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Original article

Rapid reconstruction of historical urban landscape: The surroundings of Czech chateaux and castles

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ABSTRACT

Modern digital techniques of contemporary cartography allow us to study changes in the landscape character with the use of tools primarily designed for geomatics science. Old maps and plans can be scanned, georeferenced and vectorised and historical photographs can be geocoded in the GIS environment, and thus experienced users can get an idea about the landscape character throughout history from these data sources. However, a lot of users from the general public are not familiar with the language of maps, especially the old ones, and are not able to understand the landscape appearance from 2D datasets only. For that reason, 3D modelling can be very beneficial because 3D models can significantly improve users' experience gained from the portrayed landscape situations. This article presents a complete workflow of landscape model creation based on old maps, plans, drawings and photographs. The described approach employs a combination of GIS techniques, 3D CAD software and procedural modelling tools and aims to maximally exploit datasets which are processed for the purposes of a classical 2D web mapping application. The main goal of this research is not to create highly-precise models, but rather to provide simple though credible visualisations, from which even less-experienced users could identify the urban landscape character in history and its changes in time.

1. Research aims

The main goal of our research is to develop a comprehensive workflow suitable for the creation of information-rich 3D visualisations of Czech urban landscapes. As a basis, we use old maps, plans and drawings that have been previously pre-processed using geomatics skills, i.e. they have been digitised, georeferenced and vectorised. The 3D visualisations should mainly serve for presentation and dissemination purposes and they ought to be maximally simple and time-effective to produce. Therefore, we utilise the procedural modelling approach for the reconstruction of common urban areas, and only landmark buildings (in our case mainly chateaux or castles) are modelled using classical CAD software. The resulting 3D scenes are supplemented with metadata originating in 2D GIS layers. Thus, models of all historically significant buildings can be queried for attributes. As procedural modelling facilitates rapid 3D reconstruction of landscape, multiple models can be created for multiple time periods and users can also study the development of urban areas in time which is more intuitive in 3D. Finally, historical and up-to-date photographs are added as "billboards" to the 3D scenes enabling further investigation of the landscape appearance and its changes in time.

2. Introduction

2.1. Historical photographical material – the project

The workflow described in this article is at present deployed mainly for the purposes of the "Historical photographical material" project of the Czech Ministry of Culture. This project intends to collect, process and visualise various old maps, plans, pictorial, photographic and textual documents related to 60 chateaux and castles formerly in the property of noble families and at present owned by the Czech Republic and administrated by the National Heritage Institute (NPU). In this way, the general public will be acquainted with the history of selected domains and their development from the beginning of the 19th century to the mid-20th century.

The essential thing is that not only the chateaux or castles themselves, but also wider surroundings of the manor houses are considered, which enables us to depict the economic and cultural background of the whole domain. The result of our effort will be a web mapping application which consolidates all the heterogeneous data sources found and makes the outcomes of extensive archival

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and geomatics skills accessible to the general public in a comprehensive and understandable way. For the most interesting objects, classical 2D application will be supplemented by 3D web scenes portraying the state of landscape in the past. The creation of these three-dimensional scenes is the main topic of this article.

To facilitate the collection and processing of the vast amount of data sources, not only the academics but also selected undergraduate students are involved in our project. The results of this project can then serve as a basis for their theses and they can benefit from engaging in a real-world research project in general. Involving students in the project means that understandable workflows have to be developed to be adaptable and applicable for less experienced users without reducing the quality of outputs. This applies especially to the pre-processing of data for the purposes of 2D application (data collection, georeferencing, vectorisation, etc.).

2.2. Background and related work

In our research, we have worked with the premise that 3D scenes can be more legible than plain 2D visualisations, especially for users inexperienced in cartography. This assumption is based not only on subjective opinions of application testers, but it is also supported with serious research using modern scientific methods (e.g. eye-tracking [1]). Nevertheless, highly detailed 3D visualisations of urban landscape can be in the final consequence confusing due to high cognitive load on users who are focused on geometrical details and are not able to perceive the wider context of the landscape [2]. Moreover the creation of such splendid scenes is very time consuming and extensive knowledge of the appearance of all real world objects in all modelled time periods is necessary to develop credible visualisation. For this reason, we decided to model rather semi-photorealistic scenes where only the most important buildings, i.e. mainly chateaux and castles would be modelled in high detail.

Modellers who aim to reconstruct urban landscape can basically choose from two options. First, they can model all buildings point by point in a simple CAD software (such as Trimble SketchUp or Bentley MicroStation). This is a well-established approach in 3D cartography adopted e.g. by [3–7] and many others. However, this method is highly time consuming and therefore, it is advantageous to employ a more automated approach. Hence, the second option is constituted by procedural modelling, which can be used in various fields of study, e.g. in modelling of textures, plants, terrain, buildings, urban areas, road networks, rivers or in art creation. A comprehensive review of contemporary techniques used in procedural modelling can be found in the paper by Smelik et al. [8]. They consider *shape grammars* to be "the most developed, used and compact method for building representation" although these tools have in general several limitations such as the inability to control the results interactively and directly in 3D scenes [9].

The first appearance of the shape grammars term can be traced back to 1971 when it was first mentioned in the article by Stiny and Gips [10]. The basic principle of shape grammars lies in the progressive refinement of basic shapes according to specified rules and the creation of more complex geometries is analogous to the formation of strings from symbols, described in the field of formal languages. This principle is also used in the computer generated architecture (CGA) grammar, which was primarily developed to serve as a tool for rapid architectural modelling. The origins of this tool were described in the articles by Parish and Müller [11] (creation of *simple* 3D city models based on 2D polygons), Wonka et al. [12] (reconstruction of geometrical *details*) and finally Müller et al. [13] (combination of methods, implementation in a software called CityEngine). Recently, a new derivation of this grammar, called CGA++, was presented in [14].

Although CityEngine was originally designed for movie and gaming industry [13], it has also been employed for the tasks of virtual reconstruction of cultural heritage. Examples of this approach can be found in the articles by Haegler et al., Watson et al. or Calogero et al. [15–17] whereas the first two papers mainly deal with models of large ancient cities (Rome, Pompeii) on the basis of archaeological excavations and the last effort tries to reconstruct various unrealised designs of one particular building (Louvre). The usage of CityEngine is not necessarily limited to the exterior of buildings but can also be utilised to model indoor spaces [18]. Furthermore, another researchers experiment with the application of different approaches to procedural modelling. Examples can be found in Rodrigues et al. [19] (Roman houses in Conimbriga) or Quattrinni and Baleani [20] (Palladian architecture) although they modelled individual building complexes rather than whole conurbations. Laycock et al. [21] dealt with the reconstruction of urban areas based on historical map sources while they experimented with the automated extraction of footprints of old maps [22]. An effort to depict development in time is presented in the scale of one building complex. Moreover, Belloti et al. [23] work with the premise that for users' experience it is not necessary to model all buildings in a town or city individually but it is more important to portray the general appearance of conurbation based on "architectural likelihood" which expresses the probability of occurrence of various architectural styles in a particular settlement. Last but not least, Perrin et al. [24], already in the year 2000, experimented with the procedural reconstruction of landscapes primarily for the purposes of urban planning while they tried to predict the appearance of landscape in the future (vegetation growth, development of buildings).

In our work, we would like to combine knowledge from aforementioned approaches to 3D reconstruction of landscape. Therefore, we would like to extract the information contained in old maps, mix procedural and CAD modelling and depict the historical appearance of conurbations and their changes in time. The concept of our workflow was briefly proposed in [25]. Hereafter, we would like to provide a more in-depth explanation and present several types of our results.

3. Materials and methodology

3.1. Data sources

To collect as many old maps, plans and historical photographs as possible, an extensive archival survey was carried out. In order to assemble available maps and plans, various archives in the Czech Republic were searched, namely: Central Archive of Surveying and Cadastre, State Regional Archives, State District Archives, archives of the National Heritage Institute. Moreover, other highly valuable data sources can be found in the collections belonging to particular manor houses and also in private collections.

The most common data sources for our purposes are archival documents from the Central Archive of Surveying and Cadastre. From this archive, we have obtained former cadastral maps and maps which were acquired through their derivation. To the most appealing data sources that we process and utilise belong certainly the coloured Imperial Imprints of the Stable Cadastre. The corresponding land registry was built on the basis of the Francis I patent of 1817 and it was assumed to be "stable", i.e. definitive for the whole Habsburg monarchy. The mapping of the Stable Cadastre was executed between the years 1826 and 1843 in a scale of 1:2880. While this map series gives us an overview of the state of landscape in the first half of the 19th century, we also use a set of newer discarded (i.e. replaced by a new and updated map) cadastral maps that depicts the same situation at the end of the 19th century (or

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