3D PROCEDURAL RECONSTRUCTION OF URBAN LANDSCAPES FOR THE PURPOSES OF A WEB-BASED HISTORICAL ATLAS

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ABSTRACT:

The "Czech Historical Atlas" project is a part of the NAKI II programme of the Czech Ministry of Culture and aims to create the following two main outputs: a printed atlas of the Czech history in the 20th century and an electronic map portal on the Czech history. This paper is focused on the latter mentioned output and specifically on the design of 3D scenes which should supplement the 2D map content. Currently existing literature is briefly reviewed and the procedural modelling is found to be suitable for the needs of urban landscape reconstruction. Furthermore, available data sources in the Czech republic are discussed and important aspects of modelling are presented.

1. INTRODUCTION

The "Czech Historical Atlas" project is a part of the Program of applied research and development in national and cultural identity (NAKI II) of the Czech Ministry of Culture. Within this project the two collaborating institutions – the Institute of History, Czech Academy of Science and the Department of Geomatics FCE CTU in Prague build on their previous cooperation which resulted in the release of the Academic Atlas of Czech History. This extensive cartographic work was published in print in 2014 and received numerous awards (e.g. Magnesia Litera 2015). However extensive, the printed atlas could not comprise numerous hitherto unprocessed historically important themes, attractive for the general public, especially as regards the 20th century. Therefore, an electronic portal is planned, which ought to open a non-standard access to the outcomes of historical research through electronic historical cartography to the professional as well as non-professional public, pupils and students in a way that has not been achieved in the Czech Republic yet.

The planned "Electronic map portal on the Czech history within international circumstances" will be designed as a web map application using the most up to date GIS technologies, i.e. resulting maps will be published as dynamic map services using web map servers. Moreover, the tools for interactive use of the maps (search, links between texts and pictures, combining of layers, export function, etc.) will be included. Because of its electronic web nature, the portal, unlike the printed form, will not be limited to 2D representation of the areas of interest. On the contrary, 3D models can be created, which will suitably complement the 2D map application. Such models will be published as 3D web scenes and will be useful e.g. for capturing changes of landscapes in time.

2. RELATED WORK

3D scenes as a part of a web-based historical atlas are rather innovative approach in cartography. However, the knowledge from historical 3D modelling in general can also be used in our case. The creation of simpler 3D models of historic buildings for visualisation purposes is a well-established field of study. Nevertheless, the visualisation of larger urban landscapes is a more difficult issue. After the examination of currently available literature, we find out that this problem is solved mainly in the field of archaeology while the procedural modelling approach is mostly applied.

The procedural modelling of architecture or urban landscapes is based on production systems such as Chomsky grammars. These grammars were defined by American linguist Noam Chomsky to describe syntax of formal languages. A formal language specifying grammar is formed by symbols, alphabet and constraining rules. The alphabet is a non empty finite set of symbols from which strings can be created based on the rules. Thus, a formal language is an arbitrary subset of all strings over an alphabet (Melichar, 2003). Whereas Chomsky grammars use sets of symbols to create strings according to specified rules, there also exist *shape* grammars which operate with sets of basic shapes from which more complex geometric objects are generated. Shape grammars were first described by George Stiny and James Gips in 1971. A shape grammar consists of a finite set of rules and finite set of shapes, one of which is specified as the initial shape (Stiny and Gips, 1972).
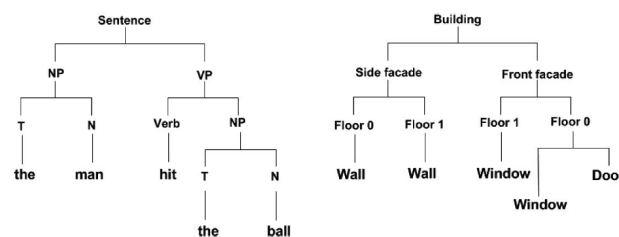

Figure 1. Chomsky context-free grammar concept and its adaptation for buildings according to Stiny and Müller

The CGA (Computer Generated Architecture) grammar, which was primarily designed for the purposes of architectural modelling, was first described by Parish and Müller (2001). In their article it was depicted how *simple* 3D models of cities can be created based on 2D polygons. Wonka et al. (2003), on the other hand, presented a method for the reconstruction of geometrical *details*. A combination of both methods was first described in (Müller et al., 2006). Moreover, the last paper also contains the description of CGA implementation in a software called City Engine.

As mentioned before the creation of historical landscape models is common in archaeology. Haegler et al. (2009) presented several examples of employing the procedural modelling for the purposes of archaeological sites reconstruction. The two most relevant examples are the model of ancient Pompeii and the Rome Reborn project, which depicts Rome in the 4th century AD. In both cases the CGA grammar and the City Engine application were used to model common urban areas and classical CAD software was utilised to portray significant monuments. Similar examples can also be found in (Watson et al., 2008). Last, Calogero et al. (2013) described the usage of City Engine for the purpose of reconstruction of three façade designs for the east wing of the Louvre. Although they model only one building without extensive reconstruction of conurbation, their work is an interesting representation of the procedural modelling possibilities.

It is worth mentioning that there also exist several efforts that use their own original approaches to the procedural modelling. One example is the work by Rodrigues et al. (2014). In their paper they presented reconstruction of Roman houses in the heritage site of Conimbriga, Portugal. Furthermore, Laycock et al. (2008) also described the use of an original unspecified procedural modelling approach. This work is especially interesting because they model urban areas in multiple periods of time which is also very important for our purposes. Last but not least, the virtual landscape models can also be created without procedural modelling, i.e. in a classical 3D CAD software. An example can be found in (Hájek et al., 2013) where the creation of the model of the Terezín town in the Czech Republic is presented.

3. METHODS OF 3D RECONSTRUCTION

All 3D scenes which aim to authentically depict landscape appearance have to use a digital terrain model as a foundation. Basically, there are two options – we can rely on available, more or less up to date, terrain models or we can reconstruct terrain using information contained in old maps.

In the Czech Republic the Digital Terrain Model of the Czech Republic of the 4th or 5th generation (DMR4G or DMR5G) can be used. This terrain model is provided by the Czech Office for Surveying, Mapping and Cadastre. DMR is a bare-earth representation, which describes terrain surface as the heights of discrete points in a regular grid with total standard error of 0.3 – 1 m (DMR4G) or in TIN with total standard error of 0.18 – 0.3 m (DMR5G) (ČÚZK, 2016). These terrain models depict, of course, the present state of landscape. Therefore, they are unsuitable for areas which have changed significantly throughout the ages (mining areas. . .) but they can be used, e.g., to model the development of conurbation in time where no significant changes in terrain relief are expected.

To study the changes of terrain relief in time, on the other hand, an archival data source, i.e. an old map, is necessary. In the Czech Republic the State Derived Map in the scale of 1 : 5000 is often utilised. The first edition of this map was published in the 1950s and contains contour lines which can be vectorised and further used for the modelling purposes. This is a very good solution for the areas which have changed drastically. However, it must be taken into account that the accuracy of altimetry in these maps is much lower than in the contemporary data sources.

After the preparation of the terrain model, we can proceed to modelling buildings and other details. Although several efforts use the classical modelling approach and employ a less or more advanced CAD system, we rather recommend using the procedural modelling. Classical CAD software such as SketchUp can be used to model landmark buildings and historic monuments whose reconstruction in a procedural modelling software would be inefficient.

4. PROCEDURAL MODELLING

The aforementioned terrain models serve as a backdrop and also as a basis for placing buildings in correct heights while a georeferenced old map can be used as a texture. Moreover, after vectorisation of the map we can also utilise resulting building footprints which are crucial for application of procedural rules. In the Czech Republic the Imperial Imprints of the Stable Cadastre from the years 1826 – 1843 or the aforementioned State Derived Map from the early 1950s can be considered as examples. This way, a semi photo-realistic model can be created based on the data that would anyway be processed within the creation of the 2D web mapping application (see figure 2).

Figure 2. Semi-photorealistic 3D scene based on an old map

Although the mentioned data sources are very important for the result and have to be preprocessed thoroughly, the key point is to design an appropriate set of procedural rules. In our case the situation is quite difficult because we have to prepare rule files which will be applicable to various regions of the Czech Republic. This would, of course, be impossible in a high level of detail because architectural styles vary from region to region. Nevertheless, as we plan to create rather medium detailed models of buildings and model possible significant landmarks manually, we try to produce one fundamental rule file. This rule file is designed to be easy extensible so that different textures, appropriate to particular region, can be added. Also all attributes are designed to

be changeable and the results can be manually adjusted to correspond to archival photographs or drawings (e.g. textures can be changed or different roof types can be chosen).

The resulting models will be available as 3D web scenes based on the latest web technologies, i.e. HTML5 and WebGL. This will make them easy accessible to general public via web browser without any additional plug-ins.

5. CONCLUSION

In this article we introduced the "Czech Historical Atlas" project which aims to develop a web mapping application covering important historical themes from the Czech Republic. In addition to the classical map application we plan to design several 3D scenes to suitably complement the 2D content. In the case of reconstructing urban areas the procedural modelling seems to be the right solution for efficient 3D modelling.

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