3D visualization of 2D scenarios

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1 Introduction

A number of Ministry affiliated Dutch research institutes simulate the future outlook on the land use development on National level. These outlooks are created by using Geo data based simulation programmes (ao. SCHOLTEN ET AL, 2001). The output of these simulations is mostly geo-referenced grid data that demonstrates a spatial pattern of land use in the near future.

Stakeholders should discuss these results, but it seems that the type of visualization doesn't support sufficiently the policy and decision making process (BORSBOOM-VAN BEURDEN ET AL, 2004). Presumably the interpretation of the map information demands a too high cognitive level to read and to understand the meaning and impact of the conceptual cartographic visualization (ZUBE, 1987).

In this paper we discuss topics to improve the representation and recognition of this two-dimensionally geo-referenced grid based output by a three-dimensional visualisation.
The discussion starts with an overview of the concepts of 3-dimensional visualization. Then, based on these concepts, the transformation of 2D grid data output into a 3-dimensional semi-realistic visualization will be presented. Finally we discuss the comparison of the scenario results via the 3-dimensional visualization.

2 3D visualisation

The introduction of the computer and in particular the research on flight simulators by NASA has led to contemporary visualisation possibilities. Simulators offer the user(s) a dynamic and interactive environment (sometimes called "Virtual Reality" – VR-) to perceive, to explore and to manipulate visual representations of possible, probable and real worlds.
To realise such 'cyber spaces' the visualisation should be three-dimensionally and be based on two- or three-dimensionally geo-referenced geodata sets.

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The division between a digital representation of the real world by geodata and a digital visual representation of the geodata is one of the basic principles of geo-information science (MacEACHREN, 1999; CHEN, 2001).

This relation between the geodata and the visual representation is really diversified, because of the different geodata references which each individually or in combination (!) can be visually represented via a reference system for visual representation (table 1).

	Visual representation			
GeoData	2D	2D + ΔT	3D	3D + ΔT
2D				
2D + Δt				
2.5D				
2D + Δt				
3D				
3D + Δt				

table 1: Different visualisations of geo-data (LAMMEREN ET AL, 2004). grey line: primary visualisation of the grid based scenario output

The table shows in the first column the different geodata sets that nowadays are available. The Δt points at continuous time series that are delivered by some spatio-temporal simulation models. The 2D, 2.5D and 3D refers to subsequently 2-dimensional referenced data (2D), digital elevation models (2.5D) and three-dimensional referenced, including three-dimensional topology, as known from computer aided design software (3D). Most of the Dutch National land use scenario studies offer an output as 2D geodata.

The second row shows the different ways to visually present the geodata. Two-dimensional geodata may be visualised in a two- (2D) or a three-dimensional (3D) way. The ΔT in the second row points at the implicit or explicit animation3 of the visualization. An example of an explicit animation is a video. The adjective explicit is used to show that the user of the visualisation doesn't have any tool to influence interactively the temporal and projection parameters of the animation. An implicit animation offers the user tools to animate the application interactively via adaptations of temporal and projection parameters. By example the user can decide upon the view path and the speed of movement.

Figure 1 illustrates clearly how hard it is to read and understand the traditional cartographic visualization of grid cell data that represents land use. To achieve a more realistic effect to

[3] This division is an extension of the concept of dynamic visualisation (ZUBE, 1987)

improve the readability and understanding of the visual representation of this 2D geodata a kind of similarity with the real world is needed.

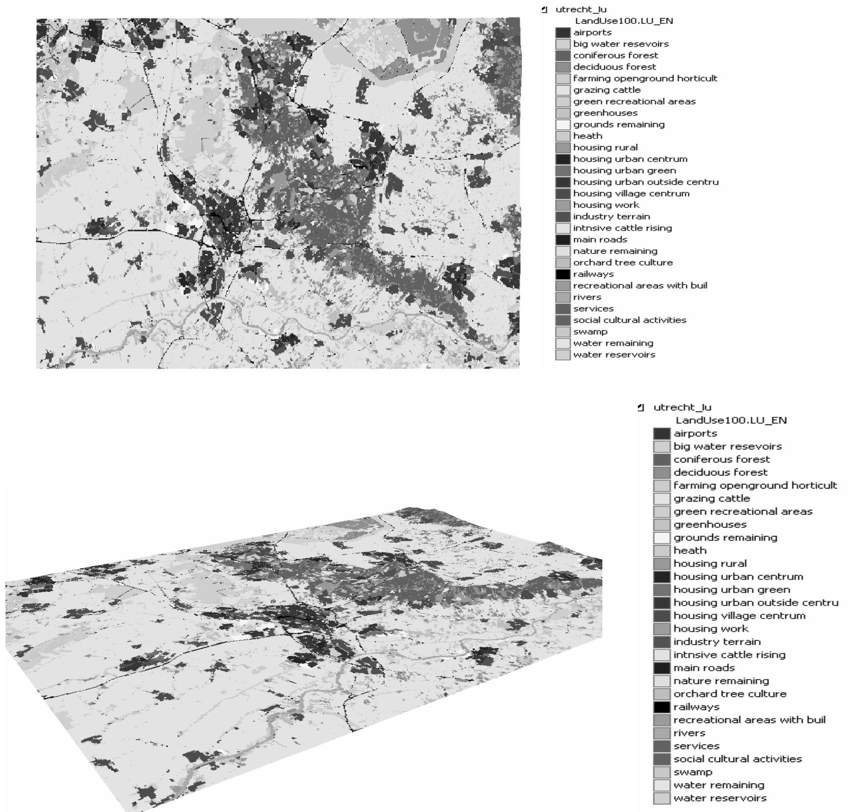

Fig 1: 2D (top) and 3D (bottom) visualisation of 2D geodata (RuimteScanner output) by MOMOT, 2004

Three-dimensional and more-realistic visualisations convey more information about the landscape comparing to the 2D ones and it seems that most users can easily read and understand them (DIBIASE, 1990; BISHOP, 1994).

Regrettably most scenario output studies create 2D raster dataset. To offer a more realistic understanding the 2D-raster dataset has to extend with representative 3D-objects. These 3D-objects should represent real world objects. The combination of 2D raster data and 3D-objects could offer a 3D-visualisation that offers more realism that fits better with the cognitive maps of most users.

A 3D-object is primarily constructed by geometric features like vertices, edges and faces (defined on X-, Y- and Z-coordinate system). This geometry could be very basic, like a plane or a cube object. These basic 3D objects are called 3D-primitives4. To improve the realism-look the geometry can be refined. This refined geometry is specified as compound object.
To visualize these 3D-objects the objects have to be rendered. The rendering result will be based on the type of bitmap to be used. Some bitmaps represent only one single colour based on an RGB-colour scale. Other types of bitmaps are photo-realistic bitmaps (pictures), bump maps that represent 3D-texture, alpha-maps that create transparency and gamma-maps that create reflection. The combination of this bitmaps could lead to very realistic visual representations. The information density, defined in pixels or dots per inch, seriously influences the level of reality.

Table 2 shows the different combinations between geometry and bitmap specification. The first column mentions the different geometries, while the first row represents the types of bitmaps. The photo-realistic picture of cell 1.b is put on a simple geometry, a plane. Cell 2.a shows a 3D-scene, a composition of different 3D-objects out of 3D-primitives that have been rendered by use of simple low resolution bitmaps. The same kind of scene is shown by cell 3.c. In that case the geometry of the scene exists of different compound objects that have been rendered by use of multi-layered complex, high resolution bitmaps.

3D-objects			
\geometry		**\bitmaps**	
	low resol.	high resol.	multilayer
planes	1.a	1.b	1.c
primitives	2.a	2.b	2.c
compound	3.a	3.b	3.c

Table 2: components of 3D objects

3 2D geodata into 3D visualisation

A number of authors [APPLETON ET AL, 2002; BALL, 2002; TRESS ET AL, 2003] did work on the type and importance of 3D visualization in strategic planning and operational planning. According HOOGERWERF (2004) the role of so-called semi-realistic 3D visualization could be crucial to create understanding and involvement of stakeholders.

To create a 3D-visualisation of the 2D scenario output the first option is based upon the transformation of the grid data into a 3D semi-realistic visual representation like presented by figure 2. This intentionally means that 3D-objects have to be created and will be linked

[4] see 3D Studio Max by Discreet ©

to the output data. In other words, the geo-referenced data, still two-dimensional, is visualised by help of related 3D objects.

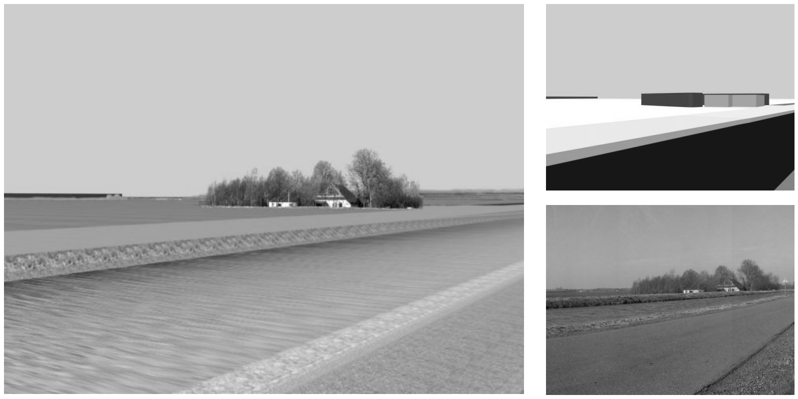

Fig.2: Left: semi-realism; upper right: conceptual; lower right: photo-realism (HOOGERWERF, 2004)

Table 2 shows this intended option via the link between table 1 (the division between geodata and visualisation data) and 2 (construction of 3D-objects) that finally offers a 3D implicit or explicit animation.

3D-objects			
\geometry	**\bitmaps**		
	low resol.	high resol.	multilayer
planes	1.a	1.b	1.c
primitives	2.a	2.b	2.c
compound	3.a	3.b	3.c

	GeoVisualisation			
GeoData	2D	2D + ΔT	3D	3D + ΔT
2D (raster)				
2D + Δt				
2.5D				
2D + Δt				
3D				
3D + Δt				

Table 2: The VisualScan LUI approach: a link between georeferenced 2D-geodata and 3D-objects

In our application it was decided upon to use a grid cell size of 100 meters by 100 meters[5] as a starting and reference data set. It has to be mentioned that the spatial configuration of 3D-objects within one grid of 100 by 100 meters for future situations is not known. For that reason 3D-objects have been designed and by use of these 3D-objects so-called 3D-models or Land Use Icons (LUI) of the 29 land use types are constructed. Each LUI represents a landscape 'stamp' which represents the imagined landscape for a certain type of land use. To conclude, these LUI are the basis for a semi-realistic representation and are intentionally meant to be stand alone 3D-models.

These LUI have originally been constructed by using 3D Studio Max 6. Every 3D-model has its own geometrical definition. The geometrical definition could range from very simple to complex. The bitmaps used for creating a semi-realism are also ranging from one simple to more combined and complicated bitmaps (figure 3). The last ones are used when semi-realism couldn't visualized by the geometry as such

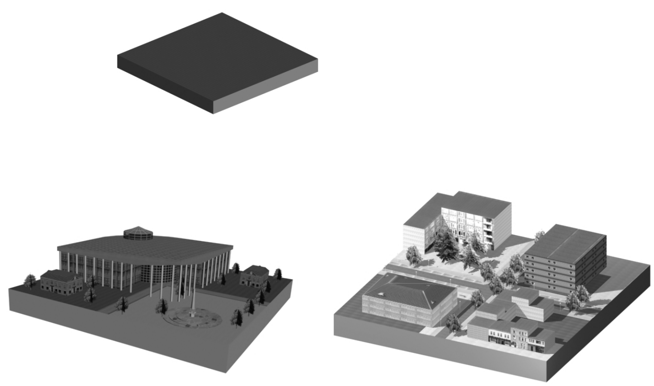

Fig 3: LUI: Simple geometry and bitmap (upper), complex geometry and simple bitmaps (left under), complex geometry and bitmaps (right under)

All the LUI have been designed. It means that each of them is based on a certain imagination of the (future) configuration of the physical space taking into consideration the expression of the land use type adapting certain social and technological developments.

[5] 100 * 100 meters is a size that is often used in the Netherlands to define land use activities (animals/ha; trees/ha; production/ha, costs/ha) and landscape constructions (houses/ha; green space/ha; parking places/ha; etc.)

[6] Discreet, 2003

Developing icons means a design task; a land use type in a particular scenario could be visually expressed by a specific LUI. In this example the rural icons have been based on contemporary expressions of nature and agricultural activities, the infrastructural icons too.

4 Construction of 3D landscapes

This first option is applied on data base principles and operated via modified game-tools technology to translate the two-dimensional grid data into a three-dimensional visualisation. Via the developed application (called VisualScan) each of the different grid cell values can be connected to a dedicated 3-dimensional land use icon (LUI) by a conversion of the dominant land use class into an RGB-color value. The transformation of the scenario output grid delivers a so-called LUI-link map. The LUI-link map is a plain BMP-file.
First the application links the LUI-link map (eg.the color red in figure 4) to the related LUI, which represents a kind of land use. Afterwards the application renders the composition of LUI into a 3D-scene (a virtual reality model). This scene we call the VisualScan Scene.

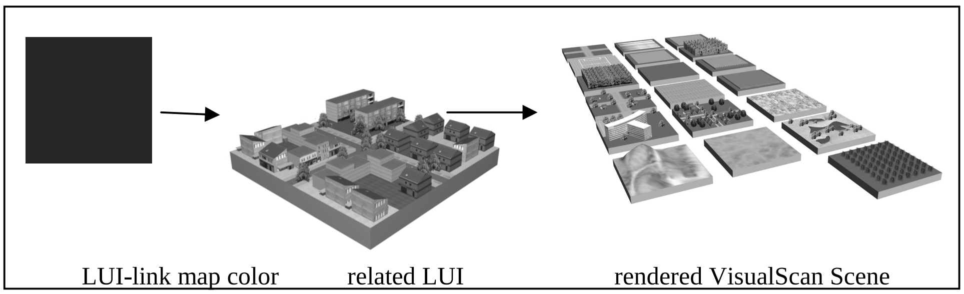

Fig 4: from 2D data into 3D visualisation: subsequently phases

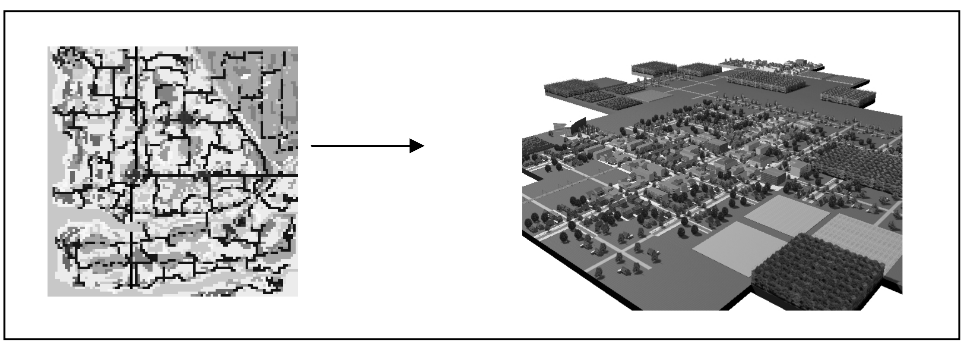

Fig 5: from 2D raster data into a VisualScan Scene

Finally the application offers a Visualscan scene (figure 5) that could be used as an implicit or explicit animation. Thanks to the game tool environment a real-time rendering offers a good environment for explicit and implicit animation.

5 Land use: now and then

The VisualScan application is beneficial to scan visually the differences between two different scenario-based landscapes. However the comparison between a future landscape and the current landscape could lead to misinterpretations due to the fact that the current situation is known by some users. Especially stakeholders who known the real world situation or the ones who are familiar with the topographic maps (in the Netherlands based on Top10vec data) will miss details of the location, especially in relation with their individual cognitive maps. LYNCH (1960) already mentioned landmarks, nodes, routes, edges and areas as primary features of relevance of which a cognitive (mental) map consists of. In other words, the visualisation model needs to meet the users' expectations and knowledge about an area. When the 3D scene would have a too abstract 3D object configuration and for that reason differs too much from the cognitive maps, it creates difficulties for recognition and interpretation. For simple interpretation of a visualisation, especially taking into account land use characteristics, it seems to be necessary to apply objects that visualize the features mentioned by Lynch.
Also AL-KODMANY (2001) has considered cognitive aspects in his research on web interface design, graphics and cartography to communicate urban design. The theoretical framework for studying cognitive maps, urban form and spatial relationships of cities (LYNCH, 1960), was used by AL-KODMANY to create cognitive maps for community planning. This framework views a city as a web of paths and nodes that are surrounded by edges and contain districts and landmarks. By means of visualizing the content of this framework in maps for community planning the residents' perception of their community could be taken into account.

In the LUI approach the scenario based output and the current land use situation are all based on grid data. All these grid data are transformed into 3D scenes by using the same land use icons. It means that known landmarks, nodes, etcetera are not represented which could lead to misunderstandings.

For that reason another option has been worked out (MOMOT, 2004) by which we try to link the scenario based grid data with the topographical data set that describes the current landscape (the best option in the Netherlands will be Top10Vec7).
For this option we started to use GIS software with 3D visualisation (!) capabilities 8 and the Top10Vec data (BULENS ET AL, 2000). The creation of the visualisation existed out

[7] Top10Vec is the Dutch National Topographic geo-data set that offers at least a 1:10000 map resolution quality
[8] In this project ESRI ArcScene (ArcGis 9.0) has been used

of two different procedures. Firstly all 2D-building features were selected and extruded: the construction of a 2.5D data set. Secondly all 2D tree features were selected and geometrically transformed into point features. 3D-objects (mainly tree-representations) were selected from an included 3D-objects database and linked to the point features. After rendering the geodata including 3D-objects and bitmaps it offers a 3D visualisation as shown by figure 6.

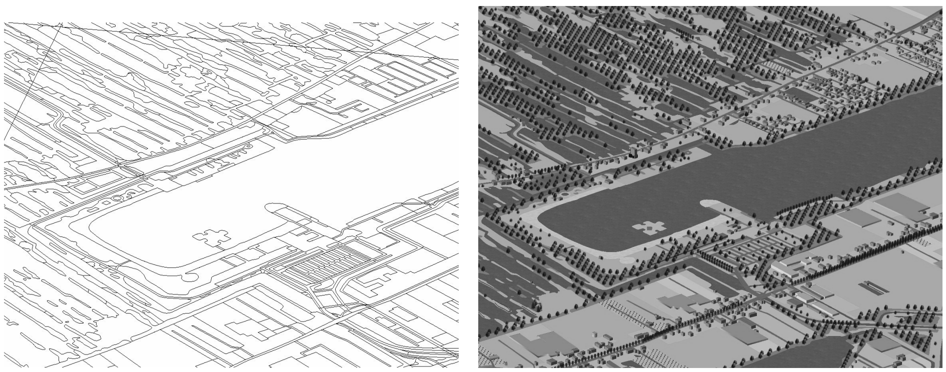

Fig 6: Part of Top10 vector and the visual representation (Momot, 2004)

As demonstrated by the LUI it is quite difficult to know how the projected land use classes will change the landscape in 30 years (APPLETON ET AL, 2002). For that reason the existing landscape data (Top10vec) is analysed in such a way that features that will not change within the next 30 years could be selected. The following assumptions have been made (MOMOT, 2004):

- the main road network will remain unchanged. New ones will be constructed.
- the existing network of canals and rivers will not change;
- the existing trees in rows will remain the same through 30 years, because most of these trees are located along the main road network and canals.
- the areas of which the land use class will not change keep the same landscape characteristics.

Based on these assumptions an overlay of the current topographical data and the new land use classes (the grid cell output) has been made. The overlay delivers a new geodata set that represents the area that will change including the features as mentioned by the assumptions. The areas that the land use classes will not change keep the same. After visualization, like described before, the land use classes that will change are shown by white squared underground with on top topographical features (infrastructure, water and trees). The unchanged land use classes are visualized by all topographic features (figure 7) from the original geodata set (top10Vec).

Finally the white squares have been filled in by a colour that represents the dominant land use class. This option is called the landscape feature approach (figure 8).

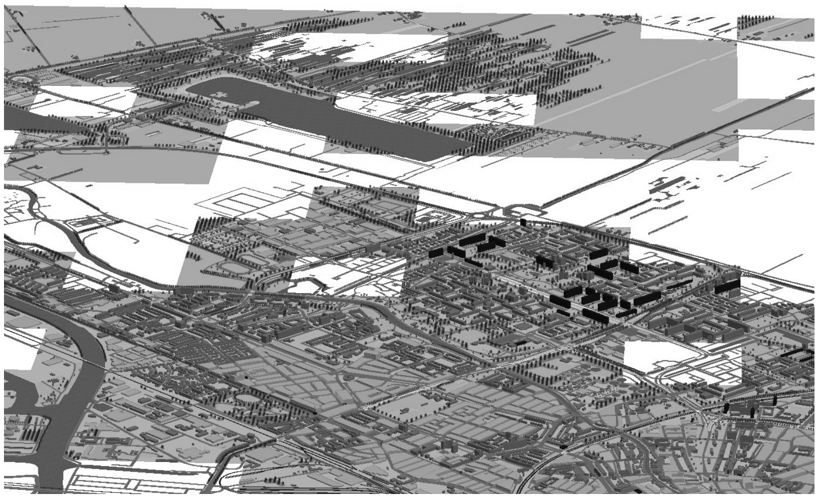

Fig. 7: Current land use (coloured) and changed land use areas (white)

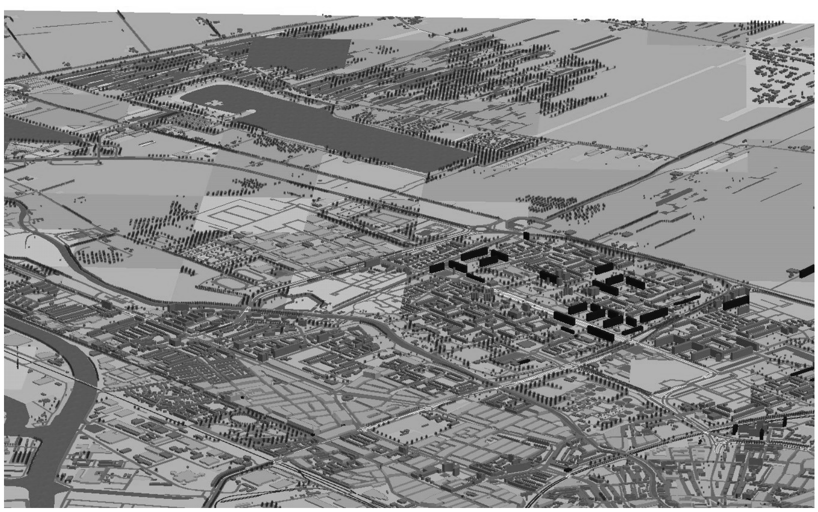

Fig. 8: land use changes: changed land use areas have been filled with colours of the dominant land use class

6 Conclusions and discussion

The paper presents the transformation of grid data that presents future options into 3D scenes. This transformation is called the Land Use Icon (LUI) approach. By this approach icons are designed to represent land use classes. The benefit of this approach is the high level of realism of the 3D-visualisation, however the drawback seems the missing link with the cognitive maps of the users. For that reason a second approach, the Landscape Feature approach, have been tried upon. In this approach the current situation, based on topographic vector data, is visualized three-dimensionally and overlaid with the grid cell data. The benefit of this approach seems the link with cognitive maps of the users. The drawback is the limited visualisation of the grid cells that represents the expected land use change and for that the landscape transition.

For the near future we expect to run into mixed 3D visualisations that are based on a combination of the Landscape Feature approach and the Land Use Icon approach. To support the link with the cognitive maps of users the landscape feature approach based on high quality topographic geodata describes the existing landscapes. Linked with grid data that represents future oriented land use it offers a readable and understandable 3D visualisation.
The areas that could change will be transformed by icons that fulfil the constraints according the decisions based on landscape features that will not change at all (eg. main road network, canals and rivers). It means that the spatial configuration of the 3D-objects in LUI have to be arranged by these constraints.

To find out if this mixed 3D visualisation will work out significantly a number of user tests should explore the possible added value of understanding the impact of land use changes on the landscape.

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