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VIRTUAL HISTORICAL LANDSCAPES

8.1   INTRODUCTION

Landscapes are changing continuously due to human interaction with the natural environment. Historical maps, landscape paintings and drawings enable us to get a visual impression of how a particular landscape looked like in the past. However, our present digital culture would welcome more interactive and richer representations than the flat historical documents on which that we have had to rely so far. Using geographical information systems (GIS) and computer graphics technology, we are able to create 3D virtual reconstructions of historical landscapes, also referred to as *virtual historical landscapes*. These virtual historical landscapes let users experience the historical landscape from different viewpoints by browsing and navigating through 3D virtual environments. Such products would be interesting for edutainment projects in cultural heritage and for historical games; they could provide a global, visual context for a more detailed presentation of historical and archaeological research data. They would allow us, so to speak, "to step through a landscape painting" into the world of the past, as Alice in Wonderland did through the looking glass.

The historical sources and traces left in the landscape itself do not provide enough ready to use data for input into 3D modelling software. The type of 3D model discussed in this chapter differs fundamentally from more accurate and small-scale 3D models as produced by archaeologists and other geo-historical disciplines. The objective of our project is to design computer-

based methods for the creation of a realistic virtual historical landscape. This landscape will contain the characteristic features of the landscape in question, as we perceive them in the mainly visual historical sources left, like old maps, paintings and drawings. This implies, that the 3D model may not be accurate and complete in detail, but that the overall landscape structure and furnishing are based on sound arguments and have been constructed in a semi-automatic way. The construction process should be made affordable for the purposes mentioned above. It is expected that such virtual historical landscapes are an effective context to present landscape history and cultural heritage to the wider public. In addition, they may also support the presentation of historical and archaeological research. For that reason, both expert and lay users from the fields of historical geography, landscape archaeology, museums, education and so forth should experience virtual historical landscapes as realistic and plausible. However, up to now there is little knowledge of what users perceive as realistic. Therefore, we need to find decisive variables that influence the user experience in order to define appropriate visualisation requirements for virtual historical landscapes. However, before this kind of usability testing can be conducted, the methodological problem of creating a virtual historical landscape model in a semi-automatic way has to be solved, which will be discussed in this paper.

The 3D virtual reconstruction of the 17th century rural estate of Palace Honselaarsdijck and its surrounding landscape (near Naaldwijk, the Netherlands) served as a case study. The Palace Honselaarsdijck has completely disappeared and only few traces are left in the current landscape. Using modern technologies of 2D/3D GIS, CAD and computer graphics, information from remaining historical documents are processed and combined with contemporary geographical data to construct a reliable digital representation of the rural estate and its surrounding landscape.

This chapter is organised as follows. First, we provide an overview of related work to virtual landscape and city reconstruction in section 2. Next, we describe methods and techniques that we used to process a collection of historical documents to derive required input data for our 3D modelling software in section 3. Section 4 describes the case study of Honselaarsdijck and deals with the historical and geographical data used to model the terrain and 3D objects of the virtual historical landscape and then render the virtual historical landscape in 3D visualisation software to make it available through a user interface. Finally, we conclude with an outlook in section 5.

8.2 HISTORICAL VIRTUAL LANDSCAPES: "HOW GOOD IS GOOD ENOUGH?"

Virtual landscapes represent a distinct genre in computer graphics (Ervin and Hasbrouck, 2001). The first attempts to create virtual representations of past, present and future land-

scapes go back to the early 80s of last century (Bishop and Lange, 2005). In the 90s, the technology of 3D GIS, CAD and computer graphics matured, and real-world and photo-realistic virtual models of cities and landscapes were developed. Applications of virtual landscapes range from visualisation and communication of spatial planning projects (Appleton and Lovett, 2005; Paar, 2006) to initiatives aimed at the study or experience of a historical city or landscape, e.g. *Walking with Vermeer* (De Boo, 2001) or the reconstruction of city Leusden (Alkhoven, 1993). Today, it is impossible to imagine the presentation of historical or archaeological research without 3D GIS and computer animation technology.

8.2.1   Virtual landscapes in the urban and rural

Virtual historical landscapes enable new approaches for exhibiting historical findings in museums and classrooms, and on the Internet. A well-known example is the *Rome Reborn* project of the University of Virginia. The project goal is to build 3D digital models showing the urban development of ancient Rome from the first settlement in the late Bronze Age (ca. 1000 B.C.) to the depopulation of the city in the early Middle Ages (ca. 550 A.D.). A Google Earth layer containing a 3D model of Rome in 320 A.D. shows more than 7,000 buildings. See figure 1.

Predominantly, these virtual reconstructions concern very highly detailed photo-realistic reconstructions of archaeological site excavations or heritage preservations using 3D capturing devices. However, Drettakis et al. (2007) observe that representations of historical situations that are too realistic are experienced by users as unbelievable or unconvincing, because (photo) realistic images pretend to be the actual truth even though the actual historical situations are uncertain or unknown. Moreover, photo-realistic and highly detailed modelling is a very laborious and skilful work, made more difficult by lack of sufficient historical data. Because of the resulting uncertainties about the precise situation in the past, the designer needs to be content with a good approximation of the historical situation. The virtual historical landscape resulting from this approximation may not lend itself to a true photorealistic representation. However, it enables more efficient realisation of virtual reconstructions of cities and landscapes, if the objective of presenting actual historical truth is somewhat loosened.

For the Rome Reborn project, a combination of detailed reconstructions of primary buildings from archaeological excavations and research, together with the procedural modelling of secondary buildings is applied (Dylla et al., 2010). Using sophisticated computer algorithms, procedural modelling creates complex city structures in an automatic way through matching objects (such as roofs, windows, and walls) from a dedicated object library along fixed (road) networks (Laycock and Drinkwater, 2008).
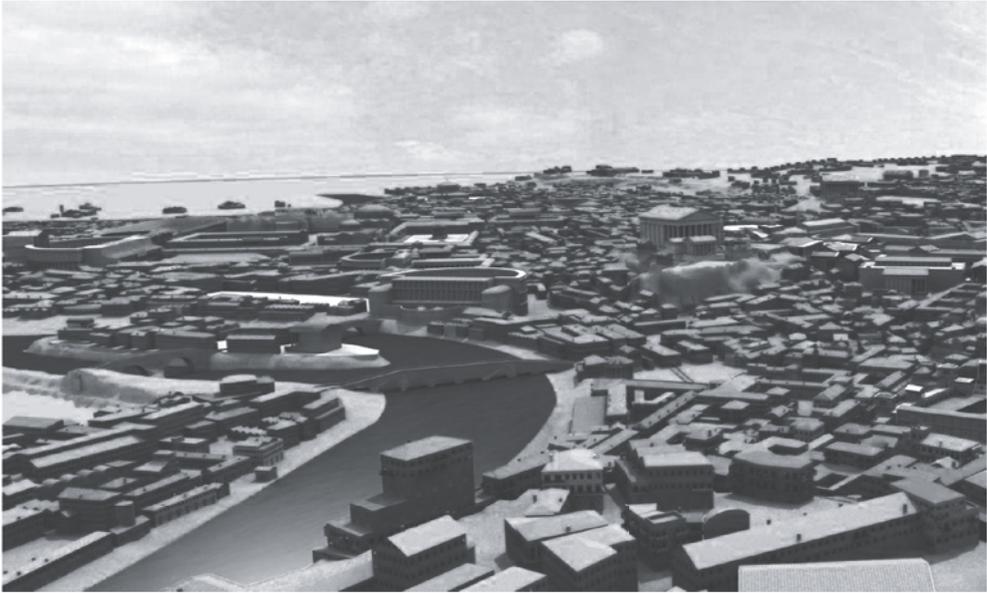
Figure 1
A download of the cityscape model of ancient Rome is available in Google Earth. This figure shows a highly detailed (offline) render of the Rome Reborn project (source: University of Virginia, 2010)

However, Ervin (2001) observes that rural landscapes are larger, continuous, more varied, and not easily bound in comparison to urban areas. In addition, there is limited availability of historical maps and other documents related to historical landscapes due to historical administrative or commercial reasons. In general, the creation of realistic vast virtual historical landscapes is experienced to be more difficult then virtual reconstructions of historical cities and villages. However, despite this larger complexity and uniqueness of landscapes, extended virtual historical landscapes may be created at reasonable efforts under certain circumstances. 3D GIS already offer the possibility to integrate, process and visualise large datasets of geographical areas in three dimensions. It enables the combination of datasets with different scales and accuracies as layered content, which is also relevant for creating vast virtual historical landscapes. For example, it could be the case that a detailed 3D building model is embedded within a low-detailed virtual environment resulting in some sort of multi-resolution / -scale visualisation of a historical landscape. This demands guidelines to visualise different accuracies and uncertainty levels, which is a well-studied topic in 2D/3D GIS research. Therefore, it is interesting to evaluate the potentials of 3D GIS methods and techniques to efficiently prepare input data for our 3D modelling software from historical documents. The integration of CAD and GIS software holds potentials to decorate a virtual historical landscape with virtual historical objects, which comprise its essential characteristics.

8.2.2   Levels of realism: 'real' vs. 'realistic'

The objective is to create virtual historical landscapes that are perceived as realistic by their viewers. Facing uncertainty and feasibility issues, one needs to consider whether the aim is to create a 'real' or a 'realistic' virtual reconstruction of historical landscapes (Ervin, 2001). Real(-world) landscapes are highly complex structures often covering very large areas. For visualisation, even in the case of a modern landscape, this is an extremely challenging task (Bishop and Lange, 2005). Ervin (2001) endorses the conflicts between resolutions, level-of-detail and object-field approaches in virtual landscape modelling with respect to a realistic experience. This modelling demands dedicated knowledge on what the image quality for perceived realism should be, or in other words "How good is good enough?" (after Perkins, 1992). The high image quality of photorealistic representations does not necessarily go together with realistic experiences (De Boer et al., 2009).

More abstract and simplified rendering of representations is also referred to as *non-photorealism*. Non-photorealism (NPR), considered as the counterpart of photorealism, uses artistic styles and rendering such as with digital paintings, drawings, and cartoons. Although the image is not photo-realistic, the experience can be realistic if the image holds identifying and recognisable characteristics for the viewer. For example, Disney's cartoon characters are not real-world characters; however, by following the principles of animation (Lasseter, 1987) the characters walk, move and talk as real-world people making us recognise and believe it. The 17th century Dutch painter Van Goyen, who adjusted the orientation of buildings to make them face forward so that viewers were able to recognise a certain city or landscape (Buijssen, 1993), already applied this 'recognition' principle.

Previous research described the potentials of NPR above photorealistic Virtual Environments (VEs) for applications in virtual heritage (Roussou and Drettakis, 2003) and landscape planning (Paar, 2005). The results of other studies also encourage exploring the potentials of non-photorealism to visualise historical landscapes, notably when applied to simplified and efficient modelling and visualising uncertainties. For example, Zuk et al. (2005) describe the use of non-photorealistic visual cues to communicate the existence of historical structures in the landscape. Bishop (1994) observes users' creative thinking (and increasing user engagement) when mixing abstract and realistic data, which stimulates both right brain-mode and left-brain mode in the thought process. Viewing these results, NPR promises to be a viable approach to create realistic virtual historical landscapes.

8.2.3   Dealing with uncertainty

If a landscape changed significantly and only a few original landscape elements are left traceable, historical documents are our only starting point for creating these virtual historical land-

scapes. Even if there are a lot of historical documents available, the derivable information will often be limited, lacunose and inconsistent. For example, with regard to historical maps Blakemore and Harley (1980) identified three types of inaccuracies, i.e. in space (*geometric*), time (*chronometric*) and theme (*topographic*). These data imperfections leave us with uncertainty about the historical situation. Because computerisation tools fail to identify landscape features (and their accuracy) from these historical documents in an automatic way, we are not able to derive input data for our 3D modelling software easily and efficiently. A detailed, reliable reconstruction would require, of course, a profound landscape study to complement the surviving cartographic material. Altogether, this is such a laborious task that it would make highly detailed virtual historical landscape construction, for the purposes mentioned, almost unfeasible.

The question is how to deal with the types of uncertainty when selecting historical documents for the 3D terrain and object modelling of virtual historical landscapes? Consider a historical document as an observation in time. If only one document is available or selected, information can be derived from that particular source only and added to the 3D model. The deduced information is very '*precise*' as no other documents reveal inconsistencies. However, the reliability is

very low as no other documents are available to corroborate the information from that single source. In modelling virtual historical landscapes from historical documents, there is always this problem of availability and selection of documents. On the one hand, a sufficient amount of historical documents would lead to an acceptable level of reliability; on the other hand, a large availability of historical documents may lead to inconsistent information and increased uncertainty about the historical situation. In that case, it is required to average, interpolate or approximate, to transform the information into appropriate input data for the 3D modelling phase. For example, for geometric information one needs to find the landscape features that still exist and derive the information by holding the unchanged and adjusting the changed. Although the landscape seems to be significantly changed, there are always some traces (e.g. church tower, canals, bridges) left serving as starting point for the 3D modelling.

These uncertainty issues demand visualisation guidelines. Zuk et al. (2005) describe the use of visual cues for visualising temporal uncertainties of historical buildings and objects, and De Boer and Voorbij (2010) elaborate on that by mapping visual cues as transparencies, saturation and fuzziness on the three types of inaccuracies.

8.3   MODELLING VIRTUAL HISTORICAL LANDSCAPES

Building and modelling virtual historical landscapes require an interdisciplinary approach, as it combines knowledge and methods from the science fields of historical geography, landscape archaeology, landscape painting, geographical information systems and computer vision technology. Specifically from a technical point-of-view, it requires efficient application and integration of methods and techniques from GIS, CAD and computer graphics.

8.3.1   An interdisciplinary approach

The aim is to build virtual historical landscapes by processing a selection of data from historical sources using sophisticated computer technology. More specifically, this process is evaluated for the feasibility of applying GIS and image processing software on historical maps and drawings, to derive appropriate input data for 3D modelling and visualisation software, i.e. CAD and computer graphics technology respectively. It is expected that a reliable and convincing virtual historical landscape can be obtained if, and only if, we consider an interdisciplinary and multi-faceted approach that integrates the fundamentals in terms of knowledge, methods and techniques from *engineering* and the *humanities*.

The fundamentals of the humanities related to our research include methods and techniques from particularly research fields of (landscape) archaeology, history of architecture and ge-

ography, landscape painting and cartographic heritage. Archaeology recovers and analyses relics from the past, environmental data using archaeological site excavations and – increasingly – virtual reconstructions of historical buildings and cities. Although we deviate from the traditional approach of minute archaeological site reconstruction, these related projects foster our 3D reconstruction methodology regarding an acceptable measure of accuracy (in terms of precision and reliability), and the application of multiple levels-of-detail in our virtual historical landscapes. Particularly, merging highly detailed archaeological virtual reconstruction with low-detailed virtual landscape environments enables the placing of (virtual) historical objects in their original landscape context.

This requires the acquisition of basic and specific information about the landscape context. Our basic principle is that we base our landscape reconstruction on historical maps and documents *without* doing extensive research on historical and archaeological reality. Therefore, we need to rely on research and deduced knowledge from history of architecture and geography. For example, we capture information about houses and buildings from architectural historical research (Blijdenstijn and Stenvert, 2000; Huijts, 1984; Meischke, 1993) and information about the landscape and its vegetation from research dedicated to historical geography and cultural-historical botany (Renes, 2010; Maes, 2006).

Furthermore, we extract information about the landscape decoration from landscape paintings and drawings. From the 17th century on, there is an increasing availability of topographical images of cities and landscapes. Bakker (2004) states that the objectives of cartographers and landscape painters are similar: capture the landscape as good as possible. However, many of these paintings and maps were custom-made, produced for a specific purpose. This implies that these documents include a measure of subjectivity. Cartographers created their maps according to purposive abstractions of the real world, leading to inaccuracies (Blakemore and Harley, 1993). Similarly, landscape painters diverted their composition from the actual topography, as long as the location remained identifiable to the audience (Buijsen, 1993). Therefore, a quality assessment on the use of landscape paintings to identify the essential characteristics of a historical landscape is required. Our future work elaborates on that in order to evaluate whether or not these historical documents are appropriate input data for creating virtual historical landscapes. Thus, historical maps and landscape paintings are processed and analyzed to seek mutual relationships regarding identifiable landscape elements, as will be shown in section 4.

Cartographic heritage concerns specifically all the valuables that are or may be inherited from historical cartography and maps. In cartographic heritage research, digital technologies are increasingly adopted to transform old maps, globes and cartographic documents into digital format, for example, and evaluate the map accuracy and spatial reference systems (Jenny, 2010). Similar to cartographic studies on the map content, GIS software is used to survey the available

landscape features in historical maps and compare these features with a collection of spatially related landscape paintings.

8.3.2 Integrating GIS, CAD, and computer graphics

The challenge is to transform the interdisciplinary knowledge and methods of the previous section into a technical realisation of a virtual historical landscape. For the case study on re-constructing Palace Honselaarsdijck and its landscape environment, a combination of GIS, CAD and computer graphics technology is applied. More specifically, GIS software is used to generate a digital historical terrain model, CAD software to build up a historical object library and computer graphics software for the final rendering of the virtual historical landscape. The advantage of GIS is its capability to process and visualise different layers of geographical data. This enables the combination of (georeferenced) historical maps with a current elevation map in order to derive a digital representation of the historical terrain. The derived historical elevation map serves as a height raster for the computer graphics software to construct the three-dimensional terrain.

Using CAD software, the distinct historical buildings and objects are modelled with the use of paintings and drawings, so as to convert the essential characteristics of historical buildings and landscape features to their virtual counterpart. Both 3D GIS and computer graphics software allow placing these virtual historical objects into the virtual environment on specific point locations. Generally, they differ in that 3D GIS software supports the visualisation of large geographic areas in a real-time rendering, though at the expense of a lower image quality, where as computer graphics' virtual environments are limited and bounded, but, using sophisticated rendering techniques, photorealistic representations are achieved. However, the tendency is that next-generation 3D GIS software packages offer more potentials to create more realistic 3D geo-visualisation, merging the principles of GIS, CAD and computer graphics technology.

8.4 PALACE HONSELAARSDIJCK AS A CASE STUDY

As a case study, a 3D virtual reconstruction of the 17th century rural estate of Palace Honselaarsdijck and its surrounding landscape (near Naaldwijk, the Netherlands) is created. Palace Honselaarsdijck was a fortified building acquired by the Dutch governor (aka *stadtholder*) Frederick Henry in the early 17th century. He re-built and extended the country estate numerous times between 1621 and 1647 (see figure 3 top). At the end of the French Revolution, this estate was nothing more than a ruin. In 1815, King William I decided to demolish it. Today, the business estate De Honsel stands on the former location of Palace Honselaarsdijck (see figure 3 bottom). The only remainder is the small outbuilding De Nederhof. This case study perfectly

demonstrates how much data from historical sources needs to be gathered, evaluated and processed, before being used as input for a virtual reconstruction. This requires data gathering and processing from historical sources as input for modelling the historical landscape terrain and landscape features using methods and techniques from 2D/3D GIS, CAD and computer graphics (De Boer, 2010).

8.4.1 Collecting and processing historical documents

The case study started with gathering digital copies of historical maps and drawings at national and local record offices. Digital copies of historical documents are increasingly available at (online) archive repositories due to increasing heritage digitisation projects. For example, some colour-prints of the Palace Honselaarsdijck estate were valuable for their rich topographic information, building plans and garden designs, and for detailed information about the building geometry and garden dimensions, along with an outline map of the landscape region around the rural estate, i.e. the Cruquius' map of Delfland (1712). The Cruquius' map of Delfland is an outline map covering the area of the district water control board Delfland, and several accompanying map sheets on a 1:10,000 scale. It was made by the Dutch land-surveyor and cartographer Nicolaus Samuel Cruquius (1678-1754) and despite the obsolete measurements techniques to capture the landscape geometry, the map is considered as highly accurate for that time (Postma, 1977). After importing the 1:10,000 scale map sheets into the GIS software (ESRI ArcGIS 9.3), a modern 1:10,000 scale vector map of the Netherlands (TOP10NL) is used for georeferencing the historical map sheets. Georeferencing enables the combination of historical maps with contemporary maps using one spatial reference system. Therefore, one needs to select connecting points of landscape features that are visible in both maps. Because parts of the parcellation in the Cruquius' map are still present on the modern vector map, it is possible to select approx. 50 points per map sheet to reference spatially the historical maps to the modern map.

Next, an affine transformation (aka *2nd order polynomial transformation*) on each map sheet is applied using the connecting points (aka *control points*) to adjust the map sheets to the Dutch spatial reference system (*Rijksdriehoekstelsel*) by rotating, scaling and translating it. This affine transformation corrects for the possible non-orthogonal axis due to the digitisation process, however without significantly changing the mutual position and angles between map elements. After merging (aka *mosaicking*) the map sheets, a rubber-sheeting transformation is used to georeference the small-scale outline map of Delfland to the map sheets. Although a rubber-sheeting transformation significantly distorts the outline map if the control points are not homogeneous distributed, it enables the seamless joining of the outline map with the map sheets. Next, the building plans and garden designs are georeferenced using the Cruquius' map and the large-scale base map of the Netherlands (GBKN). It starts with documents including the only remaining building De Nederhof (right of the main building) and depending on the al-
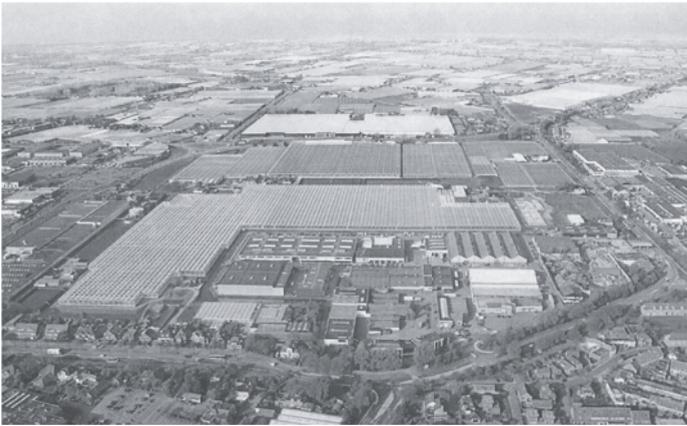
Figure 3
Palace Honselaarsdijck around 1683 (top) and the business estate De Honsel in 2009 (bottom) (sources: Erfgoedhuis ZH, 2011 (top image) and Beekhuizen, 2008 (bottom image))

ready georeferenced map elements, it continues with the other plans and designs subsequently. From digital colour-prints of historical drawings and paintings, some relevant topographic information about the outward building and garden appearance of the Palace Honselaarsdijck estate is extracted. The colour and shape of the walls, roofs, windows, ornaments, fountains, flowerbeds and tree colonnades are identified. Next, we tried to find some evidence, as good as possible, for this deduced outward appearance from dedicated (historical) research on Palace Honselaarsdijck. For example, Morren (1909) confirms the redbrick walls and the grey-coloured Maas-slate roofs, which we also find on the colour print of figure 3, and Beekhuizen (2008) confirms that the colonnades of the leaf-holding beech trees exist. After the final preparation of the historical and geographic data, we continued with the digital terrain and building modelling.

8.4.2   Terrain and 3D object modelling (constructing the virtual historical landscape)

After the data preparation, the second objective is to extrude the particularly two-dimensional historical and geographic data to a third dimension. A spatial reference is added to the historical maps and an immediate next step is to combine the old Cruquius' map of Delfland with the modern Dutch height map, i.e. *Actueel Hoogtebestand Nederland* (AHN). This height map (or elevation raster) fully covers the area of the Netherlands having a ground resolution of 5 metres and each pixel value corresponds to the height above average sea-level (datum: NAP) on a centimetre-level. However, because the landscape has changed significantly since the 17th century, present landscape features distort the 3D visualisation. See figure 4.

Therefore, an approximated elevation map consistent with the historical situation is generated. In both the Cruquius' map and the modern vector map, similar existing meadows and pastures can be identified and it is assumed that ground levels have not changed considerably since the 17th century. Selecting the underlying height values from the modern elevation map using a spatial extraction, next, missing height values are inserted for a complete coverage of the Cruquius' map using a spatial interpolation delineated by existing polders and dykes.

Figure 4
Palace Honselaarsdijck and its surrounding landscape visualised in ESRI ArcScene©. The historical map of Cruquius (1712) is combined with a current elevation map; however, the view is distorted (bulge in front) by the flower auction hall (top right inset)
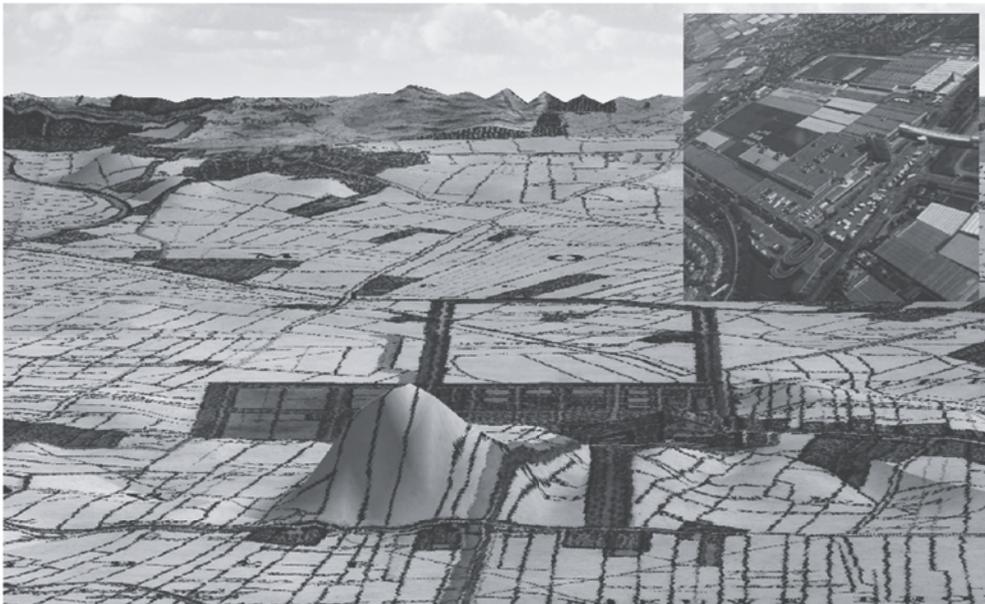
Using a combination of image processing and GIS spatial analysis, the large-scale landscape features are added to the generic historical elevation map, such as ditches, channels, villages and country estates. For example, the ditches and channels are modelled by cleaning the Cruquius' map for text and other cartographic symbols using Adobe Photoshop©, then the cleaned map is added to the generic elevation map using a simple raster calculation. Similar to the manual mapping of the parcellation and waterways, the text-cleaning process is a laborious task. However, is the experience has been that it is relatively easy to do, and it maintains the size and shape of the topographic features very well.

Green-coloured regions on the Cruquius' map depict farmhouses, country estates and villages, which we identify as 'areas-of-interest'. We add these areas to the historical elevation map by selecting pixel values using the magic selection tool in Adobe Photoshop©. Next, the derived raster is imported into ESRI ArcMap©, the pixels are converted to point features and the point features are related to one specific area-of-interest using a constraint Delaunay triangulation. After converting the Delaunay triangles to polygons, adjacent polygons are merged into single connected areas, and – in some cases – the derived polygons are generalised or smoothed. The result is an approximated delineation of the areas-of-interest, which is used in the virtual landscape decoration phase to fill with three-dimensional trees for example. See figure 5.

Figure 5
After converting the pixel colour values of the original Cruquius map into polygon features using a Delaunay triangulation to delineate the areas of interest, the virtual historical landscape is decorated with low-poly 3D tree objects; visualised in ESRI ArcScene©
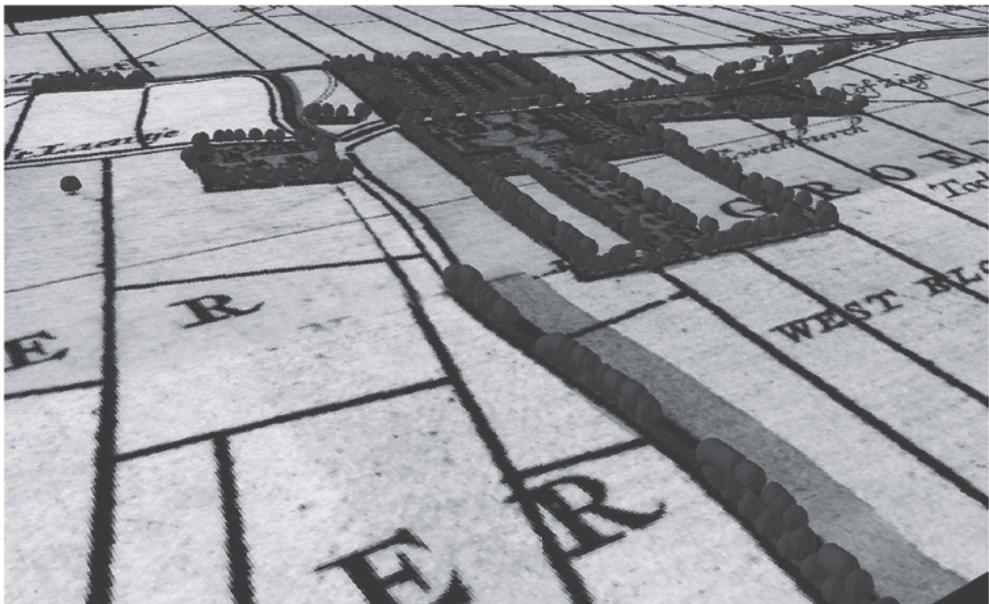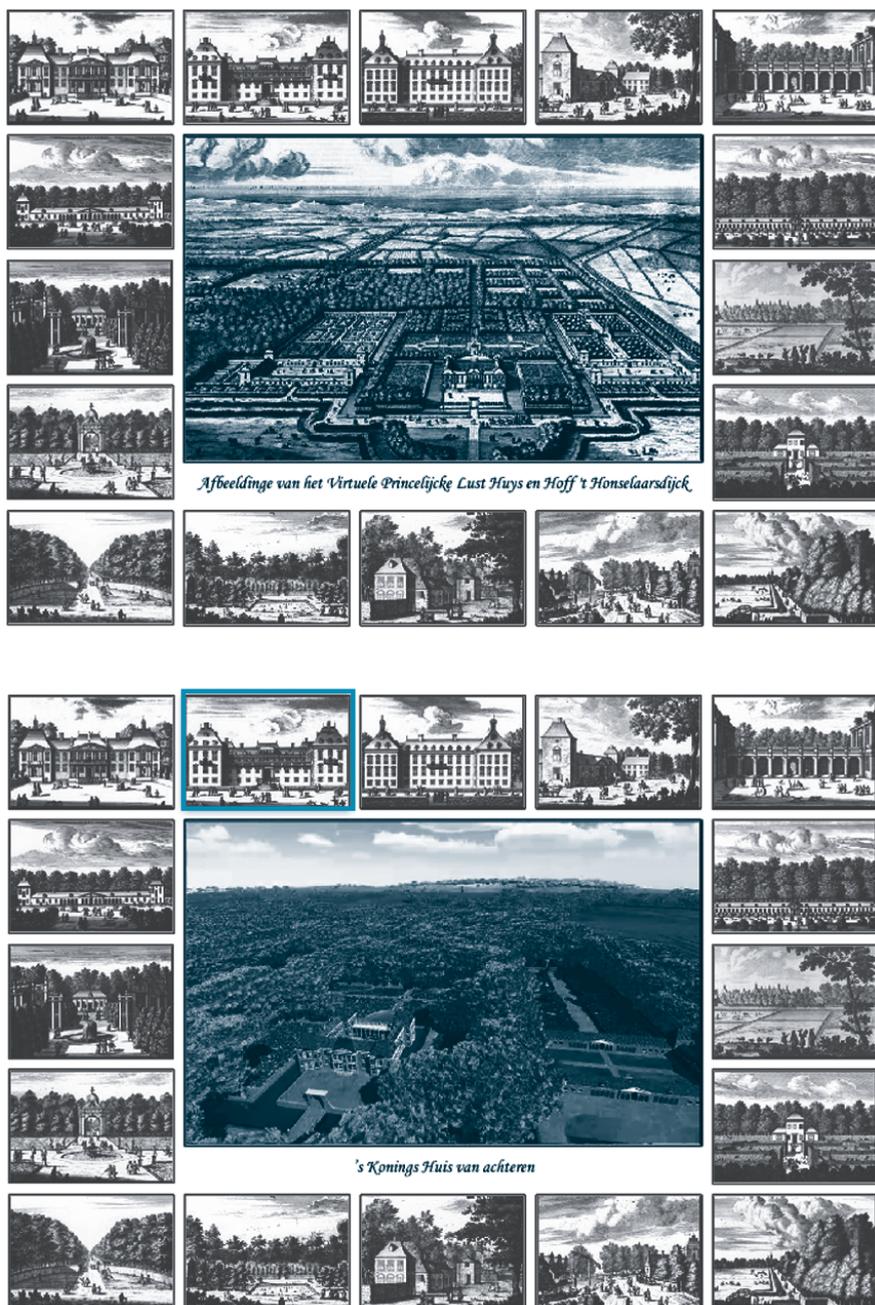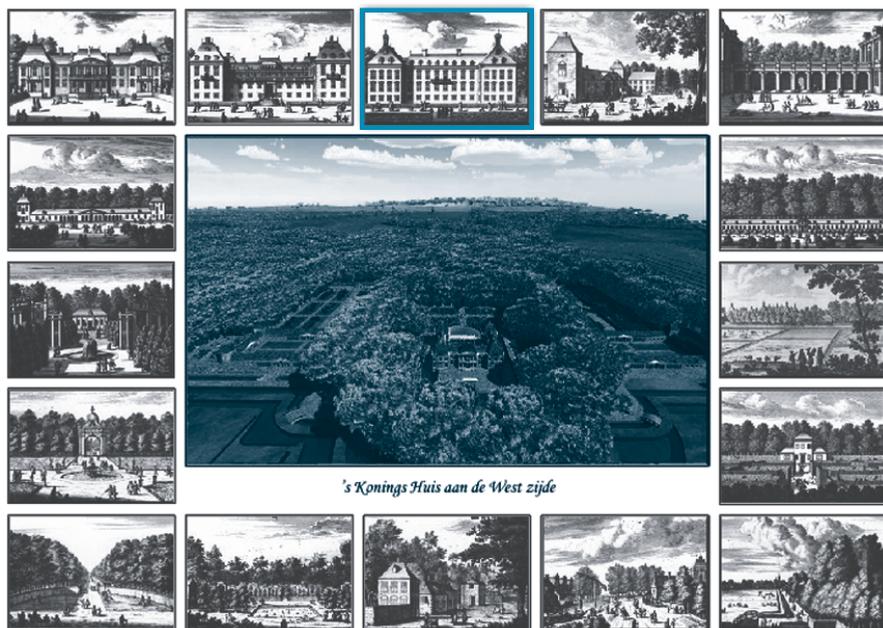
Figure 6
The user interface is based upon a collection of 17th century pictures (top left). If a user clicks on one of the small pictures, the virtual reconstruction is loaded in the middle frame (top right). Next, the user starts to fly over the virtual reconstruction (bottom left) to the corresponding location where he/she receives some additional information (bottom right)

's Konings Huis aan de West zijde

Aan weerszijden van paleis Honselaarsdijk lagen symmetrische parterres met geknipte heggen. Deze heggen waren ontworpen door de Fransman André Mollet, die voor de Franse koning ook delen had ontworpen van de tuinen van Fontainebleau en de Tuileries. In het midden van de parterre aan de westzijde van het paleis stond een grote vergulde sculptuur van de Griekse held Hercules die het vuurspuwende monster Cacus overwint.

Sluit venster

For modelling the historical buildings and structures, we use old drawings and information from architectural-historical research to select the specific characteristics and identifying features to be added to the virtual counterpart of these objects. Google Sketchup© is used to construct the 3D geometry of the virtual historical objects. In the landscape decoration phase, the historical object library is (semi)automatically used to add 3D virtual objects to point feature locations from a 2D point feature layer in the virtual historical landscape.

8.4.3   Rendering and interface

A virtual landscape comprises of five elements: water, atmosphere, vegetation, terrain and structures (Ervin and Hasbrouck, 2001). The previous section described how the terrain and 3D objects of the historical landscape have been modelled. Next, we need to complete the virtual historical landscape of Honselaarsdijck with the other three landscape elements. Numerous landscape visualisation software packages are available, e.g. Visual Nature©, Terragen© and Vue Infinite©. The latter is chosen for the case study because – despite its relatively low price – it offers high image quality rendering and large libraries for landscaping textures, atmospheres, plants and other 3D objects. Vue Infinite allows the use of a raster as height map for modelling the terrain and to import 3D objects to decorate the landscape. Finally, the virtual landscape is completed with atmosphere, water and vegetation (eco-systems).

The resulting virtual historical landscape of Honselaarsdijck was presented at the Royal Gardening exhibition of the Teylers Museum (Haarlem) in spring 2010. To make the virtual historical landscape available to the wider public, the digital landscape model is rendered and animated to derive animations and still images. Inspired by the 17th century pictures (see figure 6), a user interface is developed to show people the relationship between the rural estate and the distinct snapshots on the sides. Therefore, the choice was made to let users fly to the distinct snapshots in the main view and provide them some dedicated information about the place.

The entire user interface is implemented in Flash because of its ability to handle video. It shows a slideshow of cross fading historical images, surrounded by small clickable thumbnails. A mouse click starts one of the 16 short animations that form the heart of the presentation. In each animation, the camera wanders through the model to arrive at the very location depicted in the historical image, providing each image with some basic spatial context. The user is invited to compare the digital 3D-reconstruction with the original picture. A descriptive text containing basic facts and historical context information completes the user interface. The animations are created from a series of still images, created at regular intervals along a predefined path through the digital landscape model. The series of stills are combined into a movie, and subsequently converted to a Flash-supported video format. All the relevant files are merged

into a single Flash file from which both online and offline versions of the presentation are generated, circumventing the subtle differences between browsers. The demo is available for download at http://honselaarsdijck.geomultimedia.nl/.

8.5   DISCUSSION AND FUTURE OUTLOOK

The previous sections described the methods and techniques used to derive a 3D virtual reconstruction of Palace Honselaarsdijck and its surrounding landscape. One of the biggest difficulties experienced so far is to achieve a fully decorated landscape, as this requires the extraction of a sufficient amount of reliable information from historical documents to model the terrain and virtual objects. Information is needed about which terrain and landscape features have been present in the historical landscape, where they were located and in which frequency or density they appeared, in order to obtain a convincing and reliable virtual historical landscape. Whoever starts building virtual historical landscapes aims to create an as realistic as possible digital representation of a historical landscape. However, information about the actual historical situation is limited and information about what viewers actually experience as realistic is lacking. This requires further research to both affective and effective visual cues, i.e. user experience and uncertainty visualisation respectively.

During the case study, small experiments were performed to evaluate what viewers found more important in virtual historical landscapes: the actual objects (*content*) or the quality of image/ rendering (layout). Various images of virtual historical landscapes with different content and rendering were shown to users, who next were asked to assess the images. As most comments concerned remarks on the size, shape or lack of landscape features, it is concluded that the user experience is more influenced by the actual content of the virtual historical landscape than by the image quality and rendering. More experiments about this hypothesis are needed for further conclusions to develop some guidelines for creating realistic virtual historical landscapes. For example, the visual cues that influence user experience can be tested by evaluating the 'measure of realism' of renders containing highly detailed objects in low-detailed environments (and vice versa), or renders from which certain landscape features will be erased in a specific sequence.

If there is insufficient information about the actual historical situation, a high-detailed photorealistic representation cannot be achieved. This creates a demand for guidelines on how to visualise uncertainties using non-photorealism. Future research is recommended on which visual cues are to be applied for an effective communication of uncertainties in virtual historical landscapes, to prevent misinterpretation or misleading experiences for its viewers.

It is expected that the number of virtual historical landscapes will strongly increase, as the technology of 3D GIS, CAD and computer graphics becomes more and more available for historical and archaeological research. These virtual historical landscapes hold strong potentials for presenting cultural heritage and landscape information to the wider public. Using interactive virtual historical landscapes, it enables the access of landscape-oriented archive records through a 3D visualisation interface. Therefore, it is recommended to explore methods and techniques to integrate, share, and access virtual historical landscapes and archive records, in order to make history interactively available.

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