1 Introduction

The Garden Kingdom of Dessau-Wörlitz is part of the UNESCO world cultural heritage since the year 2000. It came into existence in 1758 due to considerable enlightening reformation efforts by Prince Leopold III Friedrich Franz duke of Anhalt-Dessau (1740-1817). Today’s appearance of the landscape of the Garden Kingdom corresponds ideally to the definition of a “historical cultural landscape” (see REICHHOFF 1996, WEISS 2005). The creative highlights are landscape parks with structures marked by the influence of classicism and neo-Gothicism. They are all effective as a combined work of architecture, gardening and fine arts. 145 km² of the aesthetic change of territory are still preserved to this day.

It was declared as a historical monument in 1979 and is therefore protected (KÜSTER 2010). The landscape is supposed to have the effect on the visitors of being created by nature and not by an artist. Numerous view axes combine the landscape elements and parks visually (TRAUZETTEL et al. 1998).

The federal state of Saxony-Anhalt is obligated to the UNESCO and therefore must process the physiographical, infrastructural and urban situation, as well as undertake the monument preservation of this unique cultural landscape as a whole. Moreover, the state shall develop prospects for further development. The Kulturstiftung DessauWörlitz (federal cultural foundation) serves as a coordinator for conservation, research and maintenance of the cultural world heritage “Garden Kingdom”. One of the most important elements of monument preservation and planning for the specialists of the Kulturstiftung is the “Denkmalrahmenplan” (LDA/KS DESSAUWÖRLITZ 2007). It serves as the fundamental base for this project and was a national, as well as international innovation when it was completed in 2007. Up to this point no such intense acquisition and assessment of a historical cultural landscape, which qualifies for protection, existed in terms of monument conservation.

Today historic gardens are visualized in numerous projects using virtual reality. Examples provide the projects of PAAR & BLAIK (2008) and MORAVCIK & KUBISTA (2008). As early as 1996 a 3D visualization of the Garden “Wörlitzer Anlagen” was generated for the exhibition “Weltbild Wörlitz – Entwurf einer Kulturlandschaft” (see URL1). The constantly growing potential of geovisualization is already being implemented to visualize cultural assets in monument planning (e.g. URL2). To further qualify the results of various planning processes the new media can be used for the Garden Kingdom. The focus of this project is the special support and upgrading of the “Denkmalrahmenplan” of the Garden Kingdom of Dessau-Wörlitz with the integration of virtual reality.

The heterogeneity of the cultural/historical matters and the size of the area require an adaption and further development of the existing range of methods. An entire analysis and presentation of the historical development of the Garden Kingdom based on virtual
landscape scenarios shall be made accessible through the interdisciplinary collaboration of landscape planners, monument preservation experts, geo computer scientists and cartographers.

This article regards itself as a report of progress on important goals, methods and implementations, which are a basis for multi-scale and multi-temporal geovisualization.

2 Motivation and Objectives

In addition to the results of the "Denkmalrahmenplan", the changes in landscape of the Garden Kingdom will be shown from the initial situation at the end of the 18th century up to the present in three dimensional, virtual scenarios. Geographical visualizations are done in different *scale levels*, *time levels* and *levels of details*. They are useful for different target groups. Specialists of the Kulturstiftung shall be supported in their work with the “Denkmalrahmenplan”. The virtual scenarios provide interactive analyses of the view axes and the natural scenery within the park. They provide a way to identify conflict potentials between different matters of regional planning, monument planning and environmental planning and serve to develop alternatives more efficiently. The visualized alternatives include for example conflicts of interest in specialist planning of flood prevention versus the target planning of the protection of historical monuments. Moreover, selected results constitute an important source of information for interested individuals. Once these results are integrated into widely used map services, such as Google Earth, they allow for globally available “virtual excursions” at World Heritage site and may serve the tourist marketing of the area. To finalize, they generate synergies in environmental education, since those visualizations can be used as visitor information systems via the new media.

The acquisition of the landscape takes place on a multi-scale level in several periods. Different scale levels are assigned to different levels of detail (see Table 1 and Figure 1).

<table>
<thead>
<tr>
<th>Visualization</th>
<th>Scale</th>
<th>Time Levels</th>
<th>Level of Detail¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vis1: Overview of visualization Garden Kingdom</td>
<td>1:25.000</td>
<td>1820, present</td>
<td>LoD1</td>
</tr>
<tr>
<td>Vis2: Garden with surrounding cultivated landscape areas</td>
<td>1:10.000</td>
<td>1800, present</td>
<td>LoD2</td>
</tr>
<tr>
<td>Vis3: Visualization of the garden, based on results of the “Denkmalrahmenplan”</td>
<td>1:2.000</td>
<td>1800, 1830, present</td>
<td>LoD3</td>
</tr>
</tbody>
</table>

Table 1: Visualization content, map and time scales and level of detail

Furthermore, theoretical approaches can be derived from the developed cartographical methods and the applied principles for the processing of historical and topographical maps (GLÄSSER et al. 2010). These recommendations for action shall contribute to the production of scientific guidelines for the development of multi-temporal and multi-scale geovisualizations of cultural assets.

¹ See Level-of-Detail-convention for Building Quality Levels, DÖLLNER & BUCHOLZ 2005.
3 Data and Methods

Comprehensive data exists for the analysis of historical stages (i.e. recent and historical cartography, status plans, pictures, documents). Spatial reconstruction of the cultural landscape is done based on historical and recent cartography, literature and knowledge of the local experts. The creation of the visualization combines the usual processing of data. Examples include the geodetic adaption of base data, the multi-temporal evaluation of maps, of geo-objects and the presentation of the chosen time steps in virtual scenarios, based on the requirements of the “Denkmalrahmenplan”.

3.1 Data Basis and Processing

According to the planned scale levels (see Table 1), recent and historical cartography was researched. As a result, the data in the grey areas of Table 2 meet the requirements of the area-wide coverage and the informational content of Vis1, Vis2 and Vis3. To adapt historical maps to the actual geodetic reference system it is necessary to use the officially available geo base data. The key challenge is the spatial processing and homogenization of all data (DEITTE et al. 2010).

3.2 Digital Elevation Model (DEM) and Digital Surface Model (DSM)

In order to map ground surface in virtual scenarios, ATKIS®-DEM40 is primary used for the medium scale level, while ATKIS®-DEM1 is used for the high scale level (see Table 2). These models represent the present shape of the relief. A range of differences in former time steps to the present geo-morphological situation can be determined from historical documents. It is necessary to adapt the models to describe the historical geo-morphological situation. Primary examples are the changing development of the stream courses of the rivers Elbe and Mulde, as well as changes in the dike system. Numerous GIS-based functions and algorithms served to determine the approximation of the relief to historical situations. Therefore, Focal Mean and Lee Filter processes, linear and inverse distance weighting interpolation methods were used, which took into account the special circum-

Fig. 1: LoD- Steps for the acquisition of the individual historic structures. Example used is the Luisium (left: Box model LoD1; middle: non-photorealistic facade model medium level of detail LoD2; right: non-photorealistic facade model high level of detail LoD3).
stances of the flat meadow grounds (Lee 1980, Hengl et. al. 2004, Florinsky, 2012). In terms of software, editing took place mainly in Esri ArcGIS/ArcInfo.

<table>
<thead>
<tr>
<th>Vis1</th>
<th>Deckersches Kartenwerk³</th>
<th>1:25.000</th>
<th>A</th>
<th>Land Use 1816/1821; Decker, 1816, Zögener, 1981</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Digital Topographical Map 25 (DTK25)</td>
<td>1:25.000</td>
<td>B</td>
<td>Topography (2010)</td>
</tr>
<tr>
<td></td>
<td>ATKIS®-DEM 40 about 1:50.000</td>
<td>B</td>
<td>Relief, Digital Elevation Model with geometrical resolution 40 × 40 meters (2007)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Digital Topographical Map 10 (DTK10)</td>
<td>1:10.000</td>
<td>B</td>
<td>Topography (2010)</td>
</tr>
<tr>
<td></td>
<td>ATKIS®-DLM 1:10.000</td>
<td>B</td>
<td>Land Use from Digital Landscape Model (2008)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Digital Ortho Photos (DOP20)</td>
<td>1:10.000</td>
<td>B</td>
<td>True color Aerial Photos with 20 cm spatial resolution (2010)</td>
</tr>
<tr>
<td></td>
<td>Map Eyserbeck not specified</td>
<td>C</td>
<td>Map of the garden “Luisium” about 1790</td>
<td></td>
</tr>
<tr>
<td></td>
<td>„Charte der Feldmarken Naundorf und Jonitz“ not specified</td>
<td>C</td>
<td>Kretzschmar, 1828</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ATKIS®-DEM1, DSM1 about 1:1.000</td>
<td>B</td>
<td>Relief, Digital Elevation Model and Digital Surface Model with high resolution 1 × 1 meters (2010)</td>
<td></td>
</tr>
</tbody>
</table>

| Table 2: Primary spatial information, scales and sources of the visualization products |

3.3 Scan Image and Referencing

According to KRESSNER (2008), if not already digitally available, analog base data has to be scanned in high resolution (600 dpi), followed by an image correction using image editing programs. In order to provide a spatial-related extraction of information, the cartography has to be georeferenced. A simple realization using a few points of reference can be guaranteed by recent plans, which do not have a geo-relation yet (analog maps of the “Denkmalrahmenplan”, see Table 1), due to their high accuracy. Object related methods for referencing are mainly used for historical data material. In the park sector, historical buildings served as the primary reference objects. However, in the area of open landscapes, the georeferencing was hindered. The geodetic quality of those sectors is limited and lacked reference objects. Considering the size of the region, the implementation of a simple reference method using the first polynomial function suited the need of “Deckersches Kartenwerk”. The area has been adapted to the recent geo base data of the national survey using about 50 points of reference (see Table 2). Despite the numerous existing reference objects, the maps of Eyserbeck and Kretzschmar (1828) feature huge differences according to the preservation of the position of the geo-objects. Sectors featuring high spatial accuracy, as well as high biases, can be identified (see Figure 2).

Fig. 2: Georeferenced maps with different spatial precisions of the geoobjects – left: Subset of Map Eyserbeck, right: Subset of “Charte der Feldmarken Naundorf und Jonitz”

3.4 Editing and Digitizing

Once all basic data has been converted into the same reference system (DHDN 4), the map content was digitized (QuantumGIS). Due to the already mentioned differences in quality (recent vs. historical material), the corresponding information for land allocation was not always transferred directly. A knowledge based adaption of the topology of the geo-objects had to be done at this point.

3.5 3D Objects and Texturing

The geometry of construction and vegetation was taken from the vectorized information for land allocation, which served as a base for the modeling of 3D objects. The derivation of
the heights, according to the resolution of detail, ranged between generalized and accurate. To fit Vis1, the floor plans of the buildings had been extruded within Esri ArcGIS Desktop with randomized heights as a simple block model, using a random function within a Visual Basic Script (urban section 5 to 15 meter, rural sector 4 to 8 meter). Based on the point and polygon geometry of the vegetation, self-made trees modeled with Autodesk 3ds Max were integrated. Finally, the creation of VR-scenarios was done with Autodesk LandXPlorer. The 3D objects, which are part of the Vis3 and have a scale of 1:2000, have been created with 3ds Max, based on pictures of facades and existing building plans. In order to texturize historical buildings, a technique was used, which conveyed indecisiveness and uncertainty. Therefore, textures had been generated in a non-photorealistic style and implemented in 3ds Max (see DÖLLNER & BUCHHOLZ 2005 and MAASS & DÖLLNER 2006). Additionally, the method of “texture baking” was employed. It allowed in a gentle way to integrate information about lighting in textures. Thus, they do not need to be rendered in real time which saved system resources (see MURDOCK 2011). Vis3 vegetation, particularly trees, was modeled in the ‘TreeCreator’, a plug-in for the Unity game engine. This plug-in is generating procedural tree models (DEUSSEN 2003). The “Denkmalrahmenplan” itself has three different signatures for trees (broad-leafed tree, conifer, fruit tree). Referring to this configuration these types of trees are used in the Vis3 as well. The models of Vis2 had been derived from the generated LoD3-Objects of the Vis3, by reducing the resolution of detail. An example would be a simple rectangle rotating about 90 degrees to simulate a 3D effect for plants (MUHAR 2001). All 3D objects were then integrated into the previously prepared cartographic ground plane. In case of the VIS1, this was the “Deckersches Kartenwerk”, subordinated by DEM40. A 3D-reconstruction of a historical landscape situation, using a historical map as a base, led to a high degree of authenticity and had already been successfully employed in urban sectors (DETTE et. al 2010). In order to visualize details, adequate textures had been chosen and implemented from the libraries of Autodesk 3ds Max to match the extracted information for land allocation.

3.6 Interface and Presentation

To suit the specific standards of the experts, an independent interface for planning processes of the “Denkmalrahmenplan” was necessary to develop a more specialized user interface (see SCHROTH et al. 2011). Therefore Unity game engine was used. The user interface accounts for a systematic integration of navigation functions, lighting situations (see GOLDSTONE 2009, GREENWOOD et al 2009) and particular menus with texts, captions, clues about view axes and further expert information. Using the fbx-format, 3D-objects were imported into Unity in order to create a presentation of data for experts. However, it is reasonable to employ a globally available and familiar interface to reach interested individuals. Reduced objects can be exported from 3ds Max to Google SketchUp using the Collada format. The export of the virtual scenarios in kmz files eventually allows visualization with Google Earth. Selected scenarios will be uploaded to the 3D Warehouse and will thus be integrated into Google Earth by default. Figure 3 outlines the characterized workflow of data and methods.
Fig. 3: Components of the geovisualization infrastructure and the related workflow of data processing

4 Results

This chapter presents preliminary results of the work in progress. Selected examples will be exemplary for the described peculiarities within the workflow. The first example represents an extract of the VIS1. The DGM40 overlaid with the “Deckersches Kartenwerk” serves as a base for this. The attached buildings represent the city of Dessau in the year of 1820. About 180,000 cartographic signatures of trees are integrated into this particular extract, which stresses especially the linear elements of the alleys. Thus, the relationship between urban and rural sectors, which existed at that time, can be experienced more clearly.

Figure 5 represents preliminary results of high resolution 3D building models within the LoD3 system. The left side shows a building (i.e. “Schlangenhaus”) created with 3ds Max. On the right side is a final import into Unity (i.e. “Luisium”) and a corresponding tree model. In order to visualize the models, a lighting system and a skybox system had been integrated. Moreover, an egocentric control system had been generated and evaluated in terms of suitability.

Within the Garden Kingdom, there are, as already mentioned, numerous axes of view among the architectural highlights of the landscape. Figure 6 describes the visual axis through a line of trees to the “Schlangenhaus”. The mapped example was taken from the visualization which had been created for the public within Google Earth.
**Fig. 4:** Visualization of Dessau with surrounding cultivated landscape areas (LoD1, LandXplorer)

**Fig. 5:** 3D model of the “Schlangenhaus” and the “Luisium” (LoD3, 3ds Max, Unity3D)

**Fig. 6:** Axe of view to the “Schlangenhaus” (LoD3, Google Earth)
5 Outlook

In order to support the planning of the “Denkmalrahmenplan” multitemporal and multiscale geographic visualizations are in development as part of an interdisciplinary project. They are designed to support the experts of the Kulturstiftung DessauWörlitz in planning processes for maintenance and further development of the world cultural heritage “Garden Kingdom”. The illustration of historical situations in virtual reality will help to qualify the target state, which was defined during the planning process. This approach constitutes a novelty within the “Denkmalrahmenplan”. Additionally, the created 3D scenarios can be used for further sectoral planning and environmental education respectively. Due to the integration of selected extracts into Google 3D Warehouse, detailed information on planned reconstruction measures was made retrievable for the general public.

In the first instance, the final implementation of all VR modules is the primary concern. Furthermore, based on the generated workflow, the cartographic development process to support the “Denkmalrahmenplan” will be put into theory, followed by an extensive evaluation and a field trial. Recommendations for action are to be derived from the generated methods, which add to automation of the development process of geovisualization of historical, cultural landscapes.

6 Acknowledgements

The interdisciplinary research in this project is the result of collaboration of landscape planners, monument preservation experts, geo computer scientists and cartographers. We are grateful for the help and contributions by many experts. We especially thank Dr. Thomas Weiss, Ludwig Trauzettel and Sebastian Doil of the Kulturstiftung DessauWörlitz for their support.

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