Architectural Styles Dependent Shape Grammar
Representation of Facades

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Abstract
In this poster, we present an idea to utilize formal rules and descriptions for architectural styles from various time periods. We focus on facades of historical buildings with identical purpose located in a specific geographical area. We have chosen the CGA shape grammar as a formal language to represent and visualise the rules and we demonstrate our approach on facades of the residence-type historical buildings located in Prague. Our aim is to show that differences in formal descriptions of various buildings are tightly related to differences in architectural styles. Having a proper metrics for such CGA grammars, we will be able to generate new virtual buildings of certain architectural style and to control their possible transitions among distinct styles.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Methodology and Techniques—Languages, I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality

1. Introduction
The procedural modelling of cities, in which we can generate an urban scene by a set of rules, started in 2001 by Parish and Müller [PM01]. Since this time, various sub-problems have arisen in this field. Procedural modelling of buildings and facades is one of them. A shape replacement method is often used in city generation. A grammar called Computer Graphics Architecture (CGA) was presented in 2006 [MWH+06] especially for creation of cities. Mass models are the basis of the building structure and rules derive a design of objects by iterative generating details by non-terminal rewriting. Rules operate on the geometry in a locally oriented bounding-box. The CGA enables basic geometric transformations and also extruding, splitting etc. In 2007, a paper about inverse procedural modelling of buildings was published [ARB07]. Authors presented an interactive tool that generates a formal description of a given building. However, their approach does not fulfill our requirements dealing with keeping and measuring architectural style differences.

2. Architectural Styles and Formal Rules
Every architectural style can be understood as a mirror of the specific time period and culture. Each style has its own rules, construction materials, typical features, characteristic parts and shapes. There are differences in a segmentation (regular, irregular, symmetric, chaotic) and fractal dimension of facades from miscellaneous historical eras. Our aim is to formalise this knowledge and use it in the procedural modelling of architectural styles.

In our opinion, descriptions of the same style, but for buildings created for various purposes (e.g. religious or secular) are distinct. On the other hand, all buildings of the same kind (e.g. train stations, churches, town halls) keep their own characteristic parts. Footprints and silhouettes of one kind of objects (but from different centuries) are significantly similar. For example, church towers have different shapes in detail, but they have the same rough characteristics (thin, tall, narrowing to top), which clearly distinguishes them from other kinds of buildings. Configurable property of appearance is also symmetry (of footprint or front facade). The footprint is symmetric mainly when there is a lot of space (e.g. manor houses). On the other hand, an adaptation to natural environment (e.g. castles on rocks) implies an asymmetric shape. Differences also depend on location binding. For example, gothic cathedrals in continental Europe and in England are distinguishable on the first view. There can be influences from other culture or religion on the design of buildings, which is often visible on country boundaries. Sometimes, it is hard to recognize an architectural style, because

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the building may contain a mix of styles. We intentionally
avoid such buildings in this phase, however, this style transi-
tions will be taken into account when new virtual buildings
will be generated upon the rules describing pure styles. The
appearance of a building depends also on owners and archi-
tects. Moreover, the same building changes in time. Various
uses of building during centuries, the elements, other prior-
ities in lifestyle may influence the appearance of building.
The layout of street network has been changing through his-
tory and sometimes it affected the arrangement of buildings
and their shapes. We believe that rebuilds are more often vis-
ible on large scale buildings than on smaller ones.

Formal rules and descriptions of buildings should con-
sider all characteristics mentioned above in order to both
generate buildings of various styles and compare differences
among existing ones.

Figure 1: Front facade of (a) the Tuscany and (b) the Thun-
Hohenstein Palace in Prague. On the right side are facades
created by CGA shape grammar.

3. Case Study

We have chosen the Tuscany Palace and Thun-Hohenstein
Palace in Prague, which were built at the turn of the 17th
and 18th century and which are examples of secular, baroque
architecture in the city. They are built in one style, have simi-
lar usage and are located nearby. This eliminated differences
mentioned in Section 2. For simplicity, we concentrate on
front facades only (Figure 1). From those two facades, we
have created rules in the CGA grammar. We have tried to
catch and keep an architectural style specific to this kind of
buildings when creating a hierarchy of CGA rules. The re-
sulted grammars then have similar shapes that can be mea-
sured, compared and evaluated. For comparison of our two
palaces, it is possible to find the same parts and also differ-
ences in their hierarchies (Figure 2). For example, the second
facade does not have balconies. Within these grammars, we
can measure and compare regularity or chaos of decorations,
windows placement on facade, absolute or relative sizes, ra-
tio of elements, a number of the same or different objects, ex-
istence of architectural components, repetition of elements,
average dimensions or colours of objects and much more.

Then, we receive rough rules that describe a given architec-
tural style for selected kind of buildings.

Figure 2: Two facades described using hierarchies in CGA.

4. Open Issues

To efficiently compare and evaluate a formal description of
historical buildings, several issues have to be solved. Firstly,
we have to collect a representative number of buildings to-
gether with their CGA grammars. We also need to define
semantic rules for CGA creation in order to obtain such sets
and hierarchies of rules that are comparable, where it is nec-
cessary to define the smallest detail that is to be generated.
Another point is to specify a metric for comparison of differ-
ences in numerically measurable quantities (sizes, counts).
The last issue is a proper definition of a metric that will allow
us to measure differences in structures of CGA grammars.

5. Conclusion

We introduced a new idea, which enables the creation of ar-
chitectural style according to formal rules and using it for
newly generated virtual buildings. We have presented an ex-
ample on two residence-type historical buildings in Prague
and an idea of extraction and comparison of rules defining
an architectural style.

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