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# Two and three-dimensional web presentation of Czech chateaux and manors

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ABSTRACT: Chateaux and castles are an important part of cultural heritage in the Czech Republic. The aim of this project is to develop a public web mapping application capturing the changes of manors and surrounding landscape during the last two centuries. This mapping application will be based on digitized and georeferenced old maps and various plans as well as both historical and up to date photographs. The application will allow users to compare various rasters, vector layers and photos from different time periods. Two-dimensional web mapping application will be also supplemented with a 3D web scene based on procedural modelling rules. The procedural modelling approach provides a quick way to create 3D models of buildings within a manor from 2D vector layers. Rules can be then continuously refined or even high detailed non-procedural models can be added to depict the most significant buildings (i.e. chateaux, castles or churches).

## 1 INTRODUCTION

The project is focused on historical photographs and old maps of castles and chateaux and their publication together within the web mapping application. The project deals with 60 chateaux and castles formerly in property of noble families and at present time owned by the Czech Republic and administrated by the National Heritage Institute (NPU). Old maps along with historic photographs, views and text documents can offer us new views into the history of castles, manors and aristocratic families using online technologies, web mapping and 3D modelling.

The focus is put on the chateau itself, its subsidiary buildings, gardens, parks, but also wider surroundings integrating economic and cultural background of the whole domain. Various old maps and plans are collected and processed. Floor and building plans show the castle interior. The coloured Imperial Imprints of maps of the Stable Cadastre, other cadastral maps and The State Derived Map provide a continuous base map depicting the castle area and the closest surroundings. Maps of domains and Maps of Military Mapping Surveys illustrate complete manor and its economy. Much information recorded only in text documents is collected via an archival survey. Important objects on maps as well as objects recognized by the archival survey are entered into the vector data model. The chateau area and its close surroundings are vectorised fully allowing a comparison of land-use and area development in different time.

Historic photographs of chateau, subsidiary buildings, gardens, etc. are collected, localized and possibly completed by present photo for comparison of state. Above mentioned maps, plans and vector data compose a frame for localized photographs publication within the web mapping application.

New approach for old maps and photo presentations brings the 3D modelling and visualization. The reconstruction of the historic landscape and the look of a chateau and its close surroundings can be created using old maps, the present digital terrain model and available historic photographs.

## 2 TWO-DIMENSIONAL DATA PROCESSING

### 2.1 *Georeferencing*

Selected old maps and plans suitable for the 2D processing should be digitized first. Raster digital data as an output of scanning must be georeferenced to be properly used in geographical information systems. There are a lot of methods of georeferencing, which can be divided into two groups (Cajthaml 2013). Global transformation methods use a set of ground control points to compute the transformation key. In the case of old maps affine or second order polynomial transformations are the most usable. On the other hand local transformation methods transform the image to be non-residual on the ground control points. There is no global transformation key and the image can be distorted to fit onto these points. For different data sources different transformation methods were chosen during our project. For older mappings either second order polynomials or local methods were used; for high-quality maps like 2nd or 3rd Military Mapping Surveys or State Derivated Maps affine or projective transformation using corner points were used.

A very important part of the whole georeferencing process is the estimation of the quality of the outputs. Within global transformation methods standard errors of position can be computed. For other methods the statistical testing of ground control points is highly recommended for the quality assessment.

### 2.2 *Vectorization*

The project is focused on buildings nearby castles' or chateaux' main buildings or buildings and areas somehow connected with them. Therefore, close surroundings of castles on selected maps are vectorised completely allowing a comparison of the land-use in different periods of time and castle area development. Vector models of maps of the Stable Cadastre, other old cadastral maps, State Derivated Maps and present cadastral data bring information about situation from the mid 19th century up to now. Vectorised polygons representing buildings then serve as a basis for procedural modelling.

Important economic and cultural objects on maps of domains, as well as objects recognized by archival survey are entered into the vector data model also. This allows broader view to the domain area and its economy. Old and present photographs are localized and stored as point layers including attributes of photograph description, owner, orientation angle, etc.

### 2.3 *2D web mapping application*

The common way of communicating spatial relationships is maps and plans, which represent two dimensional surface. Modern technologies enable interaction with maps in an online environment in the form of web mapping applications. The application created in this project serves three main purposes.

First, it offers spatial bookmarks (filters) of all studied objects enabling quick access to specific chateau or castle. The left panel with castle thumbnails gallery is connected with the map and the spatial extent of the map limits the display of thumbnails.

Second, it presents and compares various layers (maps and plans). The application allows overlaying of various rasters as well as vector layers from different times.

Third, it serves as a photograph gallery, which is linked to the map in the same way as castle thumbnails. There are historical photographs compared to up to date photographs. Each photograph is represented by a special cartographic point symbol, which next to the location also shows the point of view of the camera.

The application will be complemented by text information about chateaux, their surroundings, gardens, economic background of domains and their former owners, aristocratic families.

Example of the web mapping application can be seen in the Figure 1.

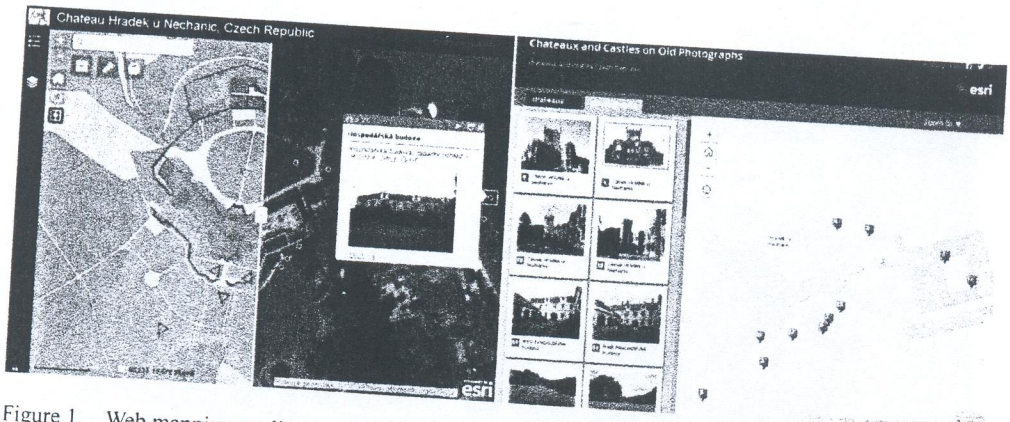


Figure 1. Web mapping application of the Hradek u Nechanic Chateau.

## 3 3D SCENE AS AN ENHANCEMENT OF THE 2D WEB PRESENTATION

### 3.1 *Procedural and non-procedural modelling*

Two-dimensional web mapping application is surely a very efficient way to make the result of this project available to the wide audience. However, the benefit of 3D visualization for presentation purposes is unexceptionable. Basically, there are two ways to model a chateau/castle and its surroundings in 3D: classical modelling in CAD and procedural modelling in suitable software. There exist a lot of efforts dealing with 3D modelling of heritage buildings in CAD software. Description of these can be found, for example, in (Dore & Murphy 2012), (Jedlicka et al. 2013) or (Jedlicka & Hajek 2014).

The latter, namely, the procedural modelling is also well established at present but it is used mainly in the gaming industry and for quick creation of extensive models of modern cities. Basis for these models are prepared sets of suitable rules and two-dimensional GIS layers. Polygon layers with footprints can serve as a foundation for buildings, line layers as centerlines for streets growing algorithms; point layers denote the placement of trees or street furniture. For examples of real landscape modelling see (Edvardsson 2013) or (ESRI 2014).

The goal of the described project is to depict the state of a manor in several different time periods. The same applies to the 3D visualization. Considering available data, it was decided to choose a combination of the two afore mentioned approaches. Because, in most cases, there is available documentation of a castle or a chateau in a particular time period e.g. in the form of floor plans, these can (and should) be modelled in greater detail using standard CAD software. In the same way should be created models of all significant buildings within the chateau/castle complex. On the other hand it is not possible to model all buildings in the surroundings in the same way. This would be highly time consuming, and also there is no existing historical documentation of all objects inside the manor. A lot of buildings do not exist anymore or they were significantly renovated. Some information can be acquired on the basis of old photographs, but mostly the only data source is the old map. Therefore, the surrounding buildings could be produced based on vectorised old maps using procedural modelling approach. Missing information (e. g. the height of buildings) can be chosen randomly or better considering the look and the characteristics of buildings in a given time.

### 3.2 *Technical platform*

Because we use the ESRI platform for the 2D data processing (namely ArcMap), it is a logical step to utilize another application of this vendor for the procedural modelling – City Engine. This program was released in 2008 by the software company Procedural. This company was later acquired by

ESRI and a lot of effort was spent to ensure its compatibility with other ESRI products (Edvardsson 2013). City Engine enables to import 2D and 3D geometry in various formats, ESRI shapefile and feature classes of a file geodatabase are among them. Backwards compatibility is also ensured so after applying procedural rules, resulting models can be exported back to the geodatabase. It was also very important for us that 3D results can be exported to the 3WS file format which is suitable for sharing via ArcGIS Online with the use of HTML5 and WebGL.

There is no doubt that City Engine is a suitable tool for 3D procedural modelling. However, as mentioned in the previous section, models of heritage objects should be created with more detail using classical modelling approach. There exist some tools in City Engine which are designed for accurate polygonal modelling. Although with these tools 3D objects can be created in a very similar way to the SketchUp solution, it is clear that accurate modelling is not the greatest strength of City Engine.

Considering the mentioned the decision was made to use the SketchUp application for heritage buildings creation rather than City Engine. Resulting models can be then imported into a City Engine scene, for example, via OBJ or DAE file formats. SketchUp models are imported as static models. Static models can be further scaled, rotated and translated in the City Engine scene but they cannot be processed with procedural rules (ESRI 2015). On the contrary, two-dimensional building footprints of surrounding buildings originating in file geodatabase classes are imported as shapes so they can serve as a basis for procedural modelling.

At the time of writing this paper ESRI City Engine 2014.1 and Trimble SketchUp 2015 are the most up to date software versions so they are currently used in our project.

### 3.3 *Modelling process*

The first step in creating a 3D scene in City Engine is importing a digital terrain model. We use the aforementioned Digital Terrain Model of the Czech Republic of the 5th generation (DMR 5G). DMR5G is a bare-earth representation which describes terrain surface as heights of discrete points in TIN with total standard error of 0.18 m. This terrain model depicts, of course, the present state of a landscape. Because our goal is to capture historical state of chateau/castle surroundings, this would be unsuitable for areas which have changed significantly during the centuries (e.g. mining areas). However, for most areas this does not represent a serious problem.

The DMR 5G terrain model consists of points with X, Y planar coordinates and an H height value so it has to be interpolated to create a raster file. It is advisable to set a higher spatial granularity of the resulting raster because it will be further clipped together with other map layers. The point spacing of DMR 5G is approximately 3 meters so we use this value for the output cell size. This ensures correct clipping of the terrain and is still not excessively space consuming. The cell size can be also further increased directly in a City Engine scene so the visualization efficiency is also ensured.

The ArcMap application is used for the terrain interpolation and clipping. The terrain is saved to the georeferenced TIFF file and the IDW method seems to give the best interpolation results for our purpose. During the clipping process in ArcMap some pixels which are crossed by a clipping polygon are set to NoData. This would be misinterpreted as zero values in City Engine and the terrain would not be displayed correctly. So it is highly recommended to use rectangular non-rotated polygons and remove NoData values using Raster Calculator or some Matlab scripting.

Having imported the terrain we can also import an old map or other raster which will be used as a texture. This texture will be stretched across the extent of the DTM so it is important to use the same clipping polygon for the terrain and all used textures/maps. In a City Engine scene the georeferencing of a map is not necessary because it is ensured by the terrain model. However, all maps have to be georeferenced in ArcMap for the proper clipping.

Before we start programming procedural rules we have to import basic shapes. Building footprints can be either exported from a geodatabase to a shapefile in ArcMap, and then imported to a City Engine scene, or they can be imported directly from a geodatabase as a feature class. After

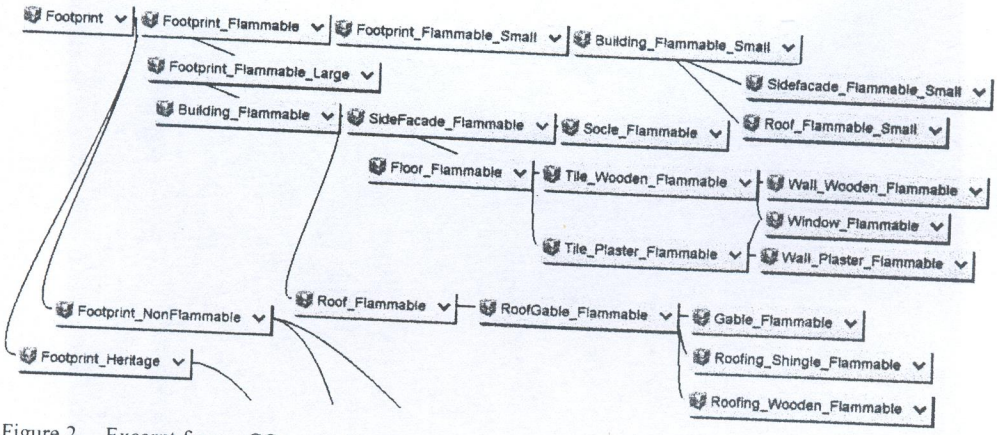


Figure 2. Excerpt from a CGA rule file utilized for modelling based on the Imperial Imprints.

importing footprints aligning shapes to terrain and then terrain to shapes is performed to ensure them to fit together correctly.

Particular procedural modelling in City Engine consists in writing rules in a CGA rule file. Speaking about buildings, these rules usually first separate their footprints depending on building type, usage or material. Footprint attributes originating in corresponding feature class are here the basis. Then, each footprint is extruded to a certain building height. This height can be random or it can be described by another attribute. Furthermore buildings are split into roof surfaces and facades, facades are further split into floors etc. Finally actual roofs are created and textures are placed onto individual partial surfaces.

In the Figure 1 there is an excerpt from the visual representation of a sample CGA rule file. We use this rule file to create a semi-photorealistic 3D scene based on the Imperial Imprints of the Stable Cadastre. The hierarchical structure of the modelling process can be seen very clearly in this figure.

The Imperial Imprints contain information about the material and type of buildings – flammable, non-flammable and significant buildings are distinguished by colour. This information is stored in a geodatabase during vectorization so it can be used in the rule file to separate buildings. Moreover small buildings (with footprint area lesser then a certain set value) have to be filtered. These buildings can only have one storey (i.e. ground floor) and another texture will be placed on them.

Both flammable and non-flammable buildings are split in the similar manner that was mentioned above. The smallest part of any facade is a tile. All tiles are covered with textures as well as roofs and windows. Most buildings have a gable roof which was very common in the 19th century. Basically, there are so far two types of flammable (with and without plaster) and three types of non-flammable building facades. Buildings can have roofs covered by different types of shingles or roof tiles. Types of facades or roofing are chosen with a certain probability and when it is necessary there is also an interactive user input possible in the randomly generated scene. It is evident from the Figure 2 that there are also rules for heritage buildings. Resulting buildings modelled according to this rules are only provisional and they will be further replaced by non-procedural SketchUp models of chateaux or castles.

## 4 CASE STUDY AT THE CHATEAU OF MNICHOVO HRADISTE

Two-dimensional data collection and processing has already been performed in various manors. At this time the work is in various stages of completion. In some manors testing web mapping applications are already prepared for use. Two examples of this web application presenting the Hradek u Nechanic Chateau are depicted afore in the Figure 1.

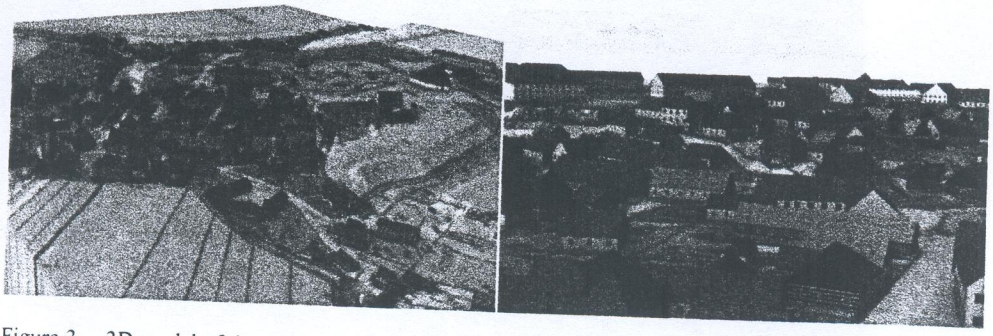

Figure 3. 3D model of the surroundings of the Mnichovo Hradiste Chateau based on the Imperial Imprints of the Stable Cadastre and procedural modelling rules.

Procedural modelling of chateau/castle surroundings is currently being tested on the case of the chateau in Mnichovo Hradiste. The state owned Mnichovo Hradiste Chateau is located in the Central Bohemia Region. It is a baroque manor house which was rebuilt to its present state at the turn of the 18th century. The 3D procedural model of chateau surroundings based on the Imperial Imprints is shown in the Figure 3.

## 5 CONCLUSION

This article introduces a project focused on the web presentation of chateaux and manors in the Czech Republic. Besides the classic way of presenting 2D data via web mapping application, the article shows possibilities of 3D modelling and presentation of this data on the internet. The City Engine software and CGA rules are promising way of modelling 3D scenes. Procedural modelling was tested on the case of the chateau in Mnichovo Hradiste and this case study lead us to use this way in further development of our project. Meanwhile the web mapping application can be seen online at http://gis.fsv.cvut.cz/castles.

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