DIE ERDE **143** 2012 (1-2)	Miscellaneous Issue	pp. 1-21

• *Landscape visualisation – Digital terrain model – Generalisation – Comprehensive cognition*

Claus Dalchow, Joachim Kiesel and **Gerd Lutze**

Visualisation and Interpretation of Moraine Landscapes in North-East Germany – the Ideal View on Landscape

Visualisierung und Interpretation von Moränenlandschaften in Nordostdeutschland – Der ideale Landschaftsblick

With 13 Figures

Visual representations of the earth's surface can nowadays be produced on the basis of data with high resolution and accuracy. Especially 3D-visualisations can provide an excellent basis for "comprehensive cognition". However, specific accentuations and generalisations are necessary to turn them into an adequate cognitive tool. Here we introduce a specific generalisation approach, presented by visualisations of two lowland landscape sections in the state of Brandenburg, Germany.

1. Introduction

To receive comprehensive, area-wide information about parameters characterising the land surface, the options are: conventional ground survey maps and, emerging during the past decades, satellite images and digital elevation data. Cognition is most fruitful, when a cross-referencing of all of these data systems is undertaken (*Donner* 2008). Improving GIS capabilities, data storage capacity and data availability strongly support the trend towards computer-based visualisation of geographical data, especially landforms and landform elements.

Previous to the digital age, visual combination of terrain information with other information layers was common practice. It was mostly done by means of hand-drawn 3D-block-diagrams published in schoolbooks as well as in scientific literature (e.g. *Solger* 1931, *Solger* 1935, *Wagenbreth* and *Steiner* 1990). For special purposes (natural heritage representation etc.) painted hand-crafted models of gypsum or wood were also manufactured.

Derivation of the elevation data from contour lines for the purpose of drawing 3D-visualisations (block diagrams) is very labour-intensive. Therefore most 3D-visualisations were drawn according to geographer's imagination of the morphographic reality. This practice gave 3D-visualisations the status of being the result of subjective personal efforts (with an unknown bias or error). Thus, 3D-visualisations (and to a smaller extent also profile sections and 2D-visualisations) of the pre-digital age were certainly suitable for teaching and knowledge transfer, but normally less applicable as a cognitive tool for discovering new facts concerning relief or the relation of relief to other information layers. Pre-existing ideas were materialised by 3D-visualisations, but no new ideas drawn out of them. As nowadays combinations of terrain data with other information layers can be produced in an unbiased form by elaborated GIS methods, digitally generated 3D-visualisations are an objective, neutral derivation from reality and thus more reliable and promising as a tool for subsequent cognition (by discovering spatial correlations, patterns, structures etc.).

Thus the purpose of this article is to illustrate that increased cognition can be achieved by generation of digital 3D-visualisations at landscape scale. This will be demonstrated by examples from low-relief areas, where the unveiling of hidden watermarks of structure and pattern are most effective. Simultaneously, the potential of creative accentuation of land surface parameters as a cognitive tool will be demonstrated.

2. State of the Art

Most research on visualisation of landscape and land surface is done to achieve photorealistic results of actual and possible future landscape situations for planning purposes (*Bishop* and *Lange* 2005a, *Wissen* 2009). The planning alternatives or future scenarios mostly refer to land cover changes, development projects, impacts of infrastructure construction and mining (*Buhmann* 2002) or of power generation, e.g. dams or wind energy parks (*Hehl-Lange* and *Lange* 2005). Similar approaches are carried out for urban areas (*Glander* and *Döllner* 2008, *Ross* et al. 2009). *Haeberling* (2004) defines modelling, symbolisation and visualisation as basic steps of 3D-visualisations and introduces related key graphic variables in an approach for standardisation of the new technology, while *Haeberling* (2005) points out the great potential of visualisations for planning tasks, scientific presentation, thematic analysis and simply for quick overview.

While planning increasingly relies on participatory approaches, the interactive potentials of visualisation tools gain importance (*Bishop* and *Lange* 2005a, *Schroth* 2009, *Paar* 2006).

Hruby and *Miranda Guerrero* (2008) distinguish the following changes of paradigms within the discipline of cartography since 1960: automation, GIS-based map generation, democratisation of visualisation and finally multimedia cartography. They state that technical progress ran faster than theoretical development, leading to a crisis in cartography with the emergence of new disciplines like visual analytics and spatial information theory.

Visualisation applications are also accompanied by theoretical considerations on the advantages of visual interpretation via comprehensive cognition ("*verstehendes Beobachten*", see *Donner* 2008), highlighting the potential of evaluations based on visualisations – a methodology similar to the commonly employed imaging techniques used in modern medicine.

Besides, for engineering purposes and geo-ecological assessments, numerous overlay operations including spatially comprehensive data collection of parameters relating to land surface qualities are carried out by standard GIS applications. However, the visual results of these computations mainly demonstrate the identified areas of interest (representing threatened areas as well as those of favourable qualities), but they are not designed to foster cognitive processes.

One discipline with special demand for visualisation is geomorphometry, the "science of

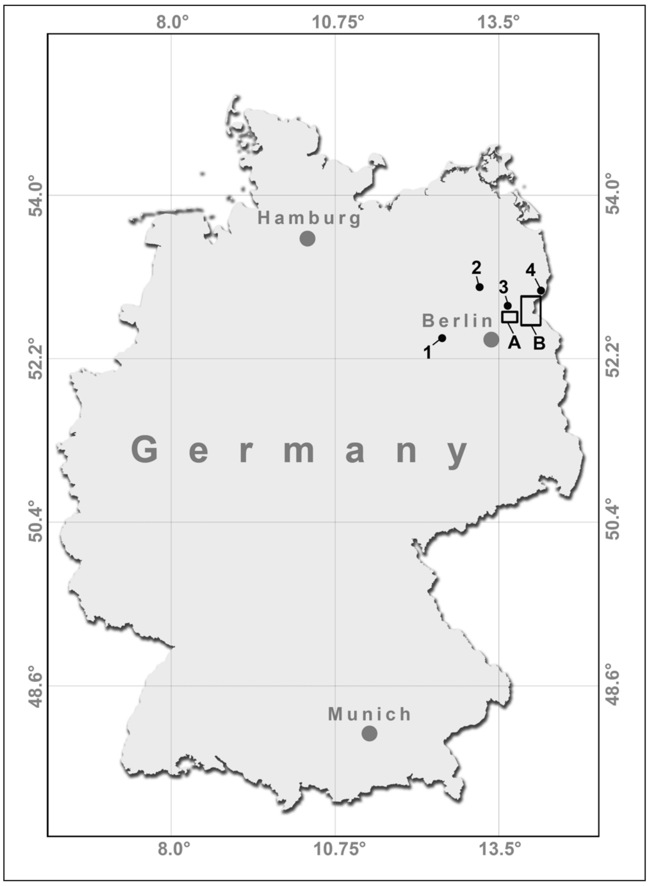


Fig. 1 Location of digital terrain data sets used for explanation purposes and of the demonstration sections presented in Section 4. 1: Rhinow (see *Fig. 2*), 2: Templin (see *Fig. 3*), 3: Eberswalde (see *Fig. 4*), 4: Schwedt (see *Figs. 5* and *6*), A: Demonstration section "Dune field south-west of Eberswalde" (see *Figs. 10* and *11*), B: Demonstration section "Neuenhagen area" (see *Figs. 12* and *13*) / *Lage der zu Erklärungszwecken vorgestellten Datensätze digitaler Geländemodelle sowie Lage der Beispielgebiete aus Kapitel 4. 1: Rhinow (siehe Fig. 2), 2: Templin (siehe Fig. 3), 3: Eberswalde (siehe Fig. 4), 4: Schwedt (siehe Fig. 5 und 6), A: Demonstrationsgebiet „Dünenfeld südwestlich von Eberswalde" (siehe Fig. 10 und 11), B: Demonstrationsgebiet „Neuenhagener Umgebung" (siehe Fig. 12 und 13)*

topographic quantification" with its operational focus on "the extraction of land-surface parameters and objects from digital elevation models" (*Pike* et al. 2009: 4). The recent overview on concepts, software and applications in geomorphometry by *Hengl* and *Reuter* (2009) offers numerous 2D/3D-visualisations of morphometric parameters. However, they rather present the spatial distribution of results than inviting users to start a thematic analysis.

For creatively focused, accentuated representations of landscape, only few overlaps into the world of research have been attempted for virtual reality, photorealistic presentations, animations or real-time approaches. There is also no affinity to visualisation techniques used for computer games.

On the other hand, methods of geographically oriented and earth-surface related data processing for 3D-representation (*Trapp* and *Döllner* 2009), generalisation procedures (*Trapp* and *Döllner* 2008) and scaling approaches (*Gallant* and *Hutchinson* 1997) provide substantial basics for our approach. One of the most important prerequisites to promote cognitive processes and better understanding of landscape structures and processes is an adequate level of detail (*Gallant* and *Hutchinson* 2008). This refers to the morphologic structure of the evolved terrain model (*Reuter* et al. 2006; *Wolock* and *McCabe* 2000) as well as to the draped thematic layers (*Glander* and *Döllner* 2008). It should be noted that with many visualisations, specifically regulated levels of detail are necessary to reduce the processing time and computer load (*Döllner* and *Buchholz* 2005).

A decreasing level of detail is often achieved by increasing the raster cell size. This is a problematic procedure regarding preservation of the higher moments of elevation models (*Grimaldi* et al. 2005), which is necessary for identifying steep slopes and curvatures. We introduce and apply the procedure of 'density estimation' (*Silverman* 1986) to enable generalisation of elevation and thematic data with a free choice of scale and raster resolution.

3. Material and Methods

Our approach to generate high-quality visualisations combines GIS-based spatial neighbourhood analysis methods with the power of current advanced image processing tools. By this combination the main characteristic of the surface and the thematic layer are emphasised whilst simultaneously nonessential features are suppressed. All data sets used to illustrate different types and qualities of digital terrain models as well as to create our results for the demonstration sections show areas in the north-western part of the state of Brandenburg, Germany (*Fig. 1*).

3.1 Types and qualities of digital terrain models

The availability of an adequate digital terrain model is – besides thematic maps – the crucial precondition to generate high-quality landscape visualisations. Digital terrain models (DTM, *Fig. 2a*) in their strict meaning describe the earth surface without buildings and vegetation, but with anthropogenic cuts and fills. Surfaces of natural or artificial water bodies are supposed to have a level surface at its mean elevation. In contrast to terrain models, digital surface models (DSM, *Fig. 2b*) include data caused by buildings and vegetation.

Both types have certain advantages in their specific fields of application. Any mixture of both types considerably reduces its range of applicability. The terrain model is used for two different visualisation applications: firstly for generating relief parameters represented in 2D-layers (e.g. slope, curvature, lighting, elevation level); secondly for generating a basic carrier ("base block") for 3D-visualisations on which a 2D-layer is draped ("drape layer", see Section 3.2). For the "drape layer" application highly detailed models are required. For the application as "base block", a considerable degree of generalisation is mandatory. Less strict are the demands on terrain models concerning the precision of horizontal and vertical position. However, because of the dual use of the data, minimal standards should be kept. Low horizontal resolution terrain data are difficult or impossible to use in 3D-modelling of small sections. Low vertical resolution may result in stair-like views of the relief. Very high horizontal resolution, prevalent in data from laser scan scenes, results in a disadvantageously high level of detail because of sheer data amount and inadequate surface roughness.

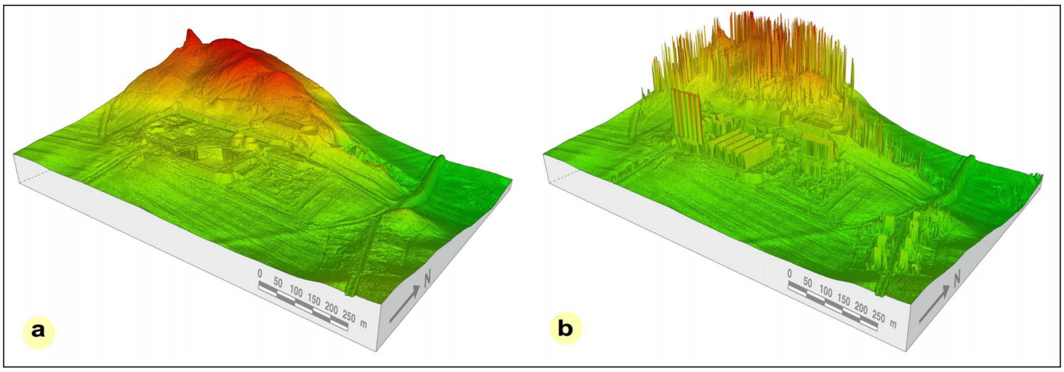


Fig. 2 Laser scan elevation data (resolution 0.5 m) of a farm stable complex with its surroundings at the village of Rhinow, north of Rathenow, Germany (1000 m x 650 m, coordinates 12°22'04"/52°44'42" to 12°22'54"/52°45'05"); generated from elevation data sets provided by the state of Brandenburg land survey; a: Digital terrain model DTM 0.5 with surface artefacts from buildings and vegetation, b: Digital surface model DSM 0.5 / *Laserscan-Höhendaten (Auflösung 0,5 m) einer Stallanlage und ihrer Umgebung bei Rhinow nördlich von Rathenow (1000 m x 650 m); generiert auf Basis der von Landesvermessung und Geobasisinformation Brandenburg bereitgestellten Höhenangaben; a: Digitales Geländemodell DGM 0.5 mit Oberflächenartefakten von Gebäuden und Vegetation,* b: *Digitales Oberflächenmodell DOM 0.5*

Additionally, the specific method employed to produce a terrain model is of importance, as there may be artefacts that are especially inappropriate for the purpose of visualisation.

Figure 3 shows the DTM25 of a surface section south of Templin, Brandenburg. In its western section a stair-like pattern of 10 cm intervals is visible, resulting from the vertical resolution in the decimetre range. In the central section, significant square artefacts show up, resulting from the generation method used for the DTM25. *Figure 4* (valley of Eberswalde, Brandenburg) has stair-like patterns from a vertical resolution in the metre range. Finally *Figure 5* (area of Schwedt, Brandenburg) shows artefacts within the official DTM25, resulting from the method of DTM generation applied by the land survey department.

To generate satisfying visualisations, an adequate terrain model with sufficient resolution and precision is necessary. Additionally, a methodology is needed which is able to improve partly inadequate terrain models and also to generalise them to a scalable degree, like shown in *Figure 6* for the same section as *Figure 5*.

3.2 Approach to create highly comprehensible 3D-visualisations

To create 3D-visualisations a base block carrying the thematic information layer is required. This "base block" (*Fig. 7*), on which a thematic layer is draped upon, has to be generalised to a considerable extent, in order to compensate artefacts which gain dominance especially in highly exaggerated lowland sections. A terrain model like the one presented in *Figure 5* would be absolutely inadequate for the use as a base block.

The final three-dimensional impression, however, is established to a high portion by the contents of

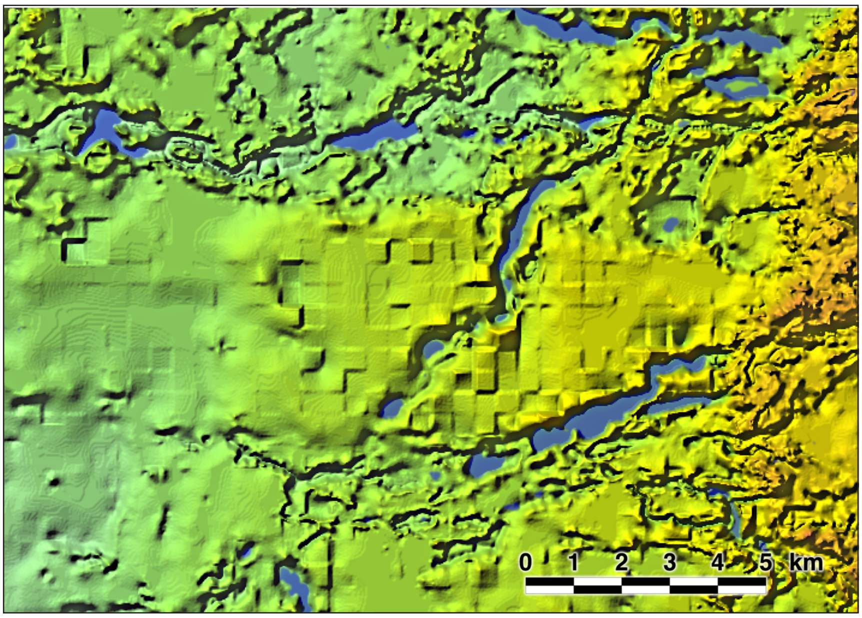


Fig. 3 Artefacts of the official DTM25 south of Templin (position 13°26'08"/52°51'47" to 13°41'50"/53°04'58"). / *Artefakte des amtlichen DGM25 südlich von Templin*

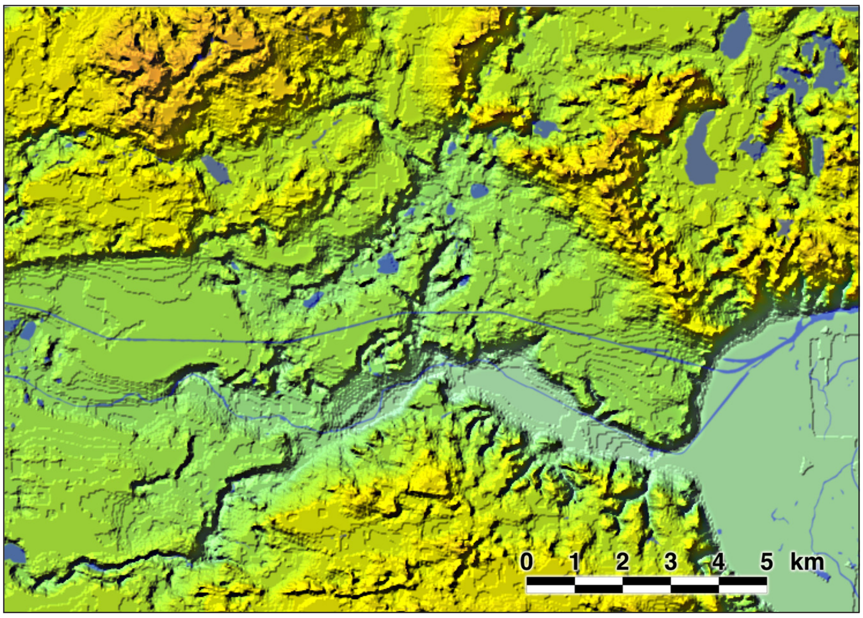


Fig. 4 Terrain levels of the DTM25 of Amt für militärisches Geowesen (AmilGeo), valley of Eberswalde (coordinates 13°43'08"/52°48'04" to 13°59'21"/52°55'15") / *Höhenstufen des DGM25 des Amtes für militärisches Geowesen (AmilGeo)*

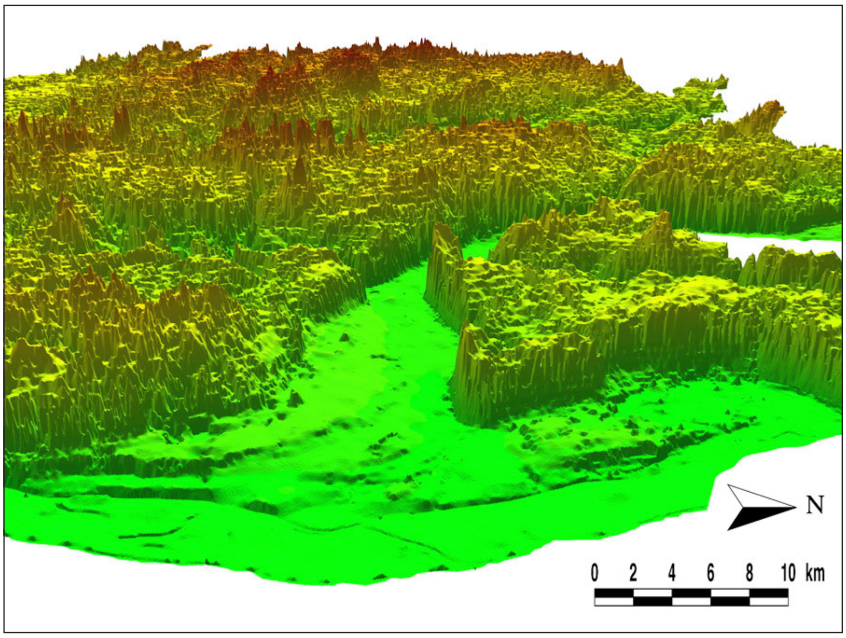


Fig. 5 Official DTM25 for the Schwedt area (vertical exaggeration 1:50; coordinates 12°17'09"/ 52°58'32" to 14°29'20"/53°37'29") / *Amtliches DGM25 der Region Schwedt (50-fache Überhöhung)*

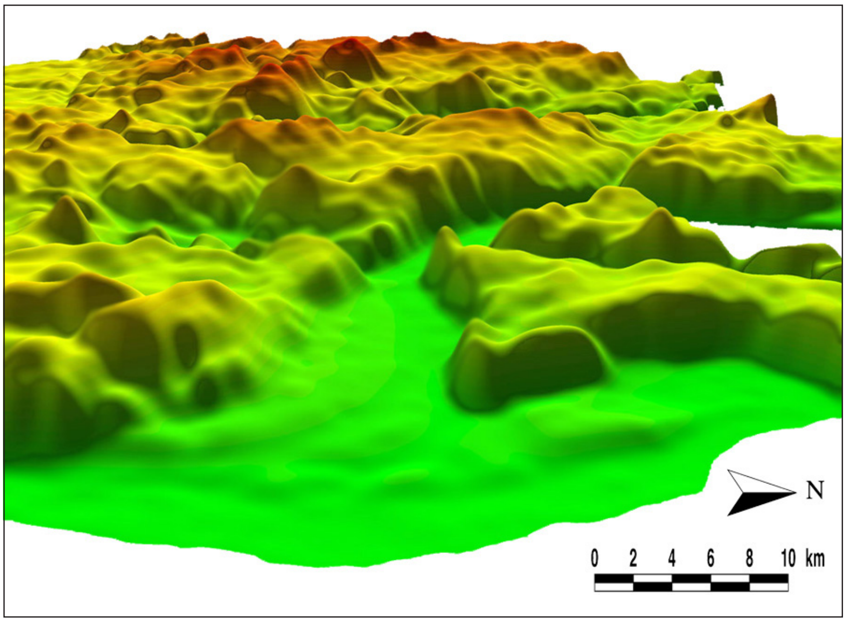


Fig. 6 Generalisation of the official DTM25 for the area of Schwedt (coordinates 12°17'09"/52°58'32" to 14°29'20"/53°37'29") / *Generalisierung des amtlichen DGM25 der Region Schwedt*

the "drape layer". On this drape layer different lighting effects are combined with shades derived from relief parameters like slope gradient or curvature. The degree of generalisation of the terrain model is of decisive importance for the quality of the relief parameters represented on the drape layer. If for this purpose the terrain model is generalised too much, important details are wiped out. If in contrast a non-generalised terrain model is used, the intended features may drown in "noisy" details.

The underlying conflict can be solved by identifying and applying the most adequate overlay function (addition, multiplication etc.) for combining the parameters presented on the drape layer. By this both large-scale landforms and small features become recognisable in combination. Especially for low relief sections this approach generates views that make wide sections applicable for comprehensive cognition, as if they were presented to the viewer's eye on a desk. If helpful for cognition, highly differentiated structures like trenches and farm roads can be added. The optimal selection and combination of thematic layers and relief parameters is the crucial factor determining any vivid visualisation.

Besides the application of well-established methods of overlaying with its adequate operators and selectable intensities, the provision of terrain models with scalable high-quality generalisation is a specific challenge. This generalisation requires more than just standardised smoothing. Rather, small-scale "noise" has to be suppressed while small-scale extremes and sharp edges have to be preserved, as well as large-scale landforms. To meet these demands, the method of point density with Kernel Density Estimation within the Moving Window approach (*Silverman* 1986) was chosen.

3.3 Scalable generalisation of terrain data based on Moving Window Technology

3.3.1 Demands on generalisation of terrain

All phases of processing have to aim at preserving the general form of the relief, including level and inclined areas, edges as well as minima and maxima. A scalable generalisation function which preserves the substantial relief structure while suppressing non-substantial relief elements and artificial noise will be universally applicable. The intensity of generalisation has to be freely scalable.

The official DTM25 has a heavy "noise" aspect and already in its first derivative (slope angle) it is dominated by effects resulting from this noise. It is obvious that aerial photographs or satellite images show extreme deformation when draped over a highly exaggerated "base block" generated from this DTM. The following sections further investigate and describe the application of a density function with kernel estimation, illustrating the excellent results achievable by generalised terrain models.

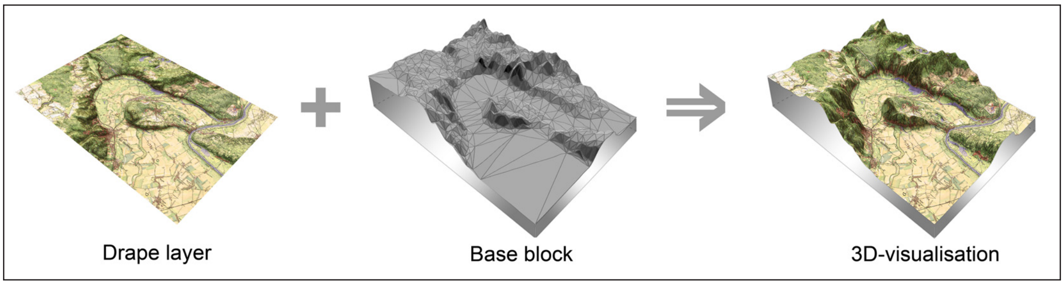


Fig. 7 Application of the drape layer to the base block / *Anwendung des Überzug-Layers auf den Basisblock*

3.3.2 Characteristics of the Moving Window functions

The Moving Window Technology (*Isaaks* and *Srivastava* 1989) is a well-known frame technology with several degrees of freedom which, at adequate parameterisation, meets all requirements listed above. The basic principle of this approach is to consider and assess each cell within the context of its neighbourhood (neighbouring operation according to *Pike* et al. 2009: 30). The size of this neighbourhood determines the degree of generalisation, which is continuously scalable. The shape of the neighbourhood and the type of the function applied within have to be carefully selected according to the purpose. Referring to a DTM, this means that each raster cell is subject to a transformation with account for its neighbouring raster cells. In a subsequent phase the next raster cell is treated similarly. For this purpose, the DTM has to be first transformed into a point matrix with the elevation assigned to each point as its weight.

Besides the definition of the size and shape of the Moving Window (neighbourhood), the choice option of the function to be applied on all raster cells within the window provides another degree of freedom.

The selection of the most adequate function to be used in the Moving Window procedure is essential for the quality of the generalisation. One basic requirement is that the arithmetic mean of all raster cells of the processed area remains constant. This complies with the demand that the volume of matter represented by the DTM section remains constant, too.

Generally, the median function suits best, as it preserves edges remarkably well, extinguishes extremes and suppresses noise as well as casual irregularities. But as many DTMs are still generated based on digitised contour lines, the median function unveils and amplifies the given oscillating slope angles while optimally suppressing noise. The arithmetic mean function, however, overacts in smoothing and reducing the extremes. To avoid those disadvantages, different density functions were investigated.

3.3.3 Characteristics of density functions

As the effect of density functions within a Moving Window strongly depends on the chosen relief section, and the actual window position overlaps the preceding window position to a great extent, the results are difficult to interpret. For this reason an experimental setting containing a simplified terrain model according to *Fig. 8a* was designed. This terrain model consists of several isolated cells with similar elevation data, forming columns. The density of the columns varies over space, building up different groups.

Figure 8b presents the result of a generalisation based on a density function within a static window, which creates larger raster cells. Here, the degree of generalisation and the resolution of the resulting distribution are not independently selectable. The resulting distribution shows many discontinuities. A density function like this is absolutely inadequate for the generalisation of terrain models.

The density distribution in *Figure 8c* results from a simple density function within a circle-shaped Moving Window. Here only the number of the columns within the specific window position is considered. The result is a much smoother distribution which nevertheless shows artefacts and "table mountains". This is due to the moving of the window in steps of the size of one full raster cell, including and excluding columns in full numbers. Also, a constant number of columns may remain included over several steps of moving.

The simple density function disregards the spatial distribution of the columns within the window.

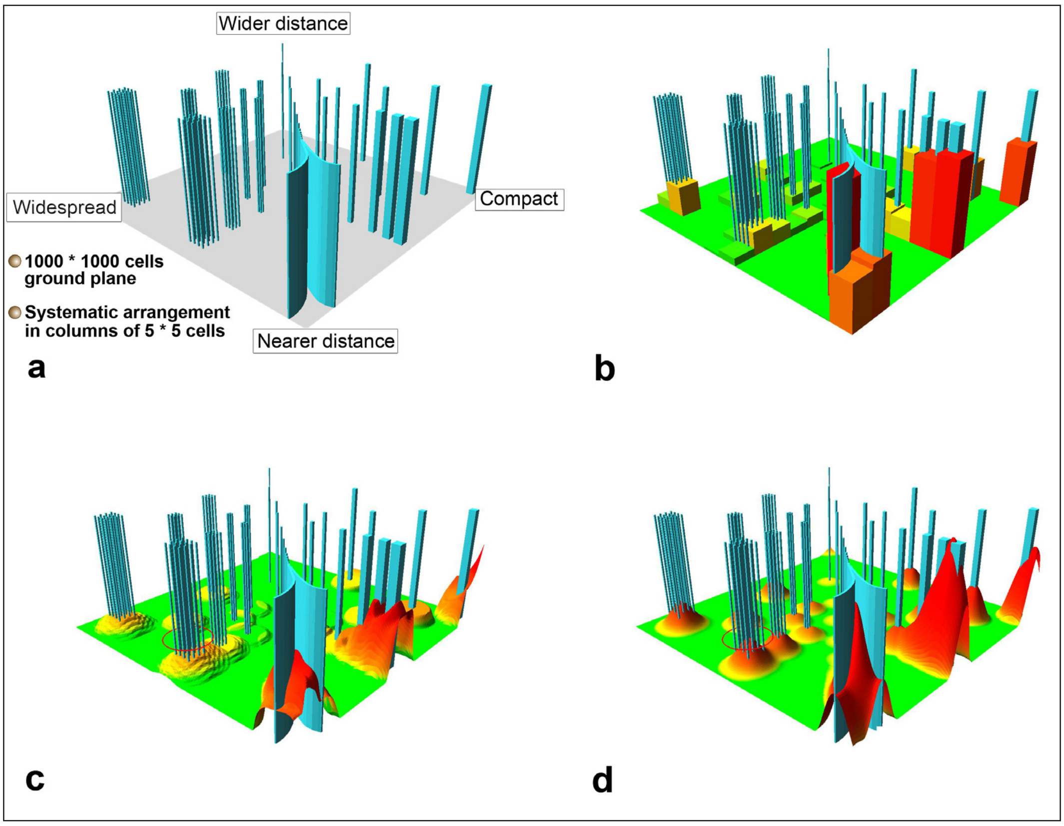


Fig. 8 Generalisation methods using different functions demonstrated in an experimental setting. a: Experimental setting, b: Generalisation over density by an enlarged raster cell, c: Generalisation with simple density method, d: Generalisation with kernel density estimation method / *Generalisierungsverfahren unter Verwendung verschiedener Funktionen, dargestellt in einer Experimentalanordnung. a: Experimentalanordnung, b: Generalisierung über Dichte in einer vergrößerten Rasterzelle, c: Generalisierung mit einfacher Dichtemethode, d: Generalisierung mit Kern-Dichte-Schätzung*

This, however, is achieved by applying the Kernel Density Estimation Method according to *Silverman* (1986) which we adapted to raster data.

The density function with kernel estimation is consecutively applied for all points of the DTM via the Moving Window. The basic formula for the Kernel Density Estimation Method is presented in *Equation 1* (*Bailey* and *Gatrell* 1995). By this, each column is represented as a volume under a bell-shaped curve, reaching the value of zero at a distance r from the centre, as shown graphically additionally to *Equation 1* with values of $w_i = 1$ and $r = 1$. The formula works the following way: While moving across the target area, the Moving Window gathers all portions of volume within its range and assigns this sum of volumes to the cell at the centre of the window. By this approach the weighted cells of the DTM do not “act” suddenly, but spread their effect within the Moving Window.

By the transformation of each column into a symmetrical bell-shaped distributed arrangement with its volume equaling the elevation value (density function with kernel estimation) the result is different from a simple density function. In contrast to the simple density function the resulting column changes its elevation smoothly, when a new point enters the window (*Fig. 8d*).

The experimental setting shown in *Figure 8* also illustrates how in case of irregularly distributed points the density function with kernel estimation produces, against general assumption, concentration peaks close to point agglomerations. This means there are higher maxima and thus there is less levelling compared to the simple density function.

The experiment confirms that the density function with kernel estimation efficiently elaborates spatial differences while at the same time high densities remain concentrated at their actual position and artefacts are avoided or at least minimised.

The required computation times are notable, especially when striving for high degrees of generalisation for large areas, e.g. moraine plateaus with extensions of tens of kilometres, based on DTM25 data. A reduction of computing time especially for visualisation purposes can be achieved by defining a larger cell size for the generalised output relative to the input data cell size. In addition, the degree of generalisation may be adapted.

Special attention has to be given to the marginal belt of the area of interest and to areas of missing data. To avoid any incorrect decrease in density while processing these sections, the density has constantly to be related to the effective area of the Moving Window.

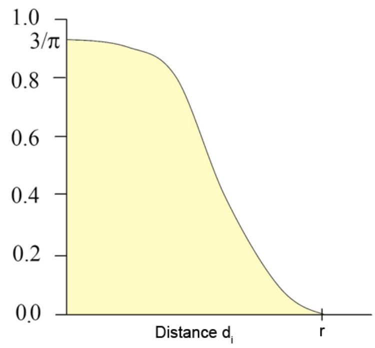
3.4 Location of demonstration sections

3.4.1 Demonstration section "Dune field south-west of Eberswalde"

At the dune field south-west of Eberswalde (see *Figs. 1, 10* and *11*), close to Melchow, south of the Eberswalde glacial valley, continental parable dunes are a common small-scale landform. These features developed under aeolian matter dislocation in dry and cold periods during the end of the Weichselian glaciation. After the establishment of a comprehensive forest cover of pine and birch during the Alleröd, the local forest

$$PD\left(x,y\right)=\sum_{i=1(d_i\le r)}^{n} w_i\,\frac{3}{\pi r^2}\left(1-\frac{d_i^2}{r^2}\right)^2$$

PD (x,y) = Intensity at position *x,y*
Wi = Weight of point *i*
Di = Distance between position *x,y* and point *i*
R = Radius of generalisation
N = Number of points



Equation 1 Kernel density estimation method according to *Bailey* and *Gatrell* (1995)
Methode der Kern-Dichte-Schätzung nach Bailey und Gatrell (1995)

retreated in the succeeding Younger Dryas. Material suitable for aeolian transport then formed large contiguous dune fields connected with deflation hollows along the sandar and glacial valleys. Natural forest fires, fire clearance and inadequate land use resulted in further aeolian activity from the Neolithic Age until the Modern Age (*Schlaak* 1997). Today these areas are almost completely forested with pines.

As a small-scale landform, the dunes accentuate the otherwise monotone level sandur areas and form an attraction for recreation purposes. However, recreational visitors have no opportunity to gain any overview concerning the distribution of the dunes. The forest-covered dune fields are not immediately comprehensible, neither by visual inspection nor via images from remote sensing.

3.4.2 Demonstration section "Neuenhagen area"

In the Neuenhagen area (northern end of the Oderbruch river plain, see *Figs. 1, 12* and *13*), strong climatic and geomorphic dynamics during and after the last glaciation formed an impressive Brandenburgian landscape section. Within this section, situated in an exposed position, there is the ship lift at Niederfinow (constructed 1927-34), a remarkable monument of German engineering.

The specific character of the landscape, however, can hardly be made aware to the visitors, because despite the remarkable differences in elevation (from 2 m up to 112 m a.s.l.), any overview of the landscape is fairly limited by vegetation and construction elements. Because of this configuration, the related landscape section including the terminal moraine at Liepe/Oderberg, the Neuenhagen peninsula and the lower Oderbruch is a promising challenge for landscape visualisation.

In addition, the demonstration section is of specific geographical interest for several reasons:

It covers the angular point at which the rolling hills of the Pommeranian terminal moraine, approaching from NW, hit the Eberswalde glacial valley. 16-15,000 BP the meltwater, in combination with the ancient River Oder, made their way from south-east and south through the area of today's Oderbruch until they turned to the West towards the Eberswalde section of the glacial valley (at the Eberswalde Gate / *Eberswalder Pforte*). The obvious reason for this westward turn was the blocking by the Pommeranian glaciation. Later on, after the ice had retreated, a northward breakthrough of the meltwater created a gap in the terminal moraine. Before this breakthrough, the last continuous flow through the Eberswalde glacial valley created the terrace at 36 m a.s.l. (*Liedtke* 1956/57, 1996, 2001).

The last significant event in the Oder valley was a covering by fine fluvial sediments resulting in a swampy floodplain (*Brose* 1994).

The Finow, as one of the few rivulets contributing to the river Oder from the West, flows through the Eberswalde glacial valley towards the lower Oderbruch. By headward erosion this rivulet incised the valley bottom of the former glacial valley, having progressed westward already halfway to the river Havel (*Dalchow* and *Kiesel* 2005). The landscape patterns originating from glaciation also have preconditioned the positioning of four canals built during the last 400 years.

The canal descent from the glacial valley bottom level at 36 m a.s.l. down to the level of the lower Oderbruch at 2 m a.s.l. was for a long time managed by lock systems. In 1934 the locks went out of action, as the new ship lift at Niederfinow began to operate. Resulting from the multiple construction phases, waterways are a dominant element in the described landscape section.

4. Results

4.1 Demonstration section "Dune field south-west of Eberswalde"

The dune field south-west of Eberswalde visualisation example (*Figs. 9, 10* and *11*) offers an excellent impression of the distribution and structure of a forest covered dune landscape – a view that never can be achieved by walking through or looking from above. The 2D-visualisation of *Figure 10* uses no underlying "base block" and the relief characteristics are shown by the use of colours ranging from light green to brown, augmented by exaggerated shadows and brownish darkening of steep slopes. A full 3D-visualisation (*Fig. 11*) appears, partly surprisingly, in this case less favourable, as it obscures the typical shape of the dunes, which is best recognisable in strict vertical view.

A detailed net of pathways and traffic infrastructure is shown, but no information on land use cover.

The predominantly western winds generated dunes elevating about 20 m above the surrounding surface with extended tails which spread about 60 m. The deflation hollows have a depth of just a few metres, related to the supposed primary relief. The conservation of the relief energy of these features became possible by rapid forest growth. However, great conservation efforts had to be made during the 18th century, when over-exploitation of the forest created bare sandy sites ("*Sandschollen*", see *Milnik* 2007) with reactivated sand dislocation. Not surprising, but nevertheless impressive is the adaptation of the traffic infrastructure going through and around the dune field. In the past planning for the overland road (today federal highway 2) and for the railway track Berlin-Szczecin, a convenient pathway was chosen to minimise cuts and fills. Detailed study of the demonstration section also unveils an ancient glacial channel along the actual rivulets Finow and Schwärze in the northern section, a feature hardly noticeable for the visitor when walking through the landscape.

4.2 Demonstration section "Neuenhagen area"

The morphology focused visualisation of the Neuenhagen area (*Fig. 12*) uses a "base block" and shows a "drape layer" that highlights the differentiation of forest and arable land as well as the ditch system of the lower Oderbruch, while suppressing the differences among arable crops. In comparison *Figure 13* illustrates the partial loss of cognitive potential when providing only 2D-visualisation. In this layer composition, the differences among water bodies and the meso-scale relief are highlighted and there are more details on settlements derived from a layer showing a topographical map.

This demonstration section provides obvious hints for the interpretation of the actual distribution of land use in relation to the main geomorphologic units. The hilly areas of the terminal moraine are covered with extended, mainly beech, forests. Forestation dominated by pine trees also covers the level or almost level dry sandar and glacial valley bottoms. The moraine plateaus in the south-western area of the section, however, are used for agriculture, and so are the areas covered by mineral Holocene floodplain sediments. Accumulated during periodical flooding, these sediments provide the basis for today's extraordinary fertile soils. A second type of Holocene surface layer is made up by fens, which are entirely used for grassland. A dense network of drainage ditches along the western margin of the lower Oderbruch and at the outlet of the Finow valley documents intensive amelioration efforts.

The man-made displacement of the pathway of the river Oder in the past, combined with the damming of the river to a level some metres above the lower Oderbruch has resulted in the need to prevent flooding and to artificially drain the fertile polders. To summarise, in reference to the complexities revealed by this demonstration section, it becomes clear that such illustrative landscape visualisations

Fig. 9 Demonstration section "Dune field south-west of Eberswalde" from a walker's perspective
Demonstrationsgebiet „Dünenfeld südwestlich von Eberswalde" aus Sicht einer Spaziergängerin

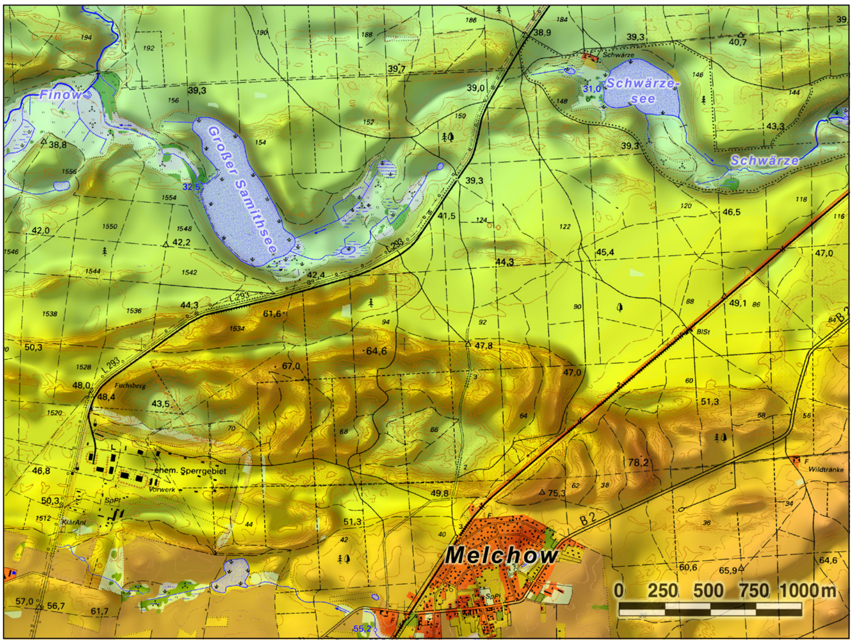


Fig. 10 Demonstration section "Dune field south-west of Eberswalde" in 2D-visualisation (coordinates 13°39'02"/52°46'27" to 13°44'41"/52°49'07") / *Demonstrationsgebiet „Dünenfeld südwestlich von Eberswalde" in 2D-Visualisierung*

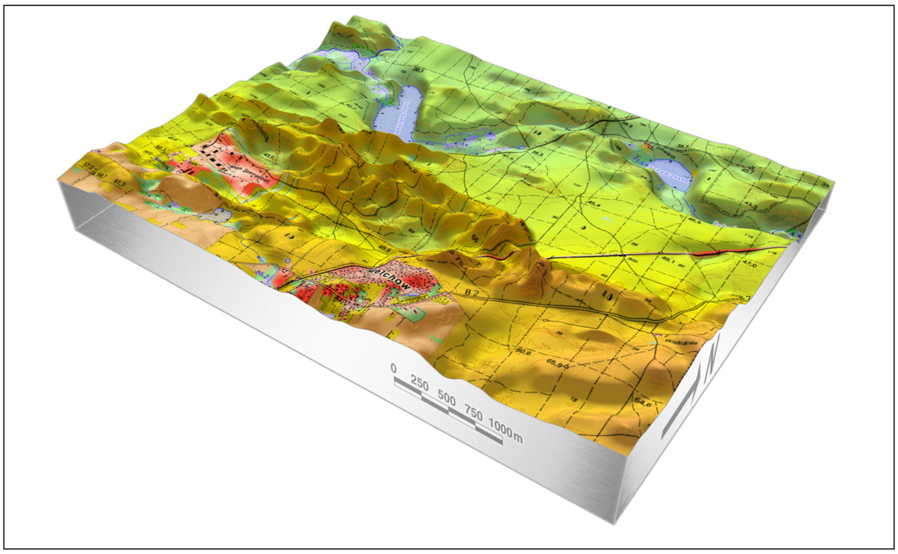


Fig. 11 Demonstration section “Dune field SW of Eberswalde” in 3D-visualisation (coordinates 13°39'02"/ 52°46'27" to 13°44'41"/52°49'07"). / *Demonstrationsgebiet „Dünenfeld SW von Eberswalde“ in 3D-Visualisierung*

support both the comprehensive cognition of correlated items in landscape development and of problems related to actual land use.

5. Discussion

It became obvious that landscape visualisation is a multi-step procedure, requiring numerous individual decisions concerning theme combination and generalisation in order to highlight or suppress the characteristics of the raw data. Despite multiple applications available through digital technology, any automated, unobserved generation of cognitively effective multi-thematic visualisations is impossible. If a “creative accentuation of reality” is intended in order to achieve specific cognitive or teaching purposes, even an experimental, iterative approach is necessary. This observation is in accordance with *Hruby* and *Miranda Guerrero* (2008), who state the upcoming of disciplinary approaches like visual analytics or spatial information theory after old knowledge from cartography got lost during the fast expansion of electronic applications.

Visualisations generated in the way described in this paper can be named “creatively accentuated reality”, because, on the one the hand, they are based on data derived from the original landscape, but, on the other hand, they are turned into a synthetic representation of the landscape in order to improve comprehensive cognition and successive interpretation. Our approach relates well to a basic statement by *Bishop* and *Lange* (2005b: 76f): “A working hypothesis behind much of the research in visualisation in scientific computing over the past decade is that the most successful visual representation methods will be ones that take fullest advantage of human sensory and cognitive systems developed for interacting with the real world.”

From our experience the most impressive visualisation effects are achieved when applying our approach to lowland sections, where landforms are widely hidden to the viewer on the ground. Also, medium-sized landscape sections are best suited, because at this scale single landforms are presented in a size comfortable for the viewer.

For teaching and information purposes, additional services may be added to the visualisations: Signatures of geologic survey maps draped over may make the complete array of landscape elements comprehensible for the laymen. For even more complex landscape interpretation, descriptions of accessible sediment profiles (in gravel pits, along road cuts etc.) can complement the assembly of land forms and landscape features and further elevate the cognitive potential of the visualisation. With the support of this new view over and into the earth's surface the broader field of understanding of the development of the entire landscape is opened up.

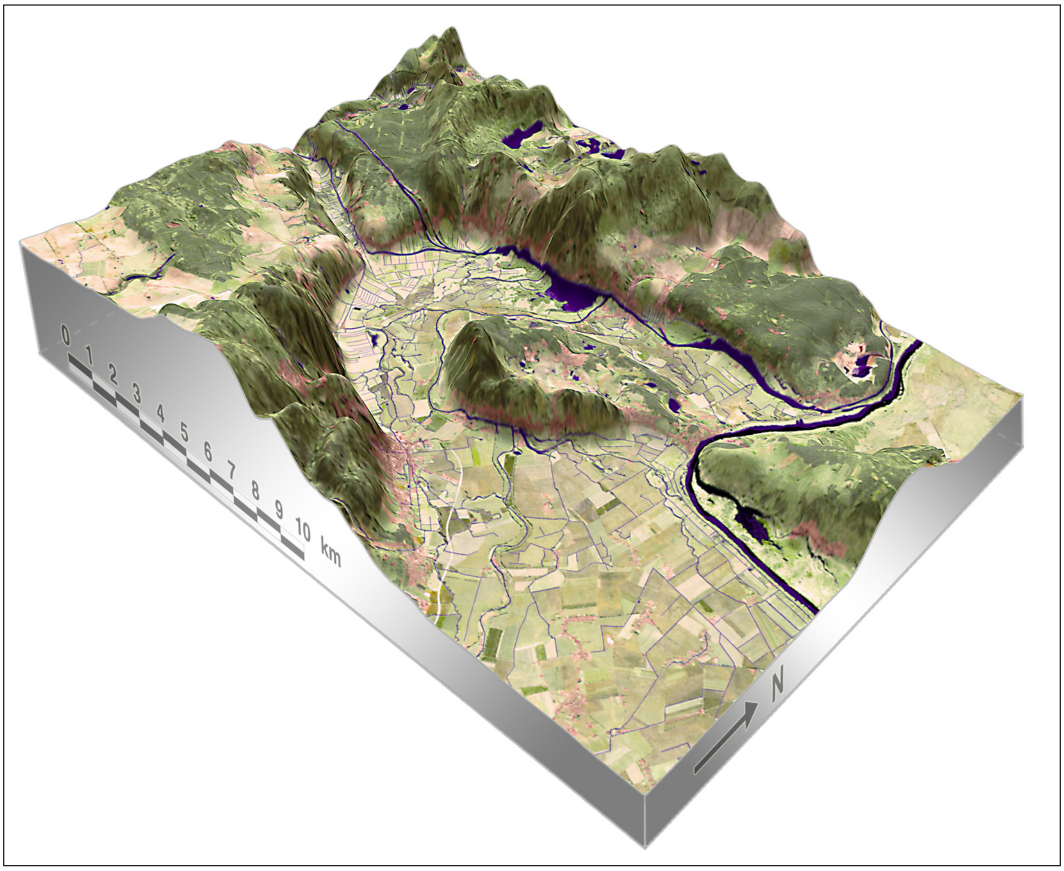


Fig. 12 Demonstration section "Neuenhagen area" (terminal moraine Liepe/Oderberg – Neuenhagen peninsula – lower Oderbruch) in 3D-visualisation (coordinates 13°50'58"/52°45'27" to 14°12'09"/ 52°54'47") / *Demonstrationsgebiet „Neuenhagener Umgebung“ (Liepe/Oderberger Endmoräne – Neuenhagener Oderinsel – Niederoderbruch) in 3D-Visualisierung*

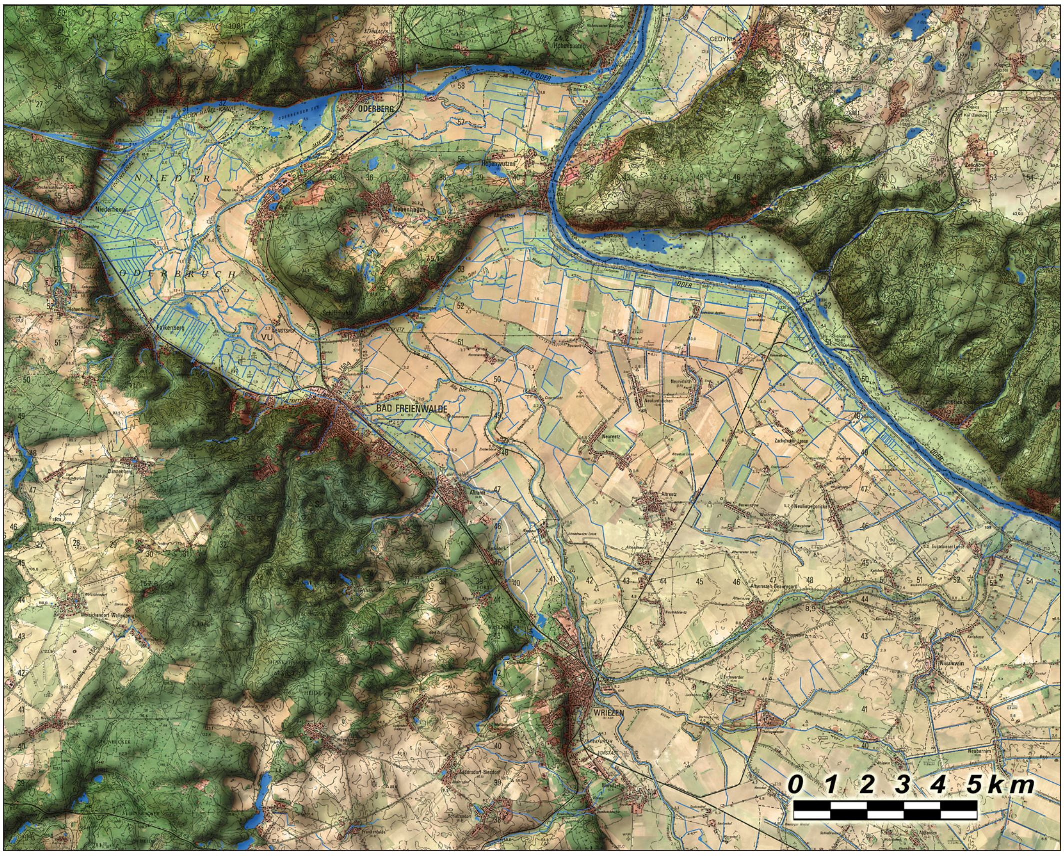


Fig. 13 Demonstration section "Neuenhagen area" in 2D-visualisation (coordinates 13°54'22"/52°40'42" to 14°19'48"/52°53'21") / *Demonstrationsgebiet „Neuenhagener Umgebung" in 2D-Visualisierung*

6. Conclusion

The strongest cognitive potential of digitally generated 3D-visualisations emerges, when medium scale sections (landscape scale) of low-relief areas are processed. In contrast, smaller sections tend to merely show what already is visible via visual ground inspection. Also, high-relief (alpine) areas will offer less new evaluative potential, because exposed hills are already present through visual ground based inspection.

In addition, the cognitive potential of digitally generated 3D-visualisations increases if the presented parameters are offered with selective accentuation, highlighting features at certain scales while suppressing and generalising others ("creative accentuation of reality").

Individually applied complex generalisation procedures play a crucial role, in combination with numerous decisions concerning layer selection, lighting, perspective etc. During the experimental phase of visualisation it may even become obvious that in some cases 2D-visualisations (including shadows and further shadings derived from terrain data) allow more comfortable cognition than full 3D-visualisations.

Relative to their great potential, landscape visualisations ought to become used more widespread for purposes of cognition (research), presentation and knowledge transfer (teaching). Also, visualisations are a good means to build interdisciplinary bridges within the broad field of landscape related sciences.

Finally, it needs to be stated that in comparison to former block diagrams as printed in schoolbooks, a new quality has been achieved: the transformation of a former method of illustration into a representation of a reality that is otherwise difficult to capture. The ability to move through space and time (animation) in the performance of landscape visualisations might in certain cases increase its informative value and relate to modern viewing habits.

Acknowledgement

This contribution was supported by the German Federal Ministry of Consumer Protection, Food and Agriculture and the Ministry of Agriculture, Environmental Protection and Regional Planning of the Federal State of Brandenburg (Germany).

7. References

Bailey, T.C. and *A.C. Gatrell* 1995: Interactive Spatial Data Analysis. – Harlow, Essex

Bishop, I.D. and *E. Lange* (eds.) 2005a: Visualization in Landscape and Environmental Planning: Technology and Applications. – London, New York

Bishop, I.D. and *E. Lange* 2005b: Presentation Style and Technology. – In: *Bishop, I.D.* and *E. Lange* (eds.): Visualization in Landscape and Environmental Planning: Technology and Applications. – London, New York: 68-77

Brose, F. 1994: Das untere Odertal. – In: *Schroeder, J.H.* (Hrsg.): Bad Freienwalde – Parsteiner See. – Führer zur Geologie von Berlin und Brandenburg **2**. – Berlin: 152-157

Buhmann, E. 2002: Using GIS for Visualization of the Changing Landscape of the Brown Coal Mining Areas at the International Building Exhibition (IBA) Fürst Pückler Land. – In: *Buhmann, E., U. Nothhelfer* and *M. Pietsch* (eds.): Trends in GIS and Virtualization in Environmental Planning and Design. Proceedings at Anhalt University of Applied Sciences 2002. – Heidelberg: 48-55

Dalchow, C. und *J. Kiesel* 2005: Die Oder greift ins Elbegebiet – Spannungsverhältnisse und Sollbruchstellen zwischen zwei Flussgebieten. – Brandenburgische geowissenschaftliche Beiträge **12** (1/2): 73-86

Donner, R.U. 2008: Die visuelle Interpretation von Fernerkundungsdaten. – Habilitationsschrift. – TU Bergakademie Freiberg

Döllner, J. and *H. Buchholz* 2005: Continuous Level-of-Detail Modeling of Buildings in 3D City Models. – In: GIS '05. Proceedings of the 13th Annual ACM International Workshop on Geographic Information Systems (ACMGIS). – New York: 173-181

Gallant, J.C. and *M.F. Hutchinson* 1997: Scale Dependence in Terrain Analysis. – Mathematics and Computers in Simulation **43** (3-6): 313-321

Gallant, J.C. and *M.F. Hutchinson* 2008: Digital Terrain Analysis. – In: *McKenzie, N.J., M.J. Grundy, R. Webster* and *A.J. Ringrose-Voase* (eds.): Guidelines for Surveying Soil and Land Resources. – 2nd ed. – Australian Soil and Land Survey Handbook **2**. – Melbourne: 75-91

Glander, T. and *J. Döllner* 2008: Automated Cell Based Generalization of Virtual 3D City Models with Dynamic Landmark Highlighting. – In: ICA Commission on Generalisation and Multiple Representation (ed.): Online Proceedings of the 11th ICA Workshop on Generalisation and Multiple Representation. – Online available at: http://aci.ign.fr/montpellier2008/papers/29_Glander_Dollner.pdf, 12/03/2012

Grimaldi, S., V. Teles and *R.L. Bras* 2005: Preserving First and Second Moments of the Slope Area Relationship during the Interpolation of Digital Elevation Models. – Advances in Water Resources **28** (6): 583-588

Haeberling, C. 2004: Highly Focussed Selected Design Aspects and Graphic Variables for 3D Mountain Maps. – Paper Presented at the 4th ICA Mountain Cartography Workshop, 30/09-02/10/2004, Vall de Núria, Spain. – Online available at: http://www.mountaincartography.org/publications/papers/papers_nuria_04/haeberling.pdf, 12/03/2012

Haeberling, Ch. 2005: Cartographic Design Principles for 3D Maps: A Contribution to Cartographic

Theory. – Paper Presented at the International Cartographic Conference, 09-15/07/2005, La Coruña, Spain. – Online available at: http://icaci.org/files/documents/ICC_proceedings/ICC2005/htm/pdf/oral/TEMA3/Session%206/CHRISTIAN%20HAEBERLING.pdf, 12/03/2012

Hehl-Lange, S. und *E. Lange* 2005: Ein partizipativer, computergestützter Planungsansatz für ein Windenergieprojekt mit Hilfe eines virtuellen Landschaftsmodells. – Natur und Landschaft **80** (4): 148-153

Hengl, T. and *H.I. Reuter* (eds.) 2009: Geomorphometry – Concepts, Software, Applications. – Developments in Soil Science **33**. – Amsterdam

Hruby, F. und *R. Miranda Guerrero* 2008: Kartographie im Spannungsfeld expliziter und impliziter Forschung. – meta-carto-semiotics, Journal for Theoretical Cartography **1**: 1-13. – Online available at: http://meta-carto-semiotics.org/uploads/mcs_vol1_2008/mcs_2008_1_hruby_miranda.pdf, 12/03/2012

Isaaks, E.H. and *R.M. Srivastava* 1989: An Introduction to Applied Geostatistics. – New York

Liedtke, H. 2001: Das nordöstliche Brandenburg während der Weichseleiszeit. – In: *Bussemer, S.* (Hrsg.): Das Erbe der Eiszeit. Festschrift zum 70. Geburtstag von Joachim Marcinek. – Langenweißbach: 119-133

Liedtke, H. 1996: Die Eiszeitliche Gestaltung des Oderbruches. – In: *Mäusbacher, R.* und *A. Schulte* (Hrsg.): Beiträge zur Physiogeographie. Festschrift für Dietrich Barsch – Heidelberger Geographische Arbeiten **104**: 327-351

Liedtke, H. 1956/57: Beiträge zur geomorphologischen Entwicklung des Thorn-Eberswalder Urstromtales zwischen Oder und Havel. – Wissenschaftliche Zeitschrift der Humboldt-Universität zu Berlin, Math.-nat. Reihe **6** (1): 3-49

Milnik, A. 2007: Sandschollen – Zerstörte Lebensräume. Ein Beitrag zur Umweltgeschichte Norddeutschlands. – Archiv für Forstwesen und Landschaftsökologie **41**: 91-96

Paar, P. 2006: Landscape Visualizations: Applications and Requirements of 3D Visualization Software for Environmental Planning. – Computers, Environment and Urban Systems **30** (6): 815-839

Pike, R.J., I.S. Evans and *T. Hengl* 2009: Geomorphometry: A Brief Guide. – In: *Hengl, T.* and *H.I. Reuter* (eds.): Geomorphometry – Concepts, Software, Applications. – Developments in Soil Science **33**. – Amsterdam: 3-30

Reuter, H.I., O. Wendroth and *K.C. Kersebaum* 2006: Optimisation of Relief Classification for Different Levels of Generalisation. – Geomorphology **77** (1-2): 79-89

Ross, L., J. Bolling, J. Döllner and *B. Kleinschmit* 2009: Enhancing 3D City Models with Heterogeneous Spatial Information: Towards 3D Land Information Systems. – *In: Sester, M., L. Bernard* and *V. Paelke* (eds.): Advances in GIScience. Proceedings of the 12th AGILE International Conference on GIScience. – Heidelberg et al.: 113-133

Schlaak, N. 1997: Äolische Dynamik im brandenburgischen Tiefland seit dem Weichselspätglazial. – Arbeitsberichte des Geographischen Instituts der Humboldt-Universität zu Berlin **24**

Schroth, O. 2009: From Information to Participation. Interactive Landscape Visualization as a Tool for Collaborative Planning. – Berichte des Instituts für Raum- und Landschaftsentwicklung (IRL) der ETH Zürich **6**

Silverman, B.W. 1986: Density Estimation for Statistics and Data Analysis. – New York

Solger, F. 1931: Der Boden Niederdeutschlands nach seiner letzten Vereisung. – Berlin

Solger, F. 1935: Die Entstehung der nordostdeutschen Bodenformen während der Eiszeit. – Berlin

Trapp, M. and *J. Döllner* 2009: Dynamic Mapping of Raster-Data for 3D Geovirtual Environments. – In: *Banissi, E.* et al. (eds.): Proceedings of the 13th International Conference on Information Visualization, 15-17/07/2009, Barcelona, Spain. – Piscataway: 387-392

Trapp, M. and *J. Döllner* 2008: Generalization of Single-Center Projections Using Projection Tile Screens. – In*: Ranchordas, A.K., H.J. Araújo, J.M. Pereira* and *J. Braz* (eds.): Computer Visions and Computer Graphics. Theory and Applications. International Conference, VISIGRAPP 2008, Funchal, Madeira, Portugal, January 22-25, 2008. Revised Selected Papers. Communications in Computer and Information Science **24**. – Heidelberg et al.: 55-69

Wagenbreth, O. und *W. Steiner* 1990: Geologische Streifzüge: Landschaft und Erdgeschichte zwischen Kap Arkona und Fichtelberg. – 4. Auflage. – Leipzig

Wolock, D.M. and *G.J. McCabe* 2000: Differences in Topographic Characteristics Computed from 100- and 1000-m Resolution Digital Elevation Model Data. – Hydrological Processes **14**: 987-1002

Wissen, U. 2009: Virtuelle Landschaften zur partizipativen Planung. Optimierung von 3D Landschaftsvisualisierungen zur Informationsvermittlung. – Berichte des Instituts für Raum- und Landschaftsentwicklung der ETH Zürich **5**

Summary: Visualisation and Interpretation of Moraine Landscapes in North-East Germany – the Ideal View on Landscape

The generation and processing of data referring to the earth's surface has undergone enormous progress during the digital age. Thus, representations of the earth's surface (visualisations of landscapes) can be very precise and may offer such content complexity that they can potentially be used as a cognitive tool. Comparable to imaging techniques in modern medicine, the accuracy and abundance of data combined with specific accentuations create an excellent basis for "comprehensive cognition". However, the generation of such representations, including the overlaying of several information layers and perspective effects requires an adapted processing of the raw data – depending on the specific cognitive intention. This processing needs both generalising and accentuating manipulations. We present visualisations of two demonstration sections in the German state of Brandenburg (dune field; river basin beneath terminal moraine) and discuss related options and limitations of processing and interpretation. The importance of an adequate generalisation approach is highlighted. An increased use of landscape visualisations for research and teaching is recommended.

Zusammenfassung: Visualisierung und Interpretation von Moränenlandschaften in Nordostdeutschland – Der ideale Landschaftsblick

Erhebung und Verarbeitungsmöglichkeiten von Daten zur Erdoberfläche haben im digitalen Zeitalter einen enormen Fortschritt erfahren. Damit können Darstellungen der Erdoberfläche (Visualisierungen von Landschaften) von solcher Genauigkeit und inhaltlicher Komplexität erstellt werden, dass sie als Grundlage für ein kognitives Werkzeug dienen können. Vergleichbar den bildgebenden Verfahren der modernen Medizin schafft die Genauigkeit sowie Datenfülle verbunden mit spezifisch gewählten Akzentuierungen eine vorzügliche Grundlage für „verstehendes Beobachten". Die digitale Anfertigung solcher Darstellungen mit Überlagerung mehrerer Informationsebenen sowie perspektivischen Effekten verlangt allerdings eine auf des jeweilige Vermittlungs- und Erkenntnisinteresse abgestimmte Bearbeitung der Ausgangsdaten. Dabei haben generalisierende wie akzentuierende Manipulationen der Ausgangsdaten vergleichbaren Stellenwert. Für zwei Demonstrationsgebiete in Brandenburg (Dünenfeld; Flussbecken neben Endmoräne) werden Visualisierungen vorgestellt und Interpretationsmöglichkeiten sowie -grenzen erörtert. Die Wichtigkeit eines angemessenen Generalisierungsansatzes wird betont. Zudem wird für eine stärkere Nutzung von Landschaftsvisualisierungen in Forschung und Lehre plädiert.

Résumé: Visualisation et interprétation des paysages de moraines en Allemagne du Nord-Est – Visualiser un paysage de façon idéale

Les processus de prélèvement et de traitement de données concernant la surface de la terre ont connu d'énormes progrès à l'ère du numérique. Il est ainsi possible d'établir des représentations de la surface de la terre (visualisation des paysages) avec une telle précision et une telle complexité du contenu que celles-ci peuvent être utilisées potentiellement comme outil cognitif. Comparables à l'imagerie médicale moderne, l'exactitude et l'abondance des données liées à des accentuations spécifiques choisies constituent une excellente base pour permettre l'« observation compréhensible ». La réalisation numérique de telles représentations, incluant la superposition de plusieurs plans d'informations et d'effets de perspective exige un processus adapté de traitement des données de base en relation avec l'objectif cognitif spécifique poursuivi. Ce processus a autant besoin de ces manipulations de généralisation que d'accentuation. Nous présentons ici les visualisations de deux domaines de démonstration situés dans le Land de Brandebourg (zone de dunes, bassin fluvial en aval d'une moraine terminale) et discutons des possibilités et des limites d'interprétation. Nous insistons sur l'importance d'une approche de généralisation adéquate. Par ailleurs, nous nous engageons pour une utilisation plus intense des visualisations de paysages dans les domaines de la recherche et de l'enseignement.

Dr. Claus Dalchow, *Joachim Kiesel*, *Dr. Gerd Lutze,* Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Str. 84, 15374 Müncheberg, Germany, cdalchow@zalf.de, jkiesel@zalf.de, gerd.lutze@googlemail.com

Manuscript submitted: 16/12/2009
Accepted for publication: 29/10/2010

Buchbesprechung

Stockmann, Reinhard, Ulrich Menzel und Franz Nuscheler: Entwicklungspolitik. Theorien – Probleme – Strategien. – München: Oldenbourg 2010. – X, 528 S., Tab., Abb. – ISBN 978-3-486-58998-6. – € 49,80

Angesichts der dynamischen, komplexen und vielleicht auch zunehmend undurchschaubaren Diskurse und Prozesse im Kontext von „Entwicklung“ ist ein umfassendes Handbuch zur Entwicklungspolitik, zumal aus kompetenter Feder, willkommen. Erfreulich ist, dass die drei Autoren erst gar nicht den Versuch unternehmen, ein konsistentes und in sich geschlossenes Werk vorzulegen, sondern die gewichtige Thematik über drei große Blöcke zu Entwicklungstheorien (*Menzel*), Entwicklungsproblemen (*Nuscheler* nennt sein Hauptkapitel „Weltprobleme“) und Entwicklungsstrategien (*Stockmann*) erschließen. Systematisch wird die Gesamtthematik in diesen Blöcken seziert und eigenständig analytisch abgearbeitet. In diesem Aufbau liegt vielleicht die große Stärke des Buches: Die Strukturierung der Kapitel ist plausibel und die Argumentationslinien bleiben stets klar erkennbar. Man könnte einwenden, dass es nicht sonderlich klug sei, die Theorie vor Phänomene wie „Unsicherheit“ oder „Unterentwicklung“ zu stellen, die sie ja überhaupt erst zu erklären beanspruche, aber Menzel verweist in seinem ideengeschichtlichen Abriss hinreichend auf entwicklungsbezogene Problemlagen, Erklärungsnöte und -notwendigkeiten, ohne dass es zu irritierenden Redundanzen mit den beiden anderen Hauptkapiteln kommt. Der Teufel steckt indessen im Detail: Der erste Themenblock liest sich als Kompendium der wichtigsten entwicklungstheoretischen Begriffe, Konzeptionen und Paradigmen. Allerdings verzichtet *Menzel* weitgehend auf Quellenangaben, so dass man sich für weiterführende Recherchen auf mühsame Literatursuche begeben muss. Auf diesen Umstand wird zwar in einer Fußnote (S. 11) hingewiesen, aber er ist in mehrfacher Hinsicht unbefriedigend und für das Buch bezeichnend: Der Fußnotenverweis bezieht sich auf ein bibliographisches Register von 1995, das man zu Rate ziehen könne, aber dass jüngere Literatur im Text kaum Berücksichtigung findet, ist angesichts der Globalisierungsumbrüche der vergangenen 15 Jahre schwer nachvollziehbar. So kommen – nicht nur im ersten Hauptkapitel – einige wichtige aktuelle Auseinandersetzungen um den Entwicklungsbegriff zu kurz. Als Beispiel sei die (gar nicht so junge, aber immer wieder prominent aufscheinende und teilweise heftig geführte) Post-Development-Debatte genannt, die die Autoren in nur wenigen Sätzen (Einleitung S. 2-3 und S. 22) recht lapidar und ohne vertiefende Quellenanalyse abhandeln. Andererseits werden jüngste entwick-