Parametric Building Typologies for San Francisco Bay Area

A conceptual framework for the implementation of design code building typologies towards a parametric procedural city model

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Abstract. This research paper concentrates on a conceptual framework for the creation of high-level procedural city models. A workflow is presented, which enables users to create city models in an intuitive way by using design-code-driven building typologies. This drastically advances traditional procedural city modelling where usually low-level implementations of city model components take place. New planning methods and instruments have to be developed for the growing demand of the rapid environmental, social and economic changes in cities and agglomerations. The presented method allows for quick visualization and iteration by using urban planning typologies.

Keywords. Procedural Modeling; Design Codes; Urban Planning; City Modeling; Decision-making process

INTRODUCTION
The goal of the presented framework is (a) to provide a better way of communication between decision-makers such as planning experts, urban designers, policy makers and lay people and (b) to develop an instrument that supports interactive prediction of urban plans. With the presented method experts and residents are enabled to exchange opinions on presented urban scenarios and use design codes for intuitive iterations during design charettes. In the presented examples, building types of the San Francisco Bay Area (SFBA), US will be analyzed in relation to the public and private structures, the transportation network and the urban design aspects. Furthermore, urban design parameters and guidelines will be generalized and implemented into a rule-based, high-level typology catalogue for procedural city models (Dyllong, 2012). Finally, this paper will give practical insights on procedural city modeling concepts for advancing curricula as well as researchers and practitioners.

Motivation
For sustainable urban planning, system-engineering approaches are needed to create a shared and holistic view on urban scenarios. The development of high-level abstraction techniques can support the
structuring of planning proposals as well as the resulting city model visualizations. Up to date, design codes are commonly used to simplify abstract legal rules. Those only exist as figurative descriptions in drawings of a specific planning regulation problem, e.g., the distance spaces on a lot within a zoning plan. On the other hand, parametric and procedural city models are becoming more and more important in urban planning and design (Kunze et al, 2011). Solutions from Autodesk, McNeel and Esri are setting the industry standard for city modeling. However, these tools are still not intuitive enough and especially switching scenarios or single typologies cannot be easily performed within design charettes.

In our work, we present a first approach on how design codes can be efficiently used to steer and refine generic procedural 3D city models in order to easily arrive at detailed urban scenarios. The created 3D visualization models of urban planning scenarios can be then used as an interface for an improved dialogue between stakeholders (Urban Vision, 2012, Kunze and Schmitt, 2010). The approach will be presented using Esri CityEngine as an implementation example. Procedures are described of how existing zoning laws are analyzed and then converted into structured CityEngine language scripts – CGA – to build a typology catalogue that can be then composed into digital urban visualization models.

The San Francisco Bay Area (SFBA) has been selected as an example for a proof-of-concept implementation. Design codes play a historical role in SFBA since the well-known ‘Queen Anne’ houses (Weingarten, 2004). However, more recent design codes – a.k.a ‘form-based codes’ – are commonly used to associate building laws with development scenarios. In order to detect the most relevant typologies in the SFBA, the main building types of the Bay Area were categorized with a design code mechanism. The result has been a typology classification consisting of the building typologies, which mostly influence the SFBA. These detected typologies are transferred into parametric models inside CityEngine on four levels: Building, parcel, urban block, and street canyon. Using this structure, the typologies can be combined and easily modified, e.g., to probe densification scenarios. In addition, they can be transferred to related planning applications in other cities. Since the resulting 3D city models are easily adjustable, it is possible to create a variety of high quality urban scenarios using the parametric building typologies.

**Design codes in urban planning**

Design codes represent a set of design and planning regulations including zoning rules, density and open space standards, building and street typologies to different local characteristics, building height...
and materials and rules (Carmona et al., 2006). Design codes relate to urban design quality aspects, like accessibility, connectivity, legibility and identity. Codes give a conceptual vision like a common language and a set of instructions for the development of urban settings. There are several contemporary design codes available worldwide, especially in the UK, driven through the ‘Sustainable Communities’ growth program of the UK government to deliver better designed and more sustainable built environments and in the North America, where within the New Urbanism initiative new developments were built on the basis on form-based codes and particular based on design codes. A main advantage of design codes to the standard written zoning laws is the visual 3D representation of the developments (Carmona et al, 2006). Beyond that, strong synergies can be identified between planning practices using design codes and applications in real-estate development, e.g., standardized housing units, increase marketability (Adams et. al, 2011).

**Geometric modeling in urban planning**

Some initial decision support tools have been developed as urban simulation models and implemented in regional planning processes (Waddell, 2002; Borning et. al, 2008). A further development is an environment supporting the interactive design of urban spaces that includes behavioral and geometrical city modeling (Vanegas, et. al, 2009). Urban design variables can be more intuitively accessed and visualized within such an environment, resulting in urban scenarios that consider proposals for highways, accessibility studies, population and projected employment distribution.

Müller et al. (2006) introduced an attributed shape grammar, called CGA shape grammar, suitable for architectural design – it is the current base of the Esri CityEngine System. CityEngine can rapidly produce and visualize 3D urban environments of any size. Integrating shape grammars into the urban planning process offers unprecedented opportunities to understand and encode urban patterns and to generate and visually assess urban design variations (Halatsch et. al, 2008; Schirmer and Kawagishi, 2011).

**CASE STUDY: THE BAY AREA**

The San Francisco Bay Area is a metropolitan area in Northern California. The Bay Area is defined in 11 counties (including San Benito, that is not part of this work because it has no border to the San Francisco Bay). The main cities are situated around the bay of San Francisco. The largest city in this region is San Jose, Santa Clara County. But the most culturally dominating city is San Francisco, the historic center of this region. The area of San Jose, San Francisco, Oakland and its surrounding area cover approximately 7.15 million inhabitants. For this reasons the Bay Area is the fifth-largest metropolitan

*Figure 2*

*Design process of quantitative single house building patterns into a procedural model.*
area in the United States and number 53 worldwide. The south bay is more populated than the North Bay and in general public buildings are located next to the Bay and private buildings are orientated more to the coast. Offices are more situated inland and close to big cities with their airports and business districts. The single-family houses are more often in the countryside and close to the Bay, such as multi-family houses. The most similar type, which could be found almost everywhere are the schools (Weingarten, 2004).

**CONCEPTUAL FRAMEWORK FOR THE CREATION OF HIGH-LEVEL PROCEDURAL CITY MODELS**

In this section a workflow will be presented, which enables users to create city models in an intuitive way by using design-code-driven building typologies. The presented method allows for quick visualization and iteration by using urban planning typologies.

The workflow of the adaptation of the form-based codes and building types into a procedural urban model is visualized in figure 2.
In a first step the urban and building patterns of the SFBA were analyzed to identify and evaluate existing building typologies based on the standardization of form-based codes. Using a survey, 14 major typologies for the SFBA have been detected. The most common types were determined, such as typical single houses, multi-family houses, offices and schools. The parametric design parameters were specified. The design parameters were then used to develop design rules and guidelines for each typology (Fig. 3). These building patterns were visualized in isometric diagrams.

The rules of the different building types were digitalized into a CGA building typology catalogue, which will be used in succeeding steps to drive the 3D city models (Fig. 4).

**IMPLEMENTATION OF THE CASE STUDY FROM DESIGN CODE INTO A PROCEDURAL MODEL**

The design process that was presented in the method section (Fig. 2) was applied in the case study SFBA.

**Form-based codesurvey**

On the basis of 14 major typologies for SFBA (Urban Vision, 2012) the most common types were determined, such as typical single houses, multi-family houses, offices and schools. The quantitative parameters of the urban and building patterns of the SFBA were specified and documented in a survey based on the SmartCode (CATS, 2009). Design parameters of the block and lot dimensions, the public and private frontages were derived (Fig. 5).

**Rules and guidelines**

Design parameters for the major SFBA types for street profiles, blocks, building geometries, facades, open spaces and vegetation were transformed in design rules and guidelines (Fig. 6). These guidelines were visualized in isometric diagrams.

The isometric diagrams of the four building typologies are summarized by their construction quality and usage. The low standard building lots are always smaller and the green areas increase with the better standard. The school typologies are not characterized by their building standard, but rather by their usage.

**Parametric building typologies for the San Francisco bay area**

Based on the guidelines each building type was implemented with the CGA grammar into a procedural urban model in Esri CityEngine (2012).

The derived models were used as a high-level typology catalogue for procedural city models (Fig. 7). The typologies are divided by their building quality and usage. The higher the standard, the more versatile and more elaborate the construction of the building.

**CONCLUSION AND FUTURE WORK**

The presented work described a conceptual framework. The implemented building typologies of the case study SFBA serve as an example for using digital design codes to drive procedural city models. The resulting typologies (Fig. 8), e.g., building types, might be integrated in geometric modeling and
connected with behavioral simulations for evaluating urban planning scenarios.

The resulting city models are used to provide generalized and simplified views on urban scenarios to experts and laymen and to therefore encourage a design-problem driven dialogue.

The complete collection of all presented building types for the SFBA will be found in Dyllong (2012).

Future work will cover case study areas in Europe or Asia to prove the generic adaptability of the presented approach and will be linked with local aspects of the individual urban setting. In addition, the building typologies will be extended to the application of parametric building regulations and zoning laws.

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