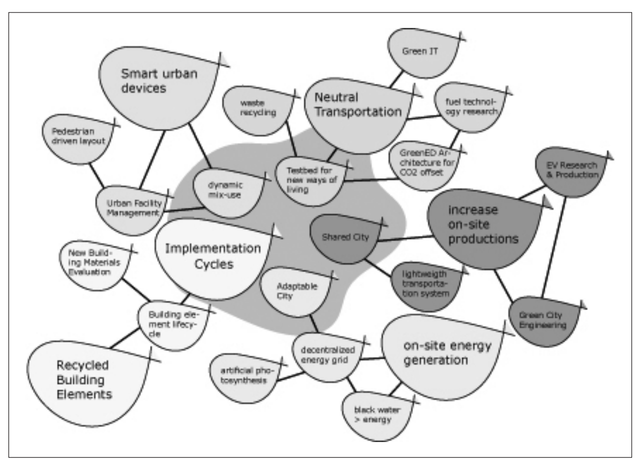

Figure 4. Functional charts representing urban interdependencies.

3.2 The matrix layout

The cards were classified into groups of key characteristics for the planning site (function, form, sustainability and time) and arranged into a matrix layout based on semantic groups (Figure 3). The importance of the cards had been weighted by the participants.

3.3 Function charts

Evaluated interdependencies between weighted cards were then translated into function charts (Figure 4) to setup a system model for the then following generation of the 3D city model.

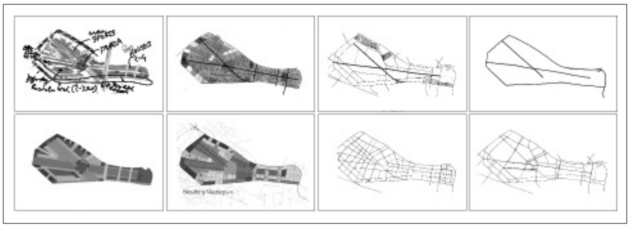

Figure 5. Masterplan: Zoning and Street network drawings

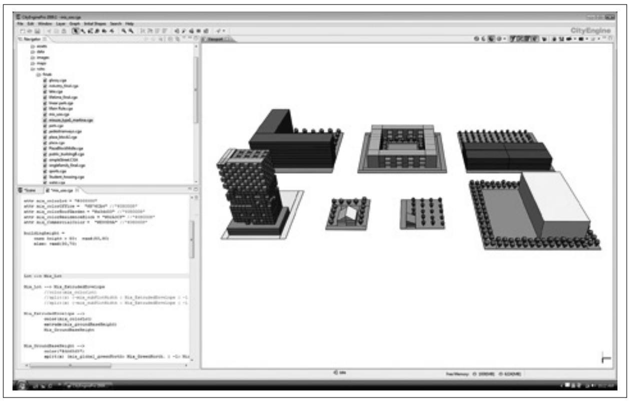

Figure 6. Generated building types inside CityEngine.

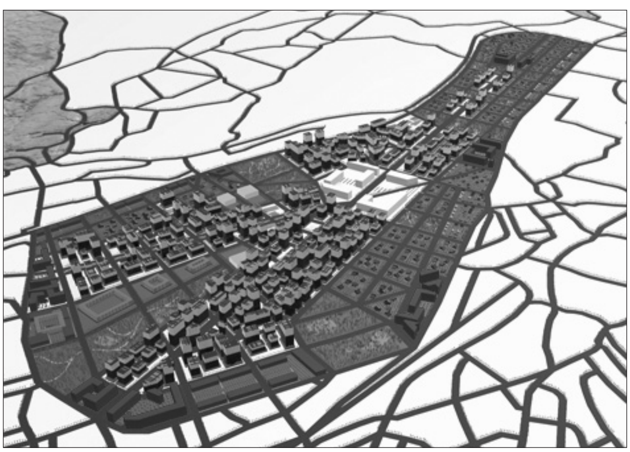

Figure 7. 3D model in real-time application Showcase.

3.4 Translation of the information into GIS and CGA

The weighted AP cards – stating a specific geometric configuration with numeric properties – had been manually translated to CGA shape grammar by the scripting team. This was performed according to the importance of a single card and its relation to others in the function graph. GIS-related cards had to be manually translated into bitmap-based maps by using conventional image manipulation tools (land use, population density). The resulting master plan (Figure 6) integrates seven building types: mixed use, industry, public facilities, student housing, single family houses, lifetime houses and the main plaza.

3.5 3D city model

The created GIS-data and pattern descriptions in CGA shape grammar are used to generate a 3D city model of 'Dubiocity', which can be iteratively edited and regenerated through a modification of the AP cards and an associated update of the GIS-maps and CGA code during the participatory design sessions. The 3D model is visualized with 'Autodesk Showcase' for real-time evaluation (Figure 7).

4. Conclusions

We have presented a participatory design cycle for the early urban design stage that can be integrated into a digital design chain. The cards based method improved the initial brainstorming and conceptual phase in efficiency and speed. The facts and concepts reported in cards, tables and charts secure that the established guidelines and constraints remain throughout the process. The resulting 3D city model is parametric and can be iteratively modified during design workshops. The results could not have been achieved with traditional planning instruments in such a short time in this quality. In recognition of their willingness to experiment and the value of their results, we would like to thank our students from the elective course spring 2009. The method will be refined in the coming semesters, and lessons learnt from the process will be implemented in the CityEngine.

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