Arnoud de Boer*

Processing old maps and drawings to create virtual historic landscapes

Keywords: virtual landscapes; digital processing; historic maps; 3D modelling.

Summary:
Virtual reconstructions of bygone landscapes are created using old maps and drawings. The creation of reliable and realistic virtual historic landscapes is problematic due to inaccuracies in historic sources, the lack of computerization tools and poor-defined visualization requirements. Our aim is to find a methodical way to process historic sources to create 3D virtual landscape reconstructions and search for decisive variables that influence user experience. This paper will focus on our proposed methodology to process old maps and drawings to create a 3D virtual reconstruction of the –almost completely- disappeared landscape around the former real estate Palace Honselaarsdijck. After digitizing and georeferencing a dedicated collection of old maps and drawings, we create a historic digital terrain model for the Cruquius map of Delfland (1712) by adapting a current elevation map to the historic situation. Next, we add more detailed topographic landscape features to the terrain model by fusing it together with the semi-automatic cleaned historic map. A 3D object library including churches, farmhouses, and windmills is created to decorate our historic landscape model in a procedural way. Finally, we rendered our virtual landscape model in 3D visualization software and validated the virtual landscape reconstruction for geometric and topographic differences.

Introduction

Using 3D GIS and computer graphics technology, we are able to create virtual reconstructions of bygone landscapes. This technology enables to explore virtually –almost completely- disappeared landscapes for applications ranging from landscape planning, edutainment and archaeology. If a landscape has significantly changed, leaving few remaining topographic features of the historic situation, we are unable to collect reliable field survey data. Therefore, we have to base our virtual reconstruction upon historic sources (e.g. maps, drawings, paintings) and some supplementary existent information.

Although technology matured and photo-realistic representations are achieved, the creation of realistic virtual landscape reconstructions remains problematic. We identified three problems that strongly impede the creation of realistic virtual reconstructions of cultural landscapes (De Boer et al., 2009):

1. Data imperfection in historic sources leaves us with uncertainty in the historic situation and limited input data for our 3D modelling software.
2. Lack of computerization solutions for 3D modelling obstructs the feasibility of large-scale and detailed 3D historic virtual reconstruction.
3. Poor-defined visualization requirements give us little hold in the required level-of-detail and image quality to let users experience a 3D virtual historic landscape as realistic, or in other words 'How good is good enough?' (Perkins, 1992).

* PhD student, Departement of Information and Computing Sciences, Utrecht University, The Netherlands [arnouddeboer@cs.uu.nl]

Our research focuses on finding a methodical way to combine and process historic sources to create large-scale 3D reconstructions of cultural-historic landscapes that fully cover a geographical area and capture its essential characteristics. Therefore, it demands that we deviate from the traditional approach of minute archaeological site reconstruction by introducing two main principles. First, we rely on historic maps and sources for landscape reconstruction *without* doing extensive research on archaeological reality. In archaeological site reconstructions, a high degree of truthfulness is required, based on extensive preceding research. However, for the creation of a more general historic landscape impression, the preparatory research can be limited to the selection and interpretation of relevant historic sources (maps and images in particular) and the acquisition of information about the landscape development and structure.

Secondly, we capture the landscape characteristics *without* surveying and detailed modelling. If the landscape has significantly changed (or completely disappeared), we are unable to survey the landscape topography. Then we should base our virtual landscape reconstruction on historic sources such as maps and drawings. However, due to missing or inaccurate evidence in this kind of documents, we are often unable to create a model that includes every detail, even if we had time to model it. As an alternative, we search for methods to combine historic landscape data into a reconstruction that captures the essential characteristics as perceived through the sources.

In one of our pilot projects, we tried to create a 3D virtual reconstruction of the -completely disappeared- 17^{th} century real estate of Palace Honselaarsdijck and its surrounding landscape (near Naaldwijk, The Netherlands). We started our pilot project with collecting digital copies of the historic sources at local and national record offices. Although digital copies of old maps and drawings are largely available, they provide us with only limited and imperfect information. Many historic sources were custom-made, produced for a specific purpose. This implies that these sources include a measure of subjectivity. Cartographers created their maps according to purposive abstractions of the real world, leading to topographic, geometric and chronometric inaccuracies (Blakemore and Harley, 1980). First, we considered which reliable information could be deduced from historic sources like maps, drawings and paintings. Then, we generated a historic digital terrain model using 3D GIS software, decorated the virtual landscape with historic buildings and structures from a dedicated 3D object library using CAD and scripting, and rendered the virtual landscape model in 3D visualization software.

Terrain modelling

In the following sections, we describe the process of georeferencing the Cruquius map of 1712, generating a generalized historic elevation map from the current Dutch elevation map, and finally adding large-scale topographic features to the generalized historic elevation map in order to derive a historic digital terrain model.

Georeferencing the Cruquius map of 1712

For modelling the surrounding terrain of Palace Honselaarsdijck, we use the map of Delfland made by the Dutch surveyor and cartographer Nicolaas Kruik -a.k.a. Kruikius or Cruquius- in 1712 (see Figure 1 left; Postma,1977). This map is produced under authority of the water control board of Delfland, and for that reason, it includes all channels and ditches which are of importance for the Delfland water management. Besides the water topography, it also includes villages

and country estates and as such, we consider it as an appropriate basis for our historic digital terrain model.
Using ESRI ArcMap©, we georeference every Cruquius map sheet by linking it to identifying topographic features of 1:10,000 scale vector map TOP10NL and applying a 2D affine transformation (i.e. 2^{nd} order polynomial transformation) to rotate, translate and scale the historic maps, and also to correct for potential skew of the axis due to the digital scanning process. The Cruquius map is considered as an advanced highly-accurate map (specifically for that time period) and using ~20 linking points per map sheet we are able to georeference the map sheets with an closing error (RMS) of approximately 10-15 meter. Finally, we merge the different map sheets into one raster mosaic (see Figure 1 right).


Figure 1: The Cruquius map of Delfland 1712 (left) and the georeferenced mosaic of map sheets (right).

Extracting a historic elevation map from current spatial datasets

After georeferencing the Cruquius map of 1712, we are able to combine it with other spatial datasets. Our objective is to create a 3D visualization of the historic landscape, so our first attempt is to combine the old map with the current 5m- resolution Dutch elevation map (AHN). However, because the landscape has changed significantly since the 17^{th} century, present landscape features (see Figure 1) distort the 3D visualization. This requires that we generate an historic elevation map that is consistent with the historic situation.
The building and structures from the elevation raster map are filtered out by interpolating between ground levels of which we know that they do not have changed considerably since the 17^{th} century. Using an overlay of the 1:10,000 scale vector map TOP10NL on the Cruquius map, we observed that for large regions the meadows and pastures have not significantly changed. Therefore, we assumed that the selection of height values from the AHN using the grassland polygon features of the TOP10NL are a representative choice for our 3D visualization. Next, we apply a spatial interpolation over the extracted height values in ESRI ArcMap© with polders and dykes as delineating boundaries to reach a complete coverage for the whole area. The result is a historic elevation map for the Cruquius map which includes the generalized heights of the polders and which is consistent with the historic situation (as contemporary landscape elements do not disturb the 3D visualization anymore).

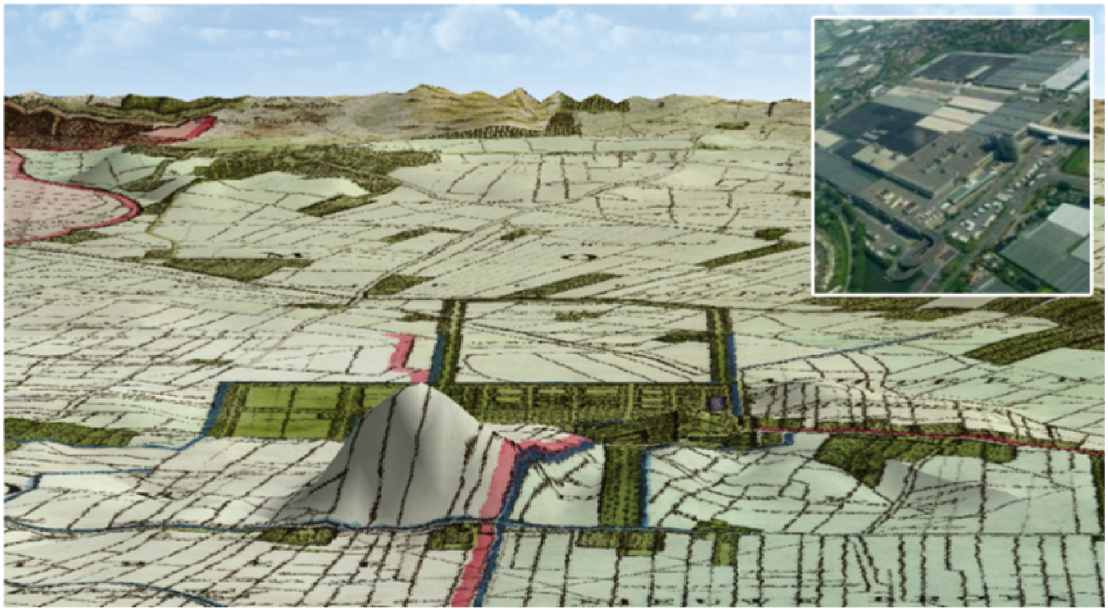

Figure 2: Palace Honselaarsdijck and its surrounding landscape visualized in ESRI ArcScene©. The historic map of Cruquius (1712) is combined with a current elevation map; however, the view is distorted (bulge in front) by the flower auction hall (top right inset).

Adding large-scale terrain features

As the previous results are only a very generic digital elevation map, we need to add large-scale landscape features (e.g. ditches, channels, villages and country estates). Obviously, we could choose to add every detail by hand; however, mapping (for example) the complete parcellation of the Cruquius map is very laborious and skilful. Therefore, we propose an alternative, semi-automatic way to add large-scale terrain features and delineate villages and country estates to our virtual historic landscape.

In order to add channels and ditches (i.e. terrain characteristics below ground level), we clean the Cruquius map for text and other cartographic symbols (see Figure 3) using Adobe Photoshop©. Next, we use a raster calculation in ESRI ArcMap© to add the cleaned map to the generalized historic elevation map. Although like manual mapping, the text-cleaning approach is also very time-consuming, we experienced that it is relatively easy to do and it keeps the size and shape of the topographic features very well.

Figure 3: A selection of the original Cruquius map (left) and the derived historic elevation map for the large-scale terrain features added to the generalized historic elevation map (right).

On the Cruquius map, we observe coloured areas (see Figure 4 top left) which correspond to farmhouses, country estates, villages and so forth. For our 3D virtual reconstruction of the surrounding landscape of Palace Honselaarsdijck, we need to add these *areas of interest* to the generalized historic elevation map to get a fully decorated virtual historic landscape.

Instead of delineating these areas by hand to be able to put historic buildings and vegetation in these areas at a later stage, we use the magic selection tool of Adobe Photoshop to select all the pixel values having a particular colour value (e.g. green). These pixels are saved to a new raster and next, ESRI ArcMap© is used to apply a raster-vector conversion to transform pixels into point features.

A Delaunay triangulation is applied to connect nearby and related point features (see Figure 4 top centre). After converting line features to polygon features, we delete polygons having a large area or having a high perimeter:area ratio as these lines connect point features that do not belong to the same area of interest. The offsets for deleting these polygons depend on the map detail and image resolution. Next, we merge adjacent polygons into one connected area, and if required, we generalize or smooth the polygons (see Fig 4 top right). The result is an approximated delineation of the areas of interest. Figure 4 below shows an example in which we put three-dimensional trees at the borders of the areas of interest; visualized in ESRI ArcScene©.

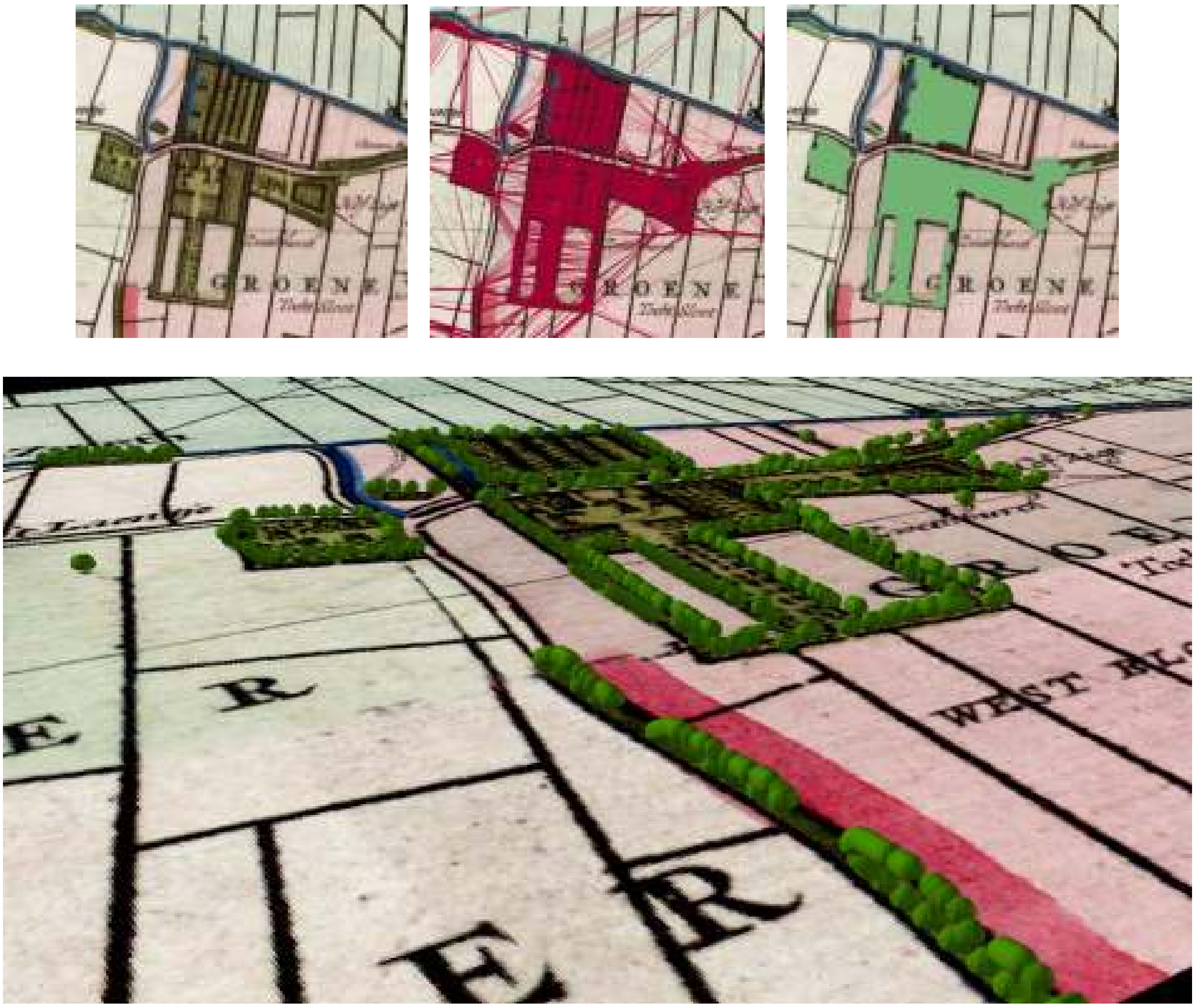

Figure 4: Converting the pixel colour values of the original Cruquius map into polygon features using a Delaunay triangulation (top) to delineate and decorate the *areas of interest*; visualized in ESRI ArcScene© (below).

The same approach is applied to map semi-automatically roads, channels and other land features, so that in the end we achieve a historic land use map. We consider this approach more effective and efficient than modelling and mapping all terrain features by hand, because the original map is used as starting point to derive a historic digital terrain model in a semi-automatic way.

3D Object modelling

After the realization of a historic digital terrain model, we need to decorate our virtual landscape with historic objects and structures. Because the decoration of large-scale 3D virtual reconstructions of historic landscapes is a very laborious and skillful task, it calls for semi-automatic solutions to build up these landscapes in a procedural way. For cityscapes, previous research (Schilling and Zipf, 2003) explored an automated way to build-up and model virtual *city* models. Using sophisticated computer algorithms, one may create complex city structures in an automatic way through matching objects (such as roofs, windows, and walls) from a dedicated object library. For landscape objects, the conditions seem to be different. They are often standing on isolated spots in the landscape. Unlike coherent city structures, they frequently display individual features, notably irregular and unique sizes and shapes.

For all that, we explore the potential of a 3D object library of landscape-related historic buildings and structures for building up virtual landscapes in a more (semi)automatic, methodical way. For the 3D object modelling, we used a dedicated collection of historic drawings and paintings - together with supplementary information from historic research of among others Huyts (1984) and Meischke (1993) - to select and model the identifying features of historic landscape decoration, such as country estate, windmills, village and farmhouses. We used Google Sketchup© to put up the 3D geometry of the historic buildings and structures. Figure 5 shows the 3D objects of some typical 17th century building architecture and historic objects. Using a point feature layer with locations of the specific 3D historic objects, we were able to semi-automatically build-up (using scripting) our virtual historic landscape.

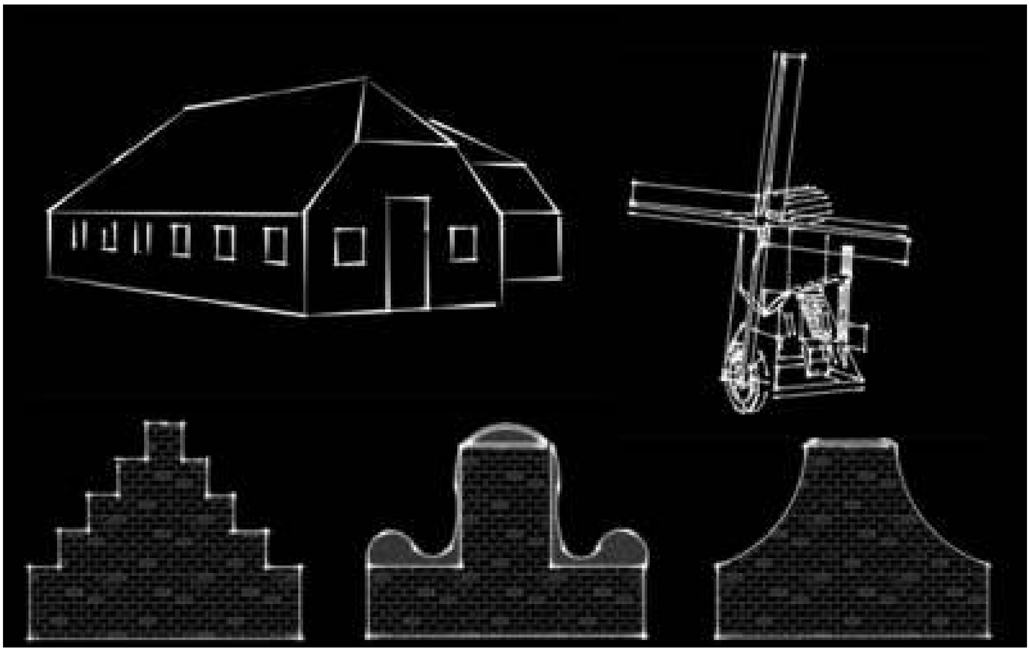

Figure 5: Typical Dutch 17th century 3D historic buildings and structures modelled in Google Sketchup©.

With respect to 3D modelling, it holds that - in general - adding more details takes increasingly more time. Because of the lack of well-defined visualization requirements, the questions are the following. What are the requirements for the historic landscape objects in the object library? What characterizes each of these objects? Which level of detail and information is required in a virtual reconstruction in order to let the audience perceive it as realistic? *"How good is good enough?"* in this matter, after Perkins (1992), who wonders what image quality for photorealistic simulations, is sufficient to act as a valid and reliable surrogate for real world conditions. Our future work will focus on which essential characteristics we need to add to the 3D objects and the virtual landscape to let users experience it as convincing, reliable and realistic.

Rendering and validation

The historic digital terrain model and 3D historic objects are used as input for rendering our 3D visualization software. Finally, we validate the virtual historic landscape for geometrical and topographic differences.

Rendering

A virtual landscape exists of five elements: water, atmosphere, vegetation, terrain and structures. (Ervin and Hasbrouck, 2001). In the previous section, we derived a historic digital terrain model and 3D historic objects, which we use as input for our 3D landscape visualization software Vue Infinite© to decorate the virtual historic landscape. This software enables to use a raster as height map for modelling the terrain and to import 3D objects to decorate the landscape. Finally, we complete our historic landscape with atmosphere, water and vegetation (eco-systems) (see Figure 6).

Figure 6: The fully decorated virtual historic landscape rendered in Vue 8 Infinite©.

Validation

Because of the data imperfection in historic sources and the computerized modelling, we need to validate our virtual historic landscape for geometric and topographic differences. We validate the geometric accuracy of our historic digital terrain model using digital photos taken at locations that have not changed according to the Cruquius map and TOP10NL. From a visual comparison of the digital photo and a render of our virtual historic landscape, we observe that our model is generally

geometrically correct, although we expected to have geometric differences as a cause of cartographic exaggeration.

For the topographic differences, we validate the automatic placement of historic buildings by means of a parallel project in which we try to reconstruct the main street of the village Rijnsburg (near Leiden, The Netherlands). We use several 17th century perspective maps to determine the type distribution of historic buildings, use this information to adjust our 3D object placement algorithm and, finally check the 3D model visually for topographic differences with respect to the perspective maps (see Figure 7). Further geometric and topographic validations are under consideration.

Figure 7: Validating the 3D model of Rijnsburg (right) using 17th century perspective maps (left).

Conclusion and future work

In the previous sections, we described our methodology for creating 3D virtual landscape reconstructions. We used a semi-automatic way to process old maps and drawings to generate a historic digital terrain model and a dedicated collection of 3D historic objects using a combination of image processing, 3D GIS, CAD, and 3D visualization software. As our preliminary results of our pilot-project are based upon a limited set of historic sources from one typical landscape, future work will evaluate our methodical way of the terrain and 3D object modelling on cultural landscapes contrastive to the polderscape of Delfland.

Due to limited information that could be deduced from historic sources, we were not able to add every detail to the virtual landscape and its historic decoration. It is the designer's choice whether or not he or she models a particular detail or feature or not. However, we need well-defined visualization requirements to be able to achieve a realistic user experience. The question is: "What is the required level-of-detail and image quality to let users perceive virtual historic landscapes as realistic?". In a preliminary user test, we observed that users are very good in describing (of what they find) characteristic elements of 17th century landscape paintings and pictures in general. They clearly identify which features in the renders they find more or less convincing and believable, or which they actually miss. Future work will elaborate on this.

Besides that, related research (Appleton and Lovett, 2003; Drettakis et al., 2007) shows, too, that realistic representations of non-contemporary (i.e. past and future) situations let users experience it as unbelievable or unconvincing. A photo-realistic render is expected by its audience to represent absolute truth and certainty. Because of the data imperfection in historic sources and therefore the uncertainty in the historic situations, we are not always able to realize a high-detailed photorealistic representation. This encourages us to explore the potentials of non-photorealistic rendering of virtual historic landscapes.

In addition to the affective qualities of virtual historic landscapes to provoke a realistic experience to its audience, we intend to focus also on the effective qualities. How to use 3D visualizations as visual search interface to disclose information about the historic landscape in a very interactive and intuitive way, i.e. enabling users to navigate to and click on objects of their interest? Which details should be added to the virtual environment as such that information about the landscape and its decoration is communicated in a visual, clear, coherent and uniform way? Future work will continue with determining ways in which we can mix realism and abstract data visualization in representations in order to influence cognitive processes regarding knowledge reconstructions (Slocum et al., 2001). We expect that our work contributes to the realization of large-scale virtual historic landscapes to present cultural heritage and landscape information to the broad public.

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