

3D VISUALISATIONS IN SIMULATIONS OF FUTURE LAND USE: EXPLORING THE POSSIBILITIES OF NEW, STANDARD VISUALISATION TOOLS

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ABSTRACT:

Three-dimensional visualisations are an interesting method for representing model outcomes. But most visualisation techniques require expensive software, and a lot of time to create them. When a large set of visualisations is needed, or when the visualisations need to be adapted frequently, a faster and more flexible method is needed. The first step of the proposed model is to create the 3D elements. These elements are combined with the base map, and distributed to the public using Google Earth. Both freely available and commercial software are used in this process.

1. INTRODUCTION

Visualisations are the key to effective public interaction because they are the only common language to which all participants within the same cultural context – technical and non-technical – can relate (King et al. 1989). Maps are an especially universal way to communicate about spatial developments. Policy makers, for instance, use maps to present their spatial plans to the local community, and scientist use maps to present for example spatial model outcomes to other scientists.

Traditionally, the paper maps in many sizes and qualities were the principle way to communicate spatial plans. These paper maps could be published in reports, magazines, newspapers, and on posters to reach the different audience types. For special occasions a maquette could be made to visualise the historic, current or future landscape with a third dimension. Building a maquette is a time-consuming and thus expensive way of visualisation. Another disadvantage is that a maquette cannot easily be shared: people have to come to the maquette to see it.

With the introduction of the Personal Computer, map making became less time consuming. With the help of map-making software (e.g. GIS or CAD), it is possible to make changes to existing maps and reprint them. The difficulty is in the redistribution of the new map. Now that the majority of households in the Netherlands have an Internet connection (15% small band, 65% broad band, 20% no connection; European Union, 2006), this medium has become an interesting option for the distribution of maps in this country.

The introduction of the Personal Computer was also the start of the leisure computer game industry. The game industry has boosted the development of Virtual Reality and Augmented Reality techniques. These techniques are also applicable for interactive 3D visualisation of spatial plans. A reason to choose for a 3D visualisation instead of conventional 2D visualisation can be that it is more appealing for the user, and may be also easier to interpret than a 2D map. A disadvantage is the time-consuming preparation of the digital model, creating a 3D virtual environment is like building a digital maquette.

In this study we are looking for a method that combines the flexibility of digital, GIS-based map making with the attractiveness of 3D visualisations. This quest builds upon previous work by Borsboom-van Beurden et al. (1996) and Riedijk and van de Velde (2006). Our need is a visualisation process that is easy and quick, and a result that is appealing, easy to distribute and interactive. We have developed a process that makes it possible to create 3D visualisations in a quick and easy way. The process is developed for a land-use model, and will be illustrated in this paper using that model as an example. The applied Land-Use Scanner model, simulates land use in the country using policy alternatives and land characteristics as an input. The resulting map is a 100 by 100 m cell size raster of the Netherlands with the future land use in the year 2040. Running the model with different policy alternatives gives different output results. We will use our proposed visualisation method to generate a set of visualisations of the simulated land-use changes.

In this paper, the above mentioned process is described and discussed. First, a short introduction to the land-use model is given. After that the construction of the 3D elements of the visualisation is described. Then the software environment to bring Land Use Scanner results and the 3D elements together is explained. The last step in the methodology is the presentation of the visualisation in Google Earth. In the conclusions section we will focus on the cost/time effectiveness and applicability of the methodology.

2. METHODOLOGY

2.1 Simulating land-use changes

The Land Use Scanner is a GIS-based land-use model that simulates future land use. Unlike many other land-use models its objective is not to forecast the dimension of land-use change but rather to integrate and allocate future land-use claims from different sector-specific models. The model has been applied in various kinds of research projects such as: the evaluation of alternatives for a new national airport (Scholten et al., 1999),

the simulation of future land use following different scenarios (Schotten and Heunks, 2001; Borsboom-van Beurden et al., 2007;) and an outlook on the prospects of agricultural land use in the Netherlands (Koomen et al., 2005). A full account of the model is provided in Hilferink and Rietveld (1999). The simulation of the spatial location of future land use is based on three kinds of data:

- *Current land use*: a representation of the 2000 land use in 17 main types, based on a combination of various datasets.
- *Regional Land use claims*: the future demand for land for all distinguished land use type specified per region.
- *Local suitability*: a user-specified combination of current land use, policy maps and thematic maps that indicates the suitability of location for a specific use. (See Figure 1).

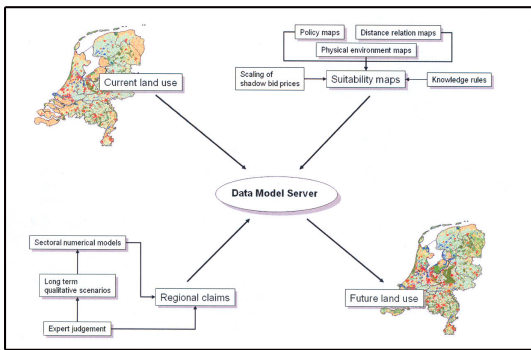


Figure 1. Structure of the Land Use Scanner model (source: LUMOS, 2007).

A seriously revised version (4.7) of the model became available in 2005. This new version offers the possibility to use a 100x100 metre grid, covering the terrestrial Netherlands in about 3.3 million cells. This resolution comes close to the size of actual building blocks and allows for the use of homogenous cells that only describe the dominant land use. The previous version of the model had a 500 metre resolution with heterogeneous cells, each describing the relative proportion of all present land-use types. Together with the introduction of homogenous cells using a dominant land use a new algorithm has been developed that finds the optimal allocation of land use given the specified demand and suitability definition. This new approach is referred to as the discrete model, as it uses a discrete description of land use per cell: each cell is assigned only one type of land use from the total range of possible land-use types. For a more detailed description of the most recent model version and its calibration and validation the reader is referred to other publications (Loonen and Koomen, 2007; Tijbosch et al., 2007).

In this study we are only particularly interested in the locations where land use has changed in 2040, compared to the current, 2000 land use. These locations are especially relevant to policymakers and other stakeholders as they indicate where changes in the landscape are likely to take place. To intuitively represent these locations we will create 3D-visualisations of the appropriate 100x100 metre grid cells. To this effect we create a difference map for selected land-use types that is exported to ArcGIS. In this standard GIS-package we will then create the 3D-visualisations with the Google Sketch-up tool. The Figures 2 and 3 depict this process graphically.

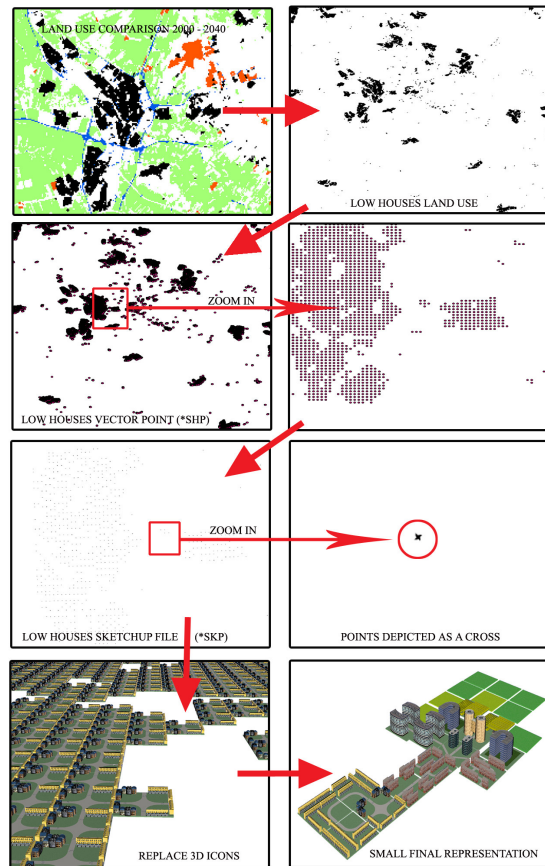


Figure 2. Graphic representation of the visualisation process.

2.2 Designing the icons for changed land use in 2040

Different software tools exist to create features in three dimensions (icons) but we selected the SketchUp software by Google for the following reasons: it allows creating, viewing and modifying 3D representations in a relatively quick and easy way. The software, furthermore, is freeware and thus available without additional costs. However, a professional version exists (SketchUp pro) for advanced users. In our pilot-study, the freeware version was sufficient to effectively create semi-realistic 3D visualisations. The SketchUp tool has the advantage that we did not have to rely on the much more complicated traditional graphic design (CAD) software. It has the further advantage of being closely linked to both the GIS-software from which we export the locations of changed land use and the GoogleEarth tool that we want to use to show the final visualisations.

We have chosen to represent the locations of land-use change in three dimensions for the following Land Use Scanner classes:

- *Low density residential areas*: single family dwellings with a maximum of three floors.
- *Medium density residential areas*: multi-family dwellings consisting of low apartment blocks of four to five floors.
- *High density residential areas*: high rise apartment blocks of about 10 floors
- *Commercial areas*: office buildings and other districts with big and small buildings
- *Greenhouses*: horticulture in greenhouses

The changed locations of the other simulated land-use types (nature/forest, agriculture and recreation areas) will be shown as two dimensional squares. For the land-use types that are not simulated by the model (infrastructure and water) no additional visualisations are created. Together with the other locations of no-change these will be represented through the GoogleEarth aerial photo base maps in the final visualisation

The 3D-design of the new land-use type icons in 2040 has been done according to criteria listed below. An overview and graphical depiction is provided in Appendix A. First, we strived to create semi-realistic icons that are made to *scale*. This means that the built 3D land-use types will correspond to the 100x100 metre size of the pixels that form the grid. So, for example, buildings that have a height of 10 metres will take up 10 percent of the length and width of the grids. An additional concern is that we want to represent the *future*. This means that the design should have a somewhat futuristic tendency, depicting houses as they may look like in the coming decades. Last, but not least, the visualisation must allow a constant speed over the whole represented area, thus strongly limiting the *file size* of the individual icons. This means that the elaboration of 3D land use will be conditioned, a priori, by avoiding maximum detail in the buildings, working with “Textures”^{*} which allows the painting of the created facades, and storage in “Components”^{**}.

2.3 Adding the icons to the locations of change

In this step we add the 3D-icons to the locations of changed land use. Starting-point in this process are the raster-grid results (ASCII-files) from the land-use model that describe, for each land-use type, the new locations. These locations are obtained from the model by comparing the 2040 land use with the current situation at a pixel-by-pixel basis.

The land-use grids are imported in a desktop GIS (ArcGIS) and converted to georeferenced points (shapefiles). These are then exported to SketchUp where every cell (it is the pixel with the land use type information) will be replaced with the created 3D icons. The SketchUp ArcGIS plugin allows conversion of the ArcGIS data vector geometric features to .SKP file for SketchUp. We can export polygons that result in a group of edges, vertices and faces in SketchUp, and we can export also polylines that they will be a set of edges and vertices, and, most importantly, we can export points.

The new SKP files will keep the georeference and size information from ArcGIS. These points will in SketchUp be depicted as small crosses that we will later replace with the 3D land use created, see figure 2.

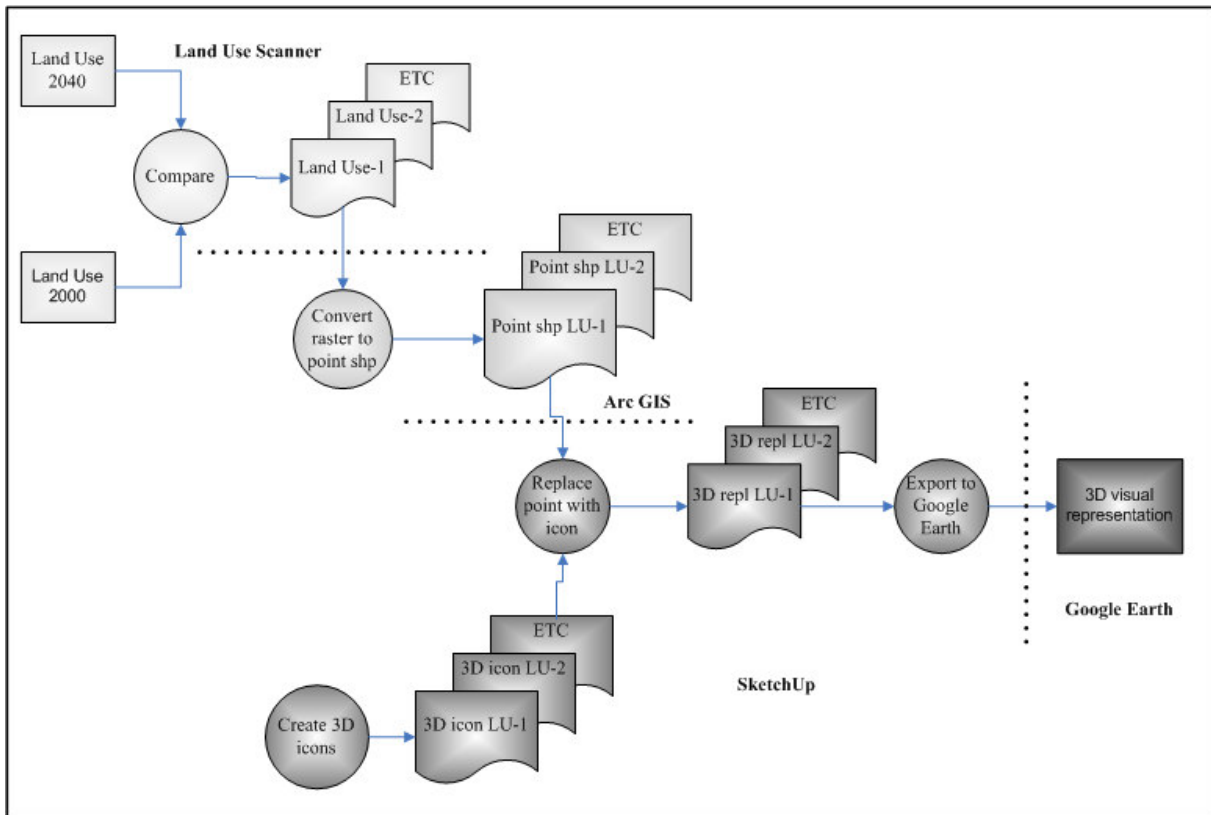


Figure 3 Flowchart representing the process

* SketchUp allows painting the icons to add detail and realism to your models. We have taken images and we save them as a texture to reduce size.

** SketchUp allows saving all your icons created as a component (special format file *.skp).

2.4 Showing the final results in Google Earth.

Google Earth is becoming more and more a platform that is used to explore, present and exchange (social) geo-information. It is easy to use and it is available for downloading and using by anyone. For these reasons we selected it as presentation platform

It is very easy to export files from Google SketchUp to Google Earth. The buttons are standard in SketchUp (View – Toolbars – Google). When the cells come from ArcMap they are already geo referenced. When clicking the “Place Model” tool, the position is also exported to Google Earth and the cells will be at the correct position in Google Earth.

We can start making a presentation when the cells are imported to Google Earth. One way to make a presentation is to make a flight path over/around the cells. This way you can explore the situation and show the effect of the cells (buildings, roads, water, etc.) on the aerial photos from Google Earth. In the toolbar of Google Earth there is a tool called “Add Path”. With this you can make your presentation path. Click “OK” and the path is added to the “My Places” folder. When the path is selected you can press the “Play Tour” button on the bottom of the Places window. Now the view will follow the path. The height, angle and speed can be adjusted in the Touring tab of the Options panel. To save the project, it is best to put everything into a folder and save it (Right mouse button – Save As...). This file can also be used to send the presentation to others.

One big disadvantage of Google Earth is that it is a demanding application: you need a fast connection to the Internet and an up to date computer to use it. Especially 3d visualisation uses a lot of capacity of the computer. For this reason you can choose to render a movie (avi or wmv) from the presentation in Google Earth. This is possible with Google Earth Pro.

But the availability of the aerial photos, the large scale on which you can present your information and the geo-referencing of the data are big advantages over professional 3d software (Maya, 3ds Max, Lightwave, etc.), which will need a lot off processing power to calculate big areas. Google Earth can be used live during a presentation if the right computer is used and the right Internet connection. This makes it possible to react to the audience and show things that are asked for.

The cells that visualise the outcome of the Land Use Scanner make the data less abstract and could make it easier to interpret the data. It visualises very globally the impact on the landscape. It is important to know whom you are showing the presentation: A researcher who is into the subject will understand that what he is seeing is (in case of the cells) a (unreliable) prediction of the future. But people who have no background information on the subject might think that they see a building project presentation and that it already is planned like that. Make sure the presentation fits the audience. (See figure 4 next)



Figure 4. Example of a final representation in Google Earth.

3. CONCLUSIONS

In this paper we have introduced a new visualisation method. This method aims to be an effective, easy and low cost way to distribute interactive 3D maps. In this section we briefly describe our findings in terms of advantages, limitations and possible further research.

An important advantage of the method described in this paper is that it relatively straightforward to perform. The Google SketchUp software is easy to learn, and the process in ArcGIS is a standard GIS procedure. But the main advantage of the method is that once the 3D icons have been created, they can be used over and over again in all scenarios that need to be visualised. Therefore this method is very suitable for the visualisation of large sets of scenarios or alternative maps. The software used in the described visualisation process is freely available, with the exception of ESRI's ArcGIS desktop software. This GIS package used is standard software used in organisations that work with digital maps, and does not have to be purchased for the purpose of visualisations only.

The application of the described method is now limited in spatial extent. Visualisations of larger areas, e.g. the whole Netherlands, are very slow in performance when icons of 100 by 100 meters are used. Therefore the method is not suitable for visualisation of large areas with small icons. Another limitation is the level of detail on the 3D icons. The level of detail has to be limited for a good performance. Therefore the method is not suitable for visualisations that need a very high level of detail. A successful distribution of the 3D maps with Google Earth depends on the penetration rate of broadband internet access. In the Netherlands most households have a broadband internet connection, but this is not the case everywhere. Limited access to broadband internet access makes this visualisation method less suitable.

This paper focuses on the methodology and not on the way the visualisations are perceived by the audience. In order to have a better comprehension of the usefulness of this method, it is advisable to investigate how people use and understand these interactive 3D visualisations.

The overall conclusion is that using 3D icons for cost efficient, easy to distribute visualisation offers an interesting application

field. Limitations in the application of the method depend on the required scale, desired level of detail and broad band internet access availability.

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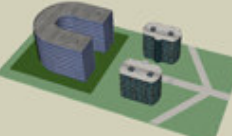
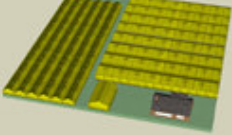


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APPENDIX A. DESCRIPTION AND DEPICTION OF THE NEW LAND-USE ICONS

Land-use class	New land use in 2040	3D features description	Picture representation
<p>Urban (built-up) areas</p> <p>Simple futuristic designs avoiding irregular structures.</p>	<p>Low density residential area</p>	<p>Futuristic single family houses with three floors (including the ground floor) and some surrounding roads and (public) green.</p>	
	<p>Medium density residential area</p>	<p>Futuristic apartment blocks with 4 or 5 floors and some surrounding roads and (public) green.</p>	
	<p>High density residential area</p>	<p>Futuristic apartment blocks with about 10 floors and some surrounding roads and (public) green.</p>	
	<p>Commercial area</p>	<p>Futuristic small and high commercial buildings.</p>	
	<p>Greenhouses</p>	<p>A relatively straightforward representation of a farmer's house and greenhouses.</p>	
<p>Nature/green areas</p> <p>Only simple polygonal colours avoiding relief forms</p>	<p>Nature/forest</p>	<p>Dark green polygonal areas</p>	
	<p>Recreation area</p>	<p>Mix of green areas (recreation) and blue areas (water)</p>	
<p>Agricultural areas</p>	<p>Agriculture</p>	<p>Light green polygonal areas</p>	