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The purpose of this publication is to present the information technology (IT) tools and techniques that have been developed at the Systems Research Institute of Polish Academy of Sciences in Warsaw (IBS PAN) and at the German Institute for Landscape System Analysis in Müncheberg (ZALF) in the area of applications of informatics in environmental engineering and environment protection. The papers published in this book were presented in the form of extended summaries during a special workshop organized by IBS PAN in Szczecin in September 2006 together with the conference BOS'2006 organized jointly by IBS PAN, University of Szczecin, and the Polish Society of Operational and Systems Research. In the papers the problems of mathematical modeling, approximation and visualization of environmental variables are described. Moreover, some questions concerning the environmental economy are also presented.

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CHAPTER 1

Specialized Software



METHODS OF UP-SCALING AND DOWN-SCALING IN SPATIAL CONTEXT

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***Abstract:** The moving window technology is a framework to describe the distribution of spatially arranged objects and features throughout the landscape. With the help of the parameters shape and size of the analysis window the degree of generalization can be adjusted and infinitely variably scaled. The up- and down-scaling is demonstrated in comparison with conventional methods of spatial interpolation. Analysis and description of the spatial distributions are carried out on the basis of data examples originated from the “Map of Vascular Plants in Eastern Germany” (Benkert, Fukarek, Korsch, 1996). A second example describes the necessity and methods of the generalization of Digital Elevation Models (DEM) for visualization purposes and introduces results.*

Keywords: Geographic Information System (GIS), moving window technology, up-scaling, down-scaling, generalization, Digital Elevation Model (DEM).

1. The moving window approach

The GIS-based explorative landscape analysis comprises questions regarding regionalization, segregation of landscape unities, their classification and description of the distribution of objects and features located inside. The main goal is to delineate quasi homogenous areas in the sense of generalization. Essential objects and features are amplified and intensified, non essential ones are suppressed and neglected. As a result, polygon areas can be computed and visualized that designate the borders of valid applications of models with a certain set of parameters or to identify conflict areas of current land use and natural potentials of the landscape. Every point (grid cell) in the investigation area is valued in its lateral context by taking into account either quantities of relevant thematic objects or features in the

neighbourhood of the current grid cell or the kind of their spatial arrangement.

The moving window technology is a suited, advanced and GIS-based operational framework for carrying out this kind of analysis. It analyzes and evaluates the spatial distribution of biotic, abiotic, socio economic, structural or functional features in their spatial distributions themselves or to each other by considering position, geometry, spatial value distribution in the neighbourhood or takes additional thematic layers into account. The spatial context can be freely and open defined and it is dynamically related to the current point (cell) that is under computation. In contrary the conventional block method is static in spatial context.

The result describes an unbiased, spatial distribution of the investigated object or feature, that can be infinitely variably scaled in terms of degree of generalization. Insignificant features are suppressed in favour of dominant ones under possible protection of local extremes (hot spot analysis by aggregation). Vice versa existing aggregated information can be broken down to a finer more realistic spatial resolution by a combined application of spatial interpolation techniques in conjunction with the moving window technology.

A great flexibility to adjust the tool to the asked question can be reached by programming the function that runs inside the moving window. The introduced framework produces outputs that are independent from shape and size of the investigation area and describe a full area covering continuous distributions of features. That's why it is best suited for visualization and interpretation purposes. Another field of application is the provision of spatial data for modeling on the basis of neural networks and fuzzy approaches. Continuous distributions can also easily modulated compared with discrete distributed objects in the landscape to build up a database for different scenarios.

After a short excursus into the basics of the moving window technology the following chosen examples should exemplary demonstrate the potential of the moving window approach.

2. The basics of the moving window technology

The moving window technology belongs to the class of hybrid analysis technologies (Silverman, 1986). It uses components of grid and vector arithmetic as well. All the involved thematic layers must not be rasterized initially, but a lot of themes will be raster ones originally like Digital Eleva-

tion Models or classified satellite images. Line and point themes remain in vector space for analysis purposes. Figure 1 demonstrates schematically how an example of several rasterized polygon themes inside an arbitrarily formed environment U (moving window) are mapped onto a single raster cell in the resulting theme with the help of a suited function f (for instance count of grid cells or mean of cell values).

In the next step the environment is moved one step aside and the described procedure is repeated again several times. In practise the environment U is often assumed a circle with radius R . This approach has the advantages of ease of implementation without use of a Geographic Information System, invariant of direction and the scalability of the degree of generalization by the radius R . A very important disadvantage is a high consumption of computing power and time that increases quadratic with the radius R .

The user of the moving window technology has three degrees of freedom with a circular environment. First he can choose an appropriate cell size for results. This determines the resolution and smoothness of the resulting grid theme and influences the time necessary for computation in a great manner. Second he can choose the degree of generalization by the radius R and third he has to think about a suited function f to solve his problem at the best. The radius R should be determined in relation to the size of the investigation area, the resolution and accuracy of the used input theme layers. In European Commission (2000) an approach for an automated estimation of this radius is described. The pragmatic approach, used in this paper, calculates a series with different radius and chooses the best suited degree of generalization. A small radius establishes a visualization of the result that resembles the input theme(s) – perhaps in another measurement depending of the used function.

With increasing radius the clear borderlines between the discrete objects, whose distribution has to be described, are smoothed and blurred in the sense of an increasing degree of generalization especially with the use of density functions inside of the moving window¹.

One can compare this effect with closing the eyes more and more by simultaneously increasing the distance to the original figure with the discrete spatially distributed objects. The variation of the distribution of the result decreases and very extreme values disappear. The normalized result keeps the mean over the whole investigation area. In the case where the radius covers the whole area the variation converges to zero and all cells of the

¹ Density functions calculate the number of spatial distributed objects inside a defined neighborhood or their degree of coverage.

result converge to the mean of the distribution of the discrete objects in the case of density functions.

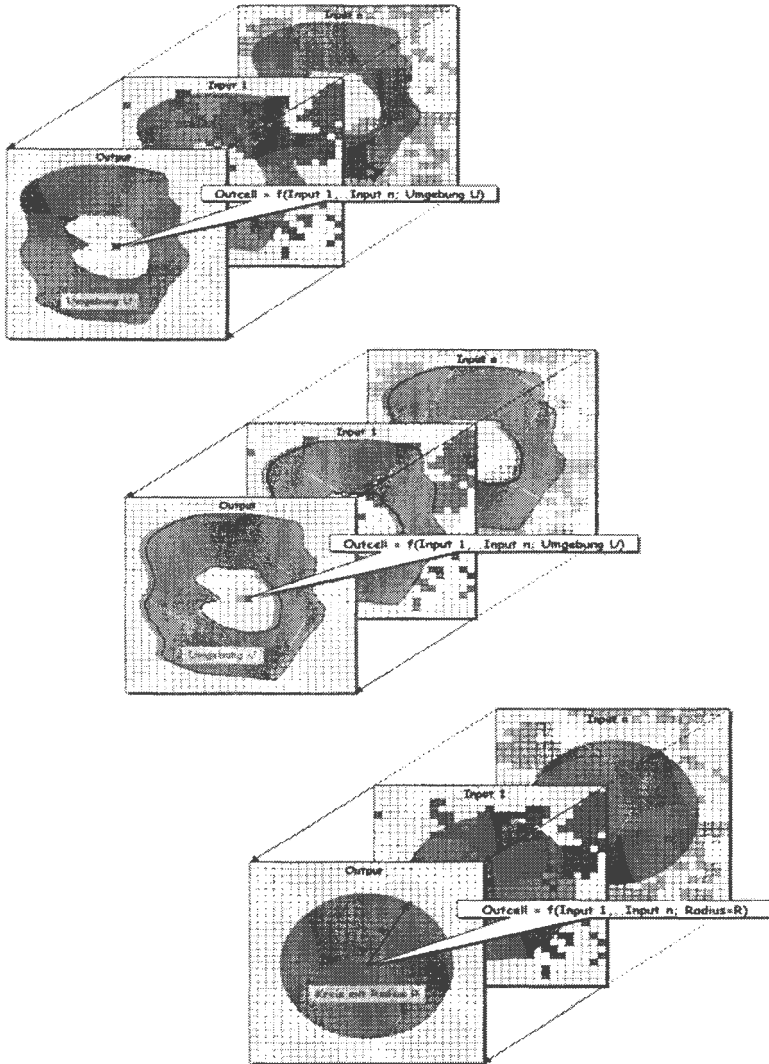


Figure 1. The basic principle of the moving window technology.

The quality of the result that is computed by the moving window technology and its matching for solving the asked problem and question depends on the kind of function you choose for running inside the window. Very often simple density functions are used like the count of cells, the degree of coverage the window area or the probability of meeting an object

in the neighbourhood. But they tend to produce poor results in quality. For instance, DEM can be smoothed and generalized at a good quality by removing the noise by the median filter. But unfortunately most DEM are generated from contour lines and supply a very poor quality after applying a median filter. Themes that describe land use can be generalized by the majority function applied on the main classes of land use. The most sophisticated functions can be defined by the user. In general they must be programmed by the user with a great amount of freedom at implementation. Complex decision algorithms can take into account the heterogeneity of the distribution of objects in the window, not only the number of the objects inside the window but the kind of their distribution and their distance to other objects. An example of a medium complex function is the Shannon Index to describe the biodiversity of the landscape. This function takes the different biotope types into account but not their distribution inside the window. A very complex function is the site comparison method (VERMOST) that was developed and implemented at ZALF and that describes the heterogeneity of classified and evaluated spatially distributed objects by a set of standardized indicators for dominance, contrast and diversity.

The moving window technology is a frame technology to transform spatially distributed objects and features with the help of a well determined, problem related function f . Thereby the moving window technology contributes as a very effective tool for solving tasks with spatial context and lateral relations.

3. Properties of density functions

The run of a density function inside the moving window belongs to the smoothing spatial interpolation procedures. The given original values at certain points are changed to emphasize the essential trend in relation to the spatial neighbourhood.

This is done for example by counting the number of discrete objects, the calculation of the degree the objects cover the window area or the summary length of line objects inside the window (simple density function). In the case of a circular window shape the chosen radius R of the circle determines the degree of smoothing or generalization. Missing data inside or outside of the investigation area have to be taken into account by extrapolating the known distribution of objects onto the no-data areas. This can be done by applying an border correction factor, that is based on the ratio of known values to missing values inside the window at every location of the investigation area the moving window is applied. The left part of Figure 2,

illustrates the effect of applying a simple density function on a test arrangement of columns of different compactness and linearity.

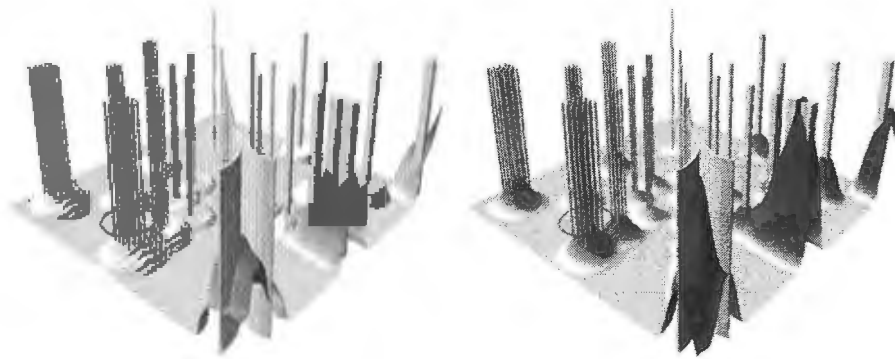


Figure 2. Experimental arrangement with simple density function (left) and kernel density (right).

This kind of density function produces a lot of artefacts and flat hills. It consists of an overlay of circular stamps. This is because a column snaps in or out with its whole value if the window moves one step aside.

On the contrary to the simple density function, the density with kernel estimation (Silverman, 1986) produces a very smooth density distribution like illustrated in the right part of Figure 2. The maximum values are better preserved and no artefacts can be detected.

The kernel estimation considers every column as a volume of different size (always the same in the experimental arrangement) and computes a 3D-bell shaped curve with the same volume like the corresponding value of the column for every column without interference each other. This curve is forced to zero at a distance of R (same value like the radius R of a circular environment) from the centre of the column. In the following step the moving window collects all the distributed virtual material inside the window and stores the value of its volume in the centre cell. Line features are treated in an analogue manner by expanding every line to a bell shaped volume with the length of the line as value of the volume. Polygon features are rasterized with a suited cell size and then treated like already explained. Point features must not be rasterized. They can be expanded to volumes at the location where they are originally located – without to deal with the problem of several points with different values in one raster cell or to move the location of the points to the centre of the respective raster cell.

This approach guarantees that an object does not enter the moving window in an abrupt manner but incrementally. The result is a smooth distribution without any shadow formation that describes in a generalized and scalable view the spatial distribution of the discrete objects.

As opposed to the general expectation, density with kernel estimation preserves maximum much better. It seems to have a magnetic effect on the distributed virtual material and tries to attract it to the location of the discrete objects. Edges in a real distribution are much more better preserved. That's why this procedure is highly recommended for generalizing Digital Elevation Models.

Both density approaches compute the same mean over the investigation area but different values and shapes of local extreme points, a different variance and a different distribution. With increasing generalization radius R they converge to the mean of the investigation area with zero variance.

4. Up-scaling of the distribution of vascular plants of the Red List of the county of Brandenburg

The "Map of Vascular Plants of Eastern Germany" (Benkert, Fukarek, Korsch, 1996) contains information about the distribution of 1998 vascular plant species throughout Eastern Germany in a very strong aggregated form on a basis of quadrants of the TK25 map. Such a quadrant is about $11\text{km} \times 11\text{km}$ (125km^2) in size. The information for each species is only a present/absent data available.

Out of the total number of plant species 526 of them belong to the special protection category "Red List of County Brandenburg" with the following classes of endangering whose weights are set up by biologists. The weights represent degrees of endanger.

The task is to generate a map that describes the spatial distribution of an endangering index and to give hints where to find locations respectively hot spots with a high density of species belonging to the Red List weighted by the degree of endangering. These identified hot spots can be used as a decision basis for applying special protection measures.

With the classic method the index is calculated separately for each quadrant by dividing the sum of the weights of each occurring species belonging to the Red List in the current quadrant by the sum of the weights of all species. Thus this index varies from 0 to 1. Figure 3 illustrates the resulting distribution. It can be seen that every quadrant is a homogenous one, but larger quasi homogenous areas can only heavily delineated.

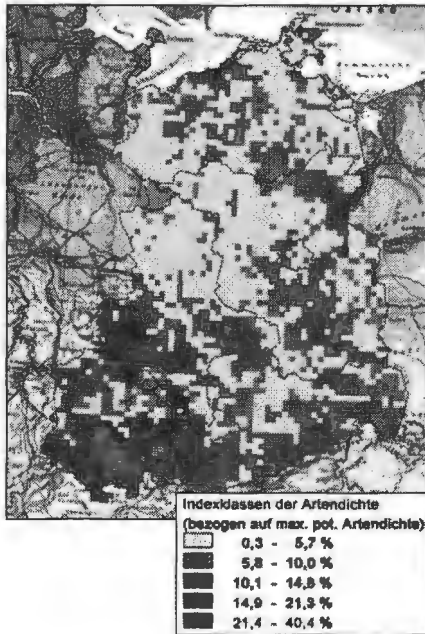


Figure 3. TK50 quadrants with endangering index of vascular plants of the Red List of the country of Brandenburg.

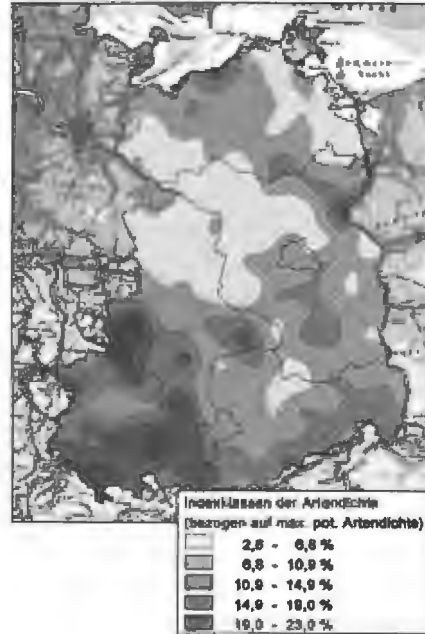


Figure 4. Hot spots of the endangering index of vascular plants of the Red List of the country of Brandenburg generalized by density with kernel estimation.

Degree of endangering	Weight
very high endangered	3
high endangered	2
endangered	1
seldom, potential endangered	2

Considering instead each centre of the quadrant in its spatial context, the artificial edges of the quadrants can be broken and generalized areas of the same index class can be delineated like illustrated with Figure 4.

To compute this resulting distribution a moving window of 25km radius with running density function and kernel estimation was used. Compared with a mean function the smoothing is lower. A simple density func-

tion generates a lot of artefacts. The standardization with the weights of all potential appearing species takes into account the increasing size of the quadrants towards south direction and the decrease of the distribution in the near of the borders of available data.

5. Down-scaling of the distribution of vascular plants of the Red

List of the county of Brandenburg

Starting point should be again the “Map of Vascular Plants of Eastern Germany”. 221 indicator species are selected that have special demands in their behaviour to farmland and fallow. The aim is to generate a map of hotspots of this indicator. Out of these 221 potential species one can meet at maximum 130 species in the county of Brandenburg in one quadrant of the TK50 map. Every single quadrant seems to be homogenously but in reality every species has special requirements regarding its habitat and every quadrant has a specific distribution of biotopes. Due to this neglect in Berlin a pseudo hot spot of the indicator can be found.

To solve these problems only the valid areas of farmland and fallow inside of each quadrant are taken into account. Thus the pseudo hot spot Berlin, because of its only few relevant areas, is neutralized and a better spatial relation of the indicator is achieved. But there are still steps of more than 100% between neighbouring quadrants. In practice such a behaviour is not to explain. For this reason a generalization on the basis of a density function with kernel estimation is applied. The selection of an appropriate degree of generalization, that is adjusted by the radius R of the circular moving window, is a little bit sophisticated. On the one hand it must be selected big enough to remove the artificial steps but on the other hand a high degree of generalization should not smooth the differentiation between the quadrants too much. By testing a series of generalization degrees it is possible to choose the best suitable one of 1km. But the generalization radius $R=1\text{km}$ would not work properly because the mean distance of the centre of the quadrants is 5.5km. It is necessary to resample the values of the computed indicator in the centre of the quadrants to a finer resolution. A suited procedure for this purpose is a bilinear interpolation that meets the exact value in the centre and tends to the neighbouring centres. All new generated values lay between the former minimum and maximum at a much higher density of values. 25m could be an appropriate cell size for this interpolation. As a result a moving window with 1km of radius can be successfully applied for generalization purposes. Figure 6 illustrates the habitat specific down-

scaling of the indicator for farmland and fallow und its fuzzy focussing on the centres of farmland and fallow.

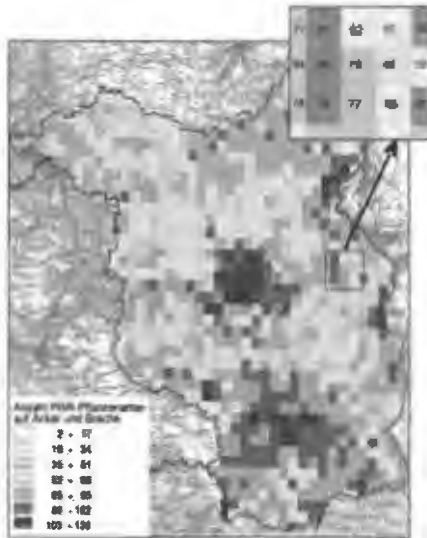


Figure 5. Distribution of vascular plants of the Red List of the county of Brandenburg in quadrants of a TK50 map.

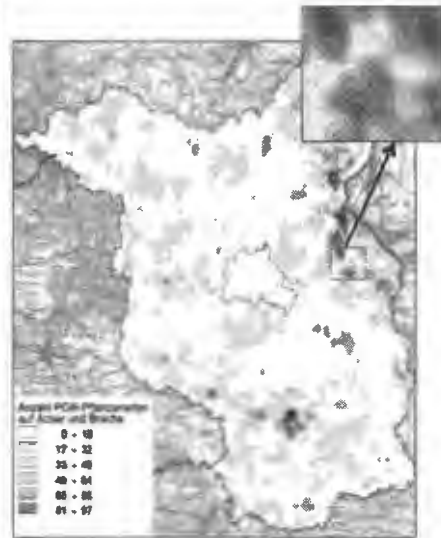


Figure 6. Habitat specific distribution of vascular plants of the Red List of the county of Brandenburg.

6. Generalization of Digital Elevation Models and their application

Very often Digital Elevation Models are used for the derivation of relief parameters or visualization purposes as they are, without checking their quality. The results are poor compared with applying advanced methods to fix the most important problems. Very rarely a user has access to the basic data and has additionally enough experience, time and computer capacity to generate his own well fitted DEM although this would be the best way to get a high quality DEM that can be used for a broad range of applications. The upper left part of Figure 7 illustrates the bad quality of the official DEM of county of Brandenburg with a horizontal resolution of 25m. Different relief parameters can be derived only with poor quality but the resulting DEM can not be used in any case for visualization by draping an image over the peaks. The only way out is to smooth and generalize it. With a carefully generalized DEM on different scales better prerequisites for deriving relief parameters and preparing high quality visualizations are available.

Figure 7 demonstrates again the advantage of using a density function with kernel estimation for DEM generalization in comparison with the median and mean functions. With laser-scan DEM, that are derived by a classification and interpolation process of points, the median function is often best suited because it preserves edges better than other functions. Because the basis of the DEM25 generation is another one, the application of the median function acts as a noise filter and reveals the basic data input of the generation process.

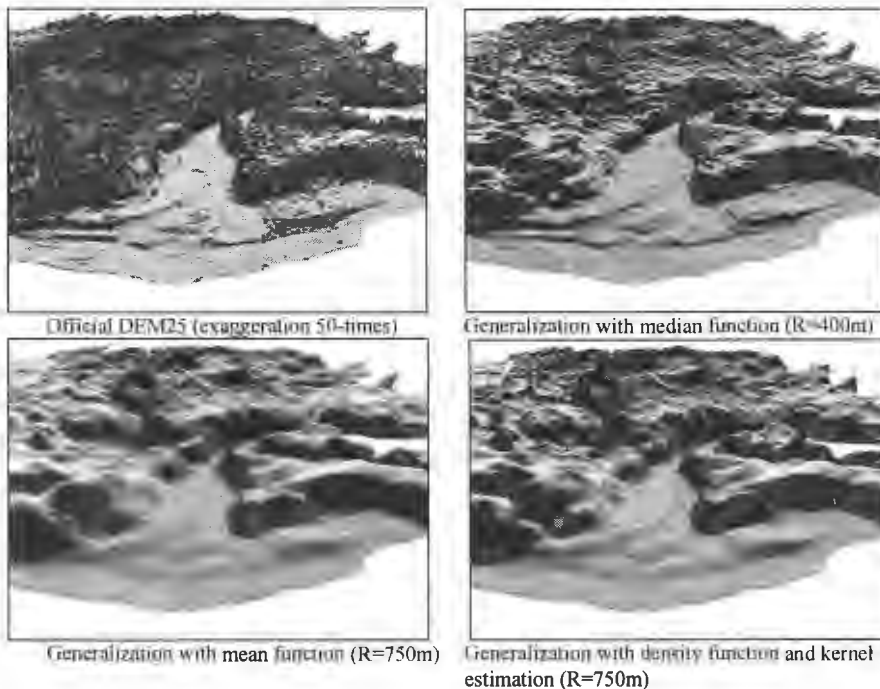


Figure 7. Application of different generalizing functions in the moving window applied on DEM25 (view from Poland to direction Prenzlau).

In the following remarks the main ideas and technologies to generate high quality non photo realistic visualizations are described. Many spatial distributed data have a strong relation to the relief. To sharpen the view on certain landscape features different angles of view are necessary and a method to omit non significant parts and to intensify significant ones to reveal the essential features. In some cases non visual information distributed throughout the landscape have to be made visible. The current landscape and its land use is only understandable in its historical, geological context (genesis). With the help of latest available data and technologies,

especially a DEM that describes the exact relief conditions, new insights and knowledge can be gained and derived that afterwards can be inspected in the real landscape. But also experiences originating from the real landscape can be generalized and be viewed in conjunction with other information. Visualization is an outstanding mean to promote an interactive discussion and recognition process between different partners.

A high quality visualization like illustrated with the following figures is achieved by preparing the necessary data in the framework of a GIS as a set of thematic layer, than to export them for post processing purposes to an advanced image tool like Adobe Photoshop to combine the layers with the help of sophisticated functions.

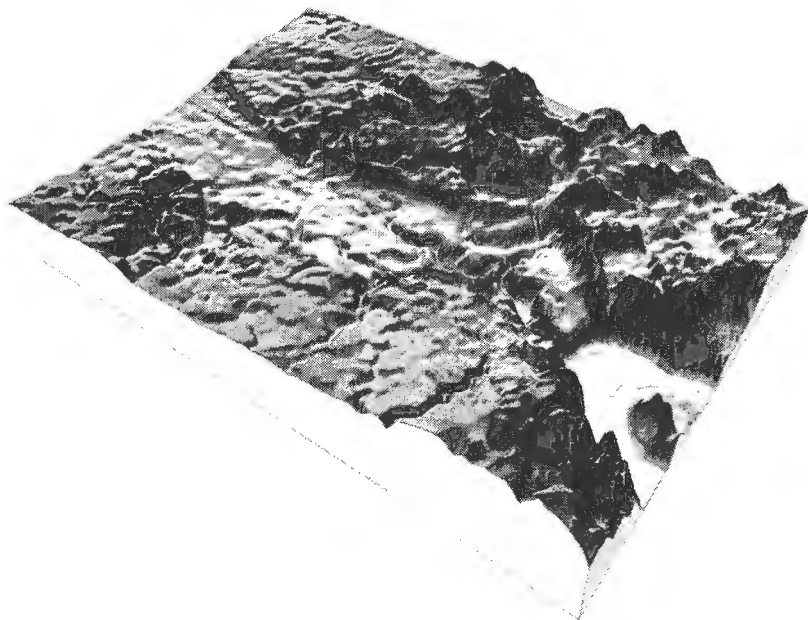


Figure 8. Morphology of the Eberswalder outwash channel.

In this process different degrees of generalization of the official DEM25 of the county of Brandenburg and improved versions of the GTOPO 30 of the USGS Geological Survey play an important role. These relief layers together with other thematic layers build up a stack of images that are superimposed with different degrees of transparency and functions. By this post processing technology certain aspects can be amplified and other suppressed. The creation of suited color maps, signatures, transparencies and

decisions regarding the sequence of the single layers in the stack can be very time consuming and resource expensive.

Most important of all is to create a realistic three dimensional impression. This is carried out as well by including a virtual light source to compute an illumination impression as by optic intensification of edges and areas of high slopes and last but not least mixing different degrees of generalization. The reason of success or flop of a special visualization lays in the right mix of all the components to meet the intended needs. The cause of fail are often the missing of needed data and to less experience of the user. In these cases the visualization looks poor with a surface like plastics or metal.

When geo referencing such a high quality composition this image can be draped like a rubber sheet on a highly smoothed, exaggerated DEM to intensify the spatial impression. By this process every pixel of the image is shifted corresponding to the high of the used DEM to each other, what has an influence on the clearness and sharpness of details like text in the image. In many cases parts of the image are hidden. Therefore planar views of a landscape, which includes three dimensional effects, are preferred to 3D-views in central or parallel perspective.

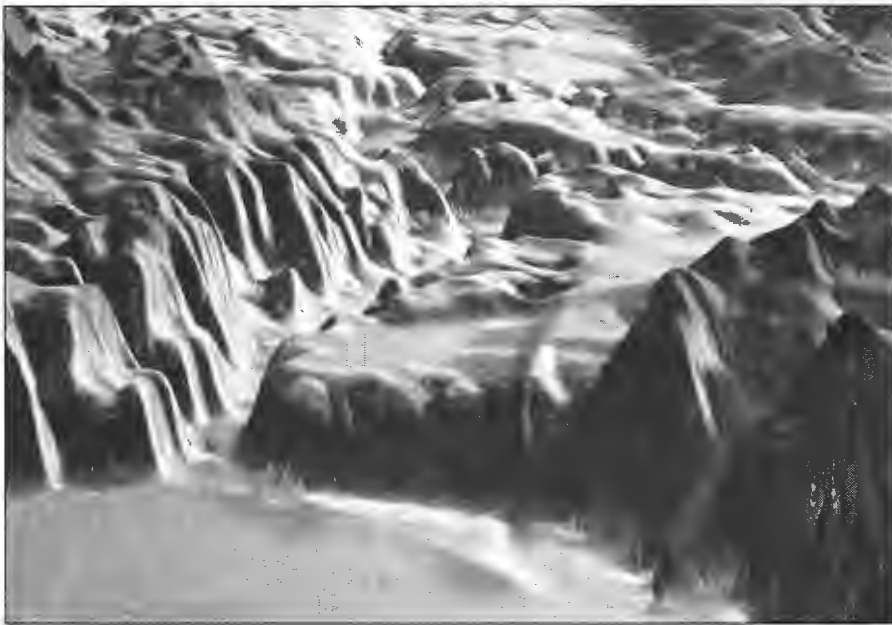


Figure 9. View from the valley of river Oder into the Eberswalder outwash channel.

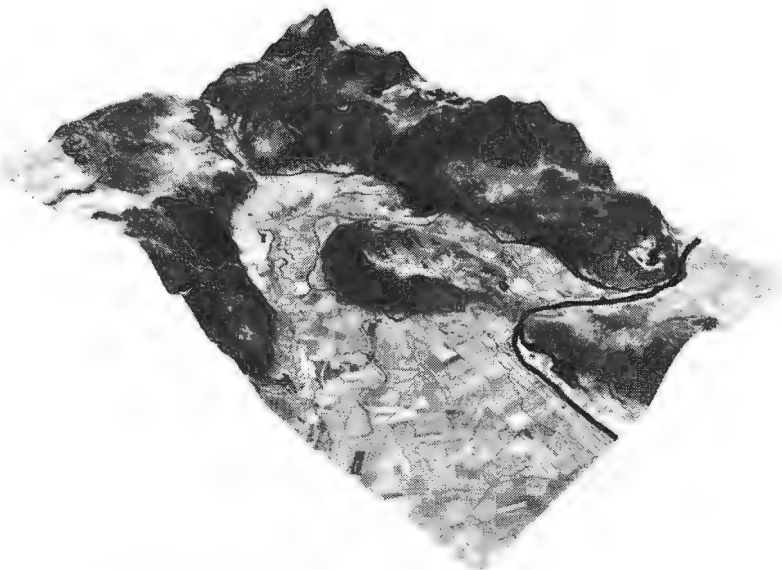


Figure 10. Northern part of Oder valley with island „Neuenhagener Insel”.



Figure 11. Village Stolpe south of Schwedt located at the erosion formed slope to the valley of river Oder.

The visualization of landscapes is an expensive, interactive process with a high degree of freedom of choosing the relevant thematic layers and the kind of their superimposing. For instance with computing of the illumination the number of lights, their position, the horizontal and vertical angles of the light rays, the intensity of shadows and scattered light or reflections, the exaggeration factor of the DEM and the classification and assigning of signatures or color maps can be freely selected by the user.

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Jan Studzinski, Olgierd Hryniewicz (Editors)

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This book presents the papers that describe the most interesting results of the research that have been obtained during the last few years in the area of applications of informatics in environmental engineering and environment protection at the Systems Research Institute of Polish Academy of Sciences in Warsaw (IBS PAN) and at the German Institute for Landscape System Analysis in Müncheberg (ZALF). The papers were presented in the form of extended summaries during a special workshop organized by IBS PAN in Szczecin in September 2006 together with the conference BOS'2006 dedicated to the applications of systems research in science, technology and economy and organized jointly by IBS PAN, University of Szczecin, and the Polish Society of Operational and Systems Research. They deal with mathematical modeling, approximation and visualization of environmental variables and with development of computer aided decision making systems in the area of environmental informatics.

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