Application of Artificial Neural Networks in Landscape Typology

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1 Introduction

The identification and assessment of landscapes is a prerequisite for their successful protection (European Landscape Convention, 2000). In this respect the landscape typology classification should serve as a reference base for spatial planning, which is one of the most efficient tools to achieve goals of landscape protection and management. It includes the definition of a usually hierarchically structured system of landscape types in a chosen territory and the definition of spatial occurrence of landscape types. The latter means the division of the territory (regionalization) into spatial units (regions) with “unique” landscape characters or common landscape characteristics. These characteristics define various landscape types. Generally, the same landscape type appears several times in different parts of the area. Guidelines for preservation and development of landscapes can be ascribed to typologically classified landscape units, but only if they have clearly defined boundaries and cover the entire treated territory. This kind of regionalisation is a demanding task, mainly because of landscape's holistic nature. All elements in the spatial structure of the landscape are related to each other and form one complex system, a whole (Antrop, 1997; Kučan, 1998; Naveh, 2000).

In landscape typology classifications a repeatable parametric approach is frequently used (Mitchell, 1973; Jug, 1995). The spatial occurrence of landscape types is usually defined by a more or less simple combination of selected physical factors, designating the landscape’s character through its morphology. But an approach that relies on simple assumptions, such as linear dependence and normal distribution for example, oversimplifies the complexity of landscapes. Some experts argue that by studying landscape with the parametric approach, their integrity is being lost and the landscape’s spatial and functional coherence is neglected. Instead of traditional approaches, a holistic approach should be taken. (Antrop, 1997; Palang et al., 2000; Naveh, 2001). One of the methods of the regionalization is based on human perception. With “Gestalt” perception landscape experts are able to intuitively recognize landscape units, which appear uniform in view of physical and morphological factors. But Gestalt perception can only be applied for those landscape units which clearly differ from a broader area and are evidently distinguishable. This way of defining landscape units would, because of the more or less continuous transitions of landscapes between themselves, means “island” drawing. The typological classification of the transition areas and drawing ‘crisp’ boundaries with a holistic approach would, however, be marked by a too large level of uncertainty and subjectivity.

The research was an attempt to test the method of landscape typology classification, namely, the one which would treat landscape as a complex system. The method should also include a generalization, which would enable it to recognize the most basic characteristics
by which landscapes differ among themselves. The use of such a method could reduce uncertainty and subjectivity in defining landscape type boundaries within transitional tracts.

The emergence of artificial intelligence has brought new options. One of its fields is the artificial neural network. It is a processing device, whose design was motivated by the design and function of the mammalian brain. It takes the form of a network of 'artificial neurons' connected by unidirectional communication channels. Neural networks' main characteristics are (OPENSHAW ET AL., 1997):

- the ability to learn by examples, which means that their functioning is not based on pre-assumptions, but rather on what was learned from known examples;
- the ability to solve complex problems and the ability to treat non-linear systems;
- the knowledge gained by learning is evenly distributed throughout the entire neural network structure, which makes remembering and recognition of patterns and of the whole possible;
- the ability to generalize “what-was-learned” and to handle noisy and missing data.

In literature, one can detect a rapid rise in the use of artificial neural networks in the geosciences. Neural networks are most commonly used for pattern recognition and classification (LEES, 1996; OPENSHAW ET AL., 1997).

The research hypothesis says that the artificial neural networks are capable of recognizing and learning general rules of spatial occurrence of landscape types from known sample examples. These are landscape units with common characteristics, recognized with the field work and classified into classes of landscape types. The trained networks are further capable of typologically defining the remaining territory including the more or less continuous transitions between different landscape types.

2 Material & Methods

2.1 Input Data

Within the project Regional Distribution of Landscape Types in Slovenia, financed by the Ministry of the Environment and Spatial Planning, a group of Slovene landscape experts has made a basic landscape inventory (MARUŠIČ, 1995; MARUŠIČ & JANČIČ, 1998). They have identified Slovenia's basic landscape morphological units with the field work and recorded the representative ones on slides. The areas of thus recorded landscapes are called landscape samples.

Data on 97 landscape samples within the region of the landscape unit Karst Landscape of Interior Slovenia was used to test the applicability of neural networks in landscape topology. KRIŽANIČ (1998) has classified landscape samples into groups of landscape types according to their morphological characteristics. Samples were arranged into a hierarchic system of landscape types, using cluster analysis. The level of the typological system that was analysed in this research was the one in which the landscape samples are classified into 7 groups of landscape types:

- landscape type 1: Hilly regions, overgrown with dense forest
- landscape type 2: Agriculture on hilly relief
- landscape type 3: Grassy slopes and levelled grassy peaks
- landscape type 4: Karst plateaux with less distinctive edges
- landscape type 5: Karst fields and valleys
- landscape type 6: Small fields intertwined with grassland
- landscape type 7: Vast grassy regions and river valleys

Research in spatial occurrence of landscape types is based on 12 selected physical factors, defining the morphology of landscape. They relate to climate (annual mean temperature, annual precipitation and exposition), topography (elevation above sea level, steepness of slopes, remoteness from the steepest slope - over 60%), parent material (bedrock) and land use (forests, agricultural land, settlement, remoteness from settlement and remoteness from surface waters). The data is recorded within the raster of 100 x 100 meters. The entire area of Karst Landscape of Interior Slovenia is depicted by 481908 pixels.

2.2 Modelling approach

The goal of the research was the use of neural networks as a tool for classification of individual pixels, described with physical factors, into groups of landscape types (Fig. 2).

The first step was pre-processing of the data into a form suitable for input into the net. In the second step the most suitable configuration parameters of the net were chosen and the network was trained. The trained network was then used for classifying the remaining pixels into groups of landscape types. The programs ESRI ArcInfo and Matlab with Neural Network Toolbox were used.
A multi-layer feed-forward neural network with back propagation learning algorithm was represented by 1000 training and 500 testing examples. To avoid any attempt to train some classes further than others, every landscape type is available for configuring, training, and classifying these nets (Jarvis & Stuart, 1996). Equal volumes of training and testing sets were used for each class (landscape type) to ensure that the sets of training and testing examples are representative and independent of each other. The number of output layer neurons is 7, which corresponds to the number of classes of landscape types. A comparison of the classification effectiveness of a three- and four-level neural network on a smaller test set showed that for the given task a three-level network is more suitable.

In the next step, a choice of a suitable number of hidden-layer nodes followed. This was again based on the comparison of the effectiveness of the nets’ different configuration parameters. The process included:
- creating 7 three-level networks with different configuration parameters;
- supervised training of the created networks;
- evaluating the effectiveness of the networks classification ability;
- comparison and selection of the most suitable network;

All networks were trained on the same training set. The Back propagation learning algorithm directs the learning process in an iterative adjustment of weights in communication channels between neurons, which is happening simultaneously with a gradual input of the training examples into the network. What has been learned is actually
being saved in weights. The training set was used to stop the training process at the point when the network learned the classification rules accurately enough and, at the same time, the rules were general enough for the classification of new examples (early stopping).

The effectiveness of the networks classification ability was estimated with:

- classification accuracy percentage (nap, eq. 1):

\[
nap = \left( \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{m} \left| X_{ij} - X'_{ij} \right| \right) * 10
\]

(1)

- Pearson's r-coefficient of correlation (r) and
- mean squared error (mse, eq. 2):

\[
mse = \frac{1}{n} \sum_{i=1}^{n} \sum_{j=1}^{m} \left( X_{ij} - X'_{ij} \right)^2
\]

(2)

In equations \( i \) presents pixel, \( j \) landscape type, \( X \) is an actual and \( X' \) a desired output. The network with 50 hidden neurons (59:50:7) was chosen as the neural network with the most suitable configuration parameters. Its ‘what-was-learned’ was estimated with one of the highest coefficient of correlation, one of the smallest percentage of wrongly classified examples and the smallest mean squared error.

**Tab. 1:** Effects of altering network configuration parameters on classification accuracy

<table>
<thead>
<tr>
<th>network configuration</th>
<th>( r )</th>
<th>nap (%)</th>
<th>mse (%)</th>
</tr>
</thead>
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<tr>
<td>57:15:7</td>
<td>0.829</td>
<td>18.26</td>
<td>2.51</td>
</tr>
<tr>
<td>57:20:7</td>
<td>0.839</td>
<td>16.69</td>
<td>2.16</td>
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<tr>
<td>57:30:7</td>
<td>0.837</td>
<td>16.77</td>
<td>2.29</td>
</tr>
<tr>
<td><strong>57:50:7</strong></td>
<td><strong>0.844</strong></td>
<td><strong>16.29</strong></td>
<td><strong>2.14</strong></td>
</tr>
<tr>
<td>57:70:7</td>
<td>0.844</td>
<td>16.66</td>
<td>2.17</td>
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<tr>
<td>57:90:7</td>
<td>0.843</td>
<td>16.40</td>
<td>2.23</td>
</tr>
<tr>
<td>57:110:7</td>
<td>0.845</td>
<td>16.54</td>
<td>2.21</td>
</tr>
</tbody>
</table>

**3 Results**

The chosen network classified the remaining examples by adapting 7 values to each one of them. These were, because of the chosen sigmoid output function of the output neurons, given in the range from 0 to 1. Normalized values can correspond to the pixel’s degree of membership in the 7 classes of landscape types. Example’s membership in more classes of landscape types simultaneously is based on the fuzzy set theory (ZADEH, 1965). The theory permits partial membership of elements in more than one set. Those pixels can represent the more or less continuous passing area between regions of different landscape types. Fuzzy regions of landscape types are depicted in Fig. 3.
The degree of class overlap is defined in terms of a confusion index ($CI$) which is the difference between the 1st highest pixel membership value ($X_{j,i}^{max_1}$) and the 2nd highest pixel membership value ($X_{j,i}^{max_2}$) (BURROUGH & MCDONNELL, 1996; eq. 3).

$$CI_{j,d} = 1 - \left( X_{j,d}^{max_1} - X_{j,d}^{max_2} \right)$$

(3)

The result is depicted in the overlap map (Fig. 4).
Assuming that a pixel can belong to only one landscape type, the degree of membership corresponds to the degree of classification accuracy. The pixel is classified into the class of landscape type in which the pixel’s membership value is the highest. The result shows a map of all landscape types (Fig. 5).

4 Conclusion

The presented research is to be taken mostly as one of the attempts of landscape typology classification in a manner, where the landscape’s integrity is not lost. The neural networks were used mostly because of their ability to learn from examples, to use what was learned on new examples, and to generalize. Its application enabled the presented typological classification to be based on expert knowledge. A subjective judgement of the research results enables the conclusion that the obtained distribution of landscape types is quite realistic. Neural networks have proven to be a useful tool for landscape classifications. Further research should be carried out, mostly by way of exploring the effects of using
different types and selections of the data. The main problem of using neural networks is
definitely their black box technology. The discovered and learned rules of typological
classification remain hidden within the network. The statistical processing of results, such
as the impact of individual input on the network’s output, at least partially transforms the
black box into a grey one. In spite of that, the argumentation of results remains difficult
without explicitly presented classification rules. Explicitly presented rules could be
completed and corrected along with considering new types of criteria. Acceptance of their
results is therefore largely a matter of trusting the technology (or controlling it by “Gestalt”
judgement). The role of neural networks in landscape typology can therefore mostly be in
giving new information or additional inputs, which make the decision on regions of
landscape types easier.

5 References

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GIS-based Expert System for Land Use Planning as a Contribution to Flood Mitigation

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1 Introduction

The number and magnitude of flood events in Europe and other parts of the world in recent years have made it clear that flood protection is universal societal issue that challenges more than just the areas of water management, disaster preparedness and the insurance industry. Flood Protection Technology (dykes, floodwater retention tanks etc.) and Flood Precaution (construction measures, human preparedness and risk management) are important components of flood protection (LAWA, 2004) that have been especially emphasised in Germany since the flooding of the Elbe in 2002. In comparison, only very limited steps have been taken in the area of Land Management. Land management is often equated with identifying flooding areas. In contrast, the aspect of adjusted land use is practically ignored. This represents a weak point in the current flood protection strategy. In the task of precaution through land management, the players and decision makers in Land Use Planning, Agriculture and Forestry must take part in the task of flood prevention. In two GIS maps it is shown how the locations more suited for storage can be identified catchment-wide, how the effectively retainable precipitation volume is quantified, and where the potentials for implementation of infiltration-encouraging measures are located. The investigated measures, e.g. conservational agriculture and on-site stormwater management, are well known processes proven in practice that serve flood protection in certain locations. The presented GIS maps are central components for a structured procedure for Flood Land (use) management. The goal is make the significance of the landscape for flood protection quantifiable with these tools. The target groups are planners and authorities from the areas of land use planning, agriculture, forestry and nature protection that can greatly implement a selective application of infiltration-encouraging measures in catchments with flooding danger.

2 Material & Methods

While selecting the input data, attention was paid to dealing with data that are available for many catchments. That way the need to develop a transferable methodology could be met.

2.1 Water Storage Map

The potential map shall show where the flooding reduction areas in the Mulde catchment can be found and how large the storage potential in the soil (in m³) is. The creation of the potential map is based on the connection of two independent expert systems.
The first part of the methodology consists of the interpretation of the digital soil map (soil concept map 1:50,000 from the Saxon State Office for the Environment and Geology). Taking the soil striation, the groundwater depth, and the layering density into consideration, the infiltration potential was determined. For this, the infiltration model according to Green & Ampt, 1911 was used in a modified form for striated soils according to Flechinger et al., 1988.

Since it can only be assumed in certain cases that the infiltrated precipitation can be stored in the soil for a while – at least for the duration of a flooding event – it was necessary to characterise the surfaces in the Mulde catchment in terms of their runoff behaviour. For this, the expert system WBS-FLAB (Peschke et al. 1999; Etzenberg, 1998; Zimmermann, 1999) was applied. Building on digital land use data (ATKIS-DLM from the Saxon Land Surveying Office) for morphology (digital landscape model (DGM) from the Saxon Land Surveying Office, resolution 20 m) of the water body network (from the Saxon State Office for the Environment and Geology) as well as the digital soil concept map (see above), a map of the dominant runoff processes was created by the Chair of Environmental Biotechnology of the Intenationale Hochschulinstitut (IHI) in Zittau.

The combination (GIS-intersection) of both of these GIS-based landscape evaluation systems leads to a catchment-wide approximation of the water retention potential for the soil (see Fig. 1). An actual water retention potential is assigned only to those surfaces that are dominated by heavily delayed runoff components. The surfaces that are marked by rapid, temporary runoff absolutely have a potential infiltration capability, although underground lateral runoff processes lead to the fact that the water retention potential is not enough to be of use to flood protection. This applies especially for areas with steep slopes and/or thin soil layers.

![Water retention potential](image)

**Fig. 1:** Methodology for creating the potential map
2.2 Measures Map

Building from the analysis of the landscape storage potential, two measures maps – one for the agriculturally used surfaces and one for built-up areas – were created with the aid of the GIS-based expert system FLEXT (Jin et. al. 2005; Jin 2005). With the aid of the measures maps, it shall be shown for the Mulde catchment, where and which changes to the land use or land management are especially effective from the point of view of flood protection.

![Figure 2: Structure of FLEXT](image)

Figure 2 schematically shows how the creation of the measures map was realised and which links exist between the geographical information system (GIS) and FLEXT. The starting point in this methodology is the decision matrix (Fig. 2, IIb). Graphic Ila in Figure symbolises the software programme FLEXT. FLEXT provides a graphic user interface that allows the input of rules of the decision matrix in which the connection is established to the input parameters below and, last but not least, the output of the decision-making process is driven.

In the decision-making process for the agricultural surfaces, measures for modified soil tillage methods, for changing land use and for ground formation were evaluated. The current type of agricultural use, the ground slope, the water storage potential in the soil and the dominant runoff process in the natural condition (potential map) as well as the distance to the ground surface, the proximity to a water body and the size of the farming units were taken into account as evaluation parameters.
The evaluation of urban surfaces has the goal of checking the suitability of various forms of stormwater management. In addition to the input parameters from agricultural surfaces, the location of drinking water protection zones as well as the current type of development was taken into account. In the foreground of the selection of measures are the swale-trench elements that provide flood retention with their storage and infiltration capacity, a retention that does not exist with direct diversion into sewers or water bodies.

3 Results

3.1 Water Storage Map

Figure 3 shows the results of the calculation of the soil’s water retention potential. The entire Mulde Catchment (area of 6300 km²) is shown. The potential map displayed is based on a 3-day flood event with a recurrence period of 100 years. That means that the 72-hour infiltration capacity was contrasted with the statistical regionalised heights of precipitation of the same duration level (DWD, 1997). It is clear that not all areas in the catchment are suitable for augmented floodwater storage in the soil. This applies especially to the flat and steep areas of the Erz Mountains in the...
southern part of the catchment as well as to the floodplains that are in direct hydraulic contact with the waterbody. In these areas, decentralised storages and runoff-retarding measures such as hedges are more effective. In the middle part of the catchment there are nevertheless wide areas on which 40% of the flood-causing precipitation can be retained. In the downstream part of the catchment in flat areas with highly permeable soils, the precipitation could be stored nearly completely stored in the soil.

3.2 Measures Map

Figure 4 is the result of the FLEXT evaluation process for agricultural areas using the example of conservational agriculture. The overview map shows that around a
third of all cultivated surfaces (1,300 km²) are suited for conservational soil treatment and at the same time, it should be expected that this measure brings positive (side-) effects for flood protection on the designated surfaces since a large portion of the additionally infiltrated precipitation can be temporarily stored in the soil. The detailed excerpt shows the spatial resolution of the measures map.

Fig. 5: Measures map for built-up areas in the Mulde catchment

The areas shown in grey and black mark the agricultural surfaces, the white areas are in the „as-is“ state of other land uses like greenland, woods or built-up areas. These surfaces were not considered because, with this methodology, a change of use from meadow to farmland or from forest to farmland was not taken into account.

In figure 5, the evaluation results of the built-up areas are depicted for the same detailed excerpt northwest of the city of Chemnitz, which, based on the entire area, has an area percentage of ca. 10%. The general analysis showed that around 30% of the built-up areas in the catchment could be „drained“ with the aid of unlinked swale-trench elements (grey surfaces). This form of on-site stormwater management, in contrast to discharging stormwater in sewers, offers the advantage that a considerable amount of the precipitation can be stored above ground (in swales) and below ground (in trenches). Simulation calculations for the Mulde Catchment show that even with 50% of the implementation potential complete, a storage volume of ca. 5.9 mil. m³ would be created that would serve urban drainage and flood protection at the same time.
4 Conclusions & Outlook

With the aid of a GIS-based expert system, maps were created as examples for the Mulde catchment in Saxony that can serve as the foundation for systematic land management. The potential map gives spatial planners, administrators and politicians as well as those involved in water management an overview of the areas marked for flood reduction in a catchment so that their priority areas, active focuses and plans can take such information into account. At the same time it allows a high spatial resolution for the map in order to identify the areas within partial catchments that because of their specific locational properties contribute to flooding, and to narrow down the areas that can store significantly more precipitation than is the case with conventional farming (Zimmerling, 2004; Sieker et al., 2002). A comparison with other approaches to landscape retention potential (Z. B. Röder and Beyer, 2002) shows that the potential map is different not only in the level of spatial detail but also in chronological resolution. Unlike the annual water balance, an observational time period of 3 days allows for better statements about the runoff behaviour of the landscape in a flood event. Last but not least, provision of equivalent storage volumes and the integration of the dominant runoff process means a clearly better representation and understanding of the processes.

The presented measures maps help the players in regional and local planning to grasp the measures fit to location and thereby to utilise systematic synergy effects (erosion prevention plus flood prevention, drainage plus flood protection). For the area of urban developments, practical examples for application (Bandermann 2005; Becker 2005) show that GIS-based decision support systems already are being used as foundations for concrete planning.

The goal is, even in the area of Agriculture, to have the information from the potential and measures maps to be integrated into the planning process. In the scope of the research project (see Acknowledgement) the measures maps are being used as the foundation for the setup of realistic future scenarios. The computer-simulated representation of these scenarios, with the aid of precipitation-runoff models, should clearly show the benefit of taking precautions in a specific area and thereby incite that the potentials of land management are better used than ever before.

5 References

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Planning at the University of Hannover and the Saxon State Office for Agriculture of the Saxon State Ministry for the Environment and Agriculture, Leipzig.
Polygon-based Regionalisation in a GIS Environment

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1 Introduction

Regionalisation is a frequently used concept in the spatial sciences, applied towards numerous use cases and real world scenarios. Although underlying data describing spatial entities are mostly available in GIS-compatible frameworks, the task of defining regions is still mostly performed manually, i.e. not based upon stringent algorithms with explicit parametrisation. One reason for that is the lack of methods implemented as explicitly spatial aggregation techniques in software products. While classification methods leading to spatial types (zones) are widely available, regionalisation adding a spatial contiguity or proximity constraint to attribute-based classification is missing from even extended toolsets.

Openshaw (1996) pointed out that the analysis of spatial information aggregated to zones is one of the most important and highly relevant spatial analysis tasks which still need to be conceptualised for wide implementation. Interestingly, one of the few implementations of regionalisation based on an extension of Cluster Analysis has been implemented in the 1970ies from a multivariate statistical analysis perspective (Wishart 1987)

In order to enable spatial analysts to perform clearly defined and parameterized regionalisation, a hierarchical, aggregative, spatially constrained clustering method has been implemented by one of the authors (D. Tiede), starting from polygons as operational taxonomic units (OTU’s).

In this paper an example for regionalisation in the field of renewable energy usage is presented, but possible areas of application are manifold: Depending on the potential pre-defined rules, region aggregation could be based on similarity criteria (e.g. in the ecological modelling domain) as well as on complementary criteria (e.g. to aggregate self-sustaining regions in case of resource use).

2 Method

2.1 Polygon-based regionalisation using a spatial contiguity constraint

Johnston (1976) introduced a contiguity constraint to the hierarchical clustering with centroid replacement procedures. At each hierarchical clustering step, an adjacency matrix had to be checked (manually), to see if the candidate groups of units were contiguous and if that was not the case, they were not considered for aggregation.

In contrast to Johnston the approach described in this paper starts by first selecting contiguous OTU’s and then comparing their attribute values for similarity-based clustering.
To do this, the algorithm needs pre-set “seed” polygons as starting units. Next, all adjacent polygons are considered in a first aggregation step, resulting in a number of initial regions. Thus, the number of “seed” polygons determines the maximum amount of resulting regions after all polygons are clustered. A contiguity constraint as it is used herein is defined as adjacency of polygons, which means that they have at least one point of a boundary in common (cf. DeMers 2005). Nevertheless, the contiguity constraint is customizable and could also be implemented as sharing a defined length of common boundary between polygons or for example as the distance between polygon centroids.

The clustering process itself depends on customisable rules, comparing similarity or also complementarity attributes of the spatially contiguous target OTU’s. The best fitting neighbouring polygon (in terms of the pre-defined rules) is merged with the initial one and new common values for the merged region are calculated according to the chosen aggregation rule. In an iterative process this is done for the entire dataset until all units are assigned to regions or another cut-off criterion is reached (e.g. maximum region size, level of dissimilarity etc).

Fig. 1:  Principle of the algorithm: 1. Initial “seed” polygons – 2. Selection of contiguous candidate OTU’s – 3. Merging of the most similar OTU’s based on pre-defined rules – 4. Next selection step

Clearly, this is a region growing algorithm starting from a fixed set of seed polygons, proceeding with a stepwise aggregative clustering strategy. Alternative approaches like divisive or non-hierarchical agglomeration techniques are not considered in this paper.

2.2 History tracking

The regionalisation process as explained above is recorded for traceability reasons. Traceability can especially be a problem with large datasets and a few hundred aggregation steps. It is also important to ensure reasonable results and to avoid a “black-box” effect, to give the user as much control as possible over the parametrisation and calculation processes. In a separate table each merged OTU gets a unique time stamp identification number (history ID). Therefore it is possible to assess and analyze the region building sequence for all original polygons = operational taxonomic units.
Additionally a tool has been developed which uses the ‘history IDs’ to visualize the iterative region building as animated graphics, dynamically presenting the region growing process.

2.3 Implementation

The described algorithm is implemented as an extension in the ArcGIS 9 environment. So far input and output datasets are limited to polygon shapefiles. A simple graphical user interface helps to calibrate the initial conditions and to define input and output parameters.

3 Example: Building autonomous regions based on renewable energy consumption and sources

The above described software tool is being tested for the delineation of ‘energy-autonomous regions’. The objective is to balance renewable energy sources and consumption in particular areas, minimizing import of (fossil-based) energy from the outside. The data is based on a combination of the effective production potential for renewable energy sources like hydropower, wind, and photovoltaic energy, biomass conversion and geothermal energy. The power consumption per unit is subtracted, resulting in a polygon layer, representing the aggregated energy supply potential (cf. figure 2).
Fig. 2: Polygon layer, representing the aggregated energy potential in a transborder region between Austria and Germany. Dark values indicate higher values of energy consumption compared to locally available renewable energy potential. Brighter values indicate a net surplus, i.e. a higher renewable energy generation potential compared to average energy consumption.

Negative values indicate higher values of energy consumption compared to the renewable energy potential, while positive values are indicating a higher renewable energy potential than average energy consumption.

Renewable energy sources are primarily used to meet the demand on local level, mainly due to the low energy density and resulting high cost of transport. Exploitation on a higher than regional level is limited by economical and technical constraints as well as by resource availability and societal acceptance of transmission infrastructures. The basic conditions for the regionalisation in this example were the balance of energy sources and energy consumption inside regions to achieve a high degree of regional autonomy concerning energy supplies. Therefore the regionalisation algorithm was adapted by customizable rules to merge polygons with complementary attribute values. A polygon with an energy potential above zero (net excess potential of renewable energy) should merge with a neighbouring polygon with a value below zero (low potential of renewable energy but high energy consumption = net energy deficit). Five densely populated areas with high energy consumption rates (i.e., population centres) are chosen as “seed” polygons, building the starting points for region growing (cf. figure 3).

4 Results

Figure 3 shows on the left the initial data set with five initial “seed” polygons and on the right the resulting regions. The target specification is completely fulfilled: All resulting regions are optimized concerning their level of self sufficiency, minimizing in- and output transfers.
Clearly the result is linked to the set of initial polygons. Not only the minimum number of regions is determined by that, also the region forming is influenced. This mainly depends on the spatial restrictions given by the dataset: If a growing region is surrounded by other regions, a balanced growth is influenced or even stopped by competing cluster building.

5 Conclusions & Outlook

In this paper a regionalisation tool based on the implementation of a hierarchical, aggregative, spatially constrained clustering method has been described. An example for regionalisation in the field of self-reliance on renewable energy usage was demonstrated and promising results are shown. Possible further areas of applications are manifold: Depending on the potential pre-defined rules, region aggregation could be based on homogeneity criteria (e.g. in the ecological modelling domain) as well as on complementarity criteria. Future work will target various areas:

- Integration of further parameters and statistical rules for the clustering process.
- A weighting algorithm to bias the region building process. This is already in development status.
- Implementation of a form descriptor (e.g. shape index), to obtain more compact regions and therefore avoid elongated region shapes.
- Optimisation of processing time, especially for large datasets.

This paper addresses multiple methodology issues which are currently not fully resolved for GIS analysts using standard software:
• Regionalisation of operational taxonomic units like simple polygons by adding proximity or contiguity constraints to attribute-based classification techniques.
• Implementing regionalisation based on pre-set seed locations (e.g., population centres).
• Generalising the standard usage of similarity measures towards measures of complementarity, demonstrating a conceptual approach to identifying self-sustaining regions.

Although concepts and practical implementation are only briefly outlined in this paper, the far-reaching potential of regionalisation methods as a currently underrepresented set of spatial analytical techniques is clearly demonstrated.

6 Acknowledgements

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7 References

Knowledge of Experiences in Digital Landscape through Textbooks on Design and Landscape Technology

Torben DAM

1 Introduction

Digital landscape modelling is going to change the way landscape architects design and work (Jørgensen, 2004, Jørgensen, 2006). Architects in Europe even think that digital design can reveal some forces that contemporary architecture need (Nilsson, 2004). Essential questions occur in the transition period from analogue to digital design about intelligence, knowledge, and the design process. Digital 3D modelling is called intelligent, and in some parts of architecture the 3D models are ahead landscape architecture. The development with-in IT goes fast, and the software evolves in some areas, where digital development is evident. How will the 3D-model challenge the way we work, and the knowledge we have? What happens to design experience and knowledge in the transitions process? The objective of this article is to merge two separated worlds, The digital, 3D model and the analogue landscape architectural design tradition. This is done by exploring 3D models and textbooks. Since the 3D models develop and the stage is different in different regions, this article uses one Danish 3D model, made on basis of ISO 12006-2. Knowledge in this article is seen as information and theory needed to reveal a landscape architectural project. Textbook enhance a concern of gathering, understanding and editing knowledge, they are the source of this article. It is often assumed that development of digital landscape models follow a progressive linear process, this is not the case if the knowledge from the analogue design process do not be used. This article suggests that the digital landscape model is made by a mix of theory and experience in textbooks with an analysis of the structure of the intelligent 3D models. The 3D models will benefit from existing knowledge in landscape architecture. The transition from analogue to digital design can even improve our understanding of the design process. This article focusses at terrain as a subject. Terrain is used as a phrase for the surface of the landscape. Terrain is the result of grading, storm water management, preparation for the coming soft or hard landscapes. The study of intelligent 3D models and knowledge in this article shows that interaction is possible. The structure of the intelligent 3D models in an early stage of the design process need categories of terrain available that keep design options open. These categories can be found in the textbooks, but categories are made for other purposes. The 3D-model will in the later and more detailed stage of the design process benefit from the technical information in the textbook, even though there are many regional differences in soil and climate that influence the design. For terrain the data in the 3D models has to generated by ourselves, because no product suppliers have any particular interest, as e.g. windows in buildings. 3D models and classification are still dependent of a general design skill, which will be essential to the 3D-model, but not included.
2 Material & Methods

2.1 Textbooks

Knowledge from 5 textbooks is analyzed. The 5 textbooks are chosen as case studies (Francis, 2000) representing a broad range of books made for landscape architects and students with-in landscape design and landscape technology. Textbooks represent knowledge and are therefore rich accessible sources with information and experience put into a design context. 3 of the book are coming from America and 1 from Germany and 1 from Denmark. (See references below). The analysis is based on quotations, review and statistics. The objectives and purpose of the book regarding terrain is analyzed, to discuss the interaction between design and knowledge.

2.2 Intelligent 3D objects

Intelligent 3D objects are described by Ian Jørgensen (Jørgensen, 2004, and Jørgensen, 2006). An object is defined in ISO 12006-2 as: “any part of the world, which one can experience or imagine” (ISO, 2001). In building architecture some components are already far ahead landscape architecture. Windows, façade elements, etc. which are repeated many times in a building, can give us an idea of the possibilities. The Danish Government demands digital 3D modelling from January the 1st, 2007¹. The digital model is created on an early stage in the design process. As the process proceeds the model is more and more detailed. Figure 1 illustrates the object, window at a rather early stage. The functions are evident and general. In the middle a product (window) is placed in a decision tree, ending up with a typical standard window.

¹ Digital Construction - in Danish 'Det Digitale Byggeri' - is a united public-private initiative to stimulate digital integration - vertically and horizontally - in the building and construction sector. Initial studies have identified six central areas for further development. The areas are: Standardisation of classifications, descriptions and formats. Common solutions for: Contracting, Projectweb, 3D models and FM-data. Best Practice cases.www.detdigitalebyggeri.dk
Experience to digital landscapes through textbooks on design and landscape technology

Fig. 1: A window illustrates the idea of the classification system, Function, Product and Location are three topics, following the design process from programming to as-built models. Authors translation. (bips, 2005)
Fig. 2: A 3D-model, objects seen as resources used in a process ending up in a construction. Properties mentioned in the text refer to the 3 aspects. (DBK, 2004)

To the right the location of a window is illustrated as a process, showing the development all objects undergo during the design process.

Classifications systems have been used in many years. The digital evolution has pushed the process further. In 2001 an ISO-standard was published. The standard was based on the British and Swedish standard. The Danish Building Classification (DBK) (DBK, 2005) is updated with the 4th domain: “properties”, 1) Resources: Materials, Building information, Tools, Persons involved. 2) Process: The lifecycle of the built, Phases, programme, design, construct, maintain, use, and conduct. 3) The result: a type of built environment, a type of space, a type of building, part of the building, a product, a built product. 4) Properties: relation between components, comparable, functions, experience, symbols, administration. Figure 2 shows the idea and a list with the classification system linked to ISO, OCCS, DBK, and terrain can be seen in Figure 5.

Fig. 3: The 3D object has to be defined by function, production data and placement in 3 dimensions

Fig. 4: 3D modelling give the opportunity to exchange drawings, to extract data, to produce drawings, to simulate specific models, to visualize, and to assess quality

3 Results

3.1 Experience in textbooks

The 5 textbooks are published from 1971 to 2002, the latest editions are from 1994 – 2002. Site Planning has its focus on the design process but shows the importance of technical information by a large appendix, and a prescriptive approach to the design process. Most of the other books have in the text considerations on the design process and the connection to
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data and standards. Time-Saver Standards, Befæstelser and Bauen mit Grün however are mostly concerned with displaying data, technology and standards. (Holgersen & Dam, 2002) describes a method for the research of materials and components. Site Engineering seeks to bring the reader through topography, grading and storm water management, with formulas, examples and tables. Most of the knowledge is selected by the authors without any specific explanation even though some general remarks indicate that the selected information is valuable to the landscape architect under the design process.

The textbooks seldom have a systematic approach, as is seen in 3D- models. They present data, tables, standards and samples on a detailed project or construction level. (Holgersen & Dam, 2002) tries to divide the description of materials and constructions into three: 1) programme, 2) outline proposal and 3) principal project, but the reader has to make her own transcription from detail or construction to programme or sketching in most of the book. Bauen mit Grün has a sample with a garden designed in connection to each chapter, here is knowledge linked to design of the garden. The high complexity of detailed natural science based knowledge on growth conditions in soil seen in the textbooks is structured in Bauen mit Grün. 7 headlines defines a soil. Site engineering and Time-Saver Standards uses typology to make the reader aware of the potential of the general information about grading. The reader is invited to structure her own specific project.

Terrain which is the specific subject in this paper is an important part of all 5 books. Site Engineering focuses on terrain. Even books with the purpose of a total coverage of all subjects in Landscape Architecture as Timer-Saver Standards and Bauen mit Grün has a substantial part of the book concerned with terrain-related subjects. Befæstelser covering hard surfaces gives the same impression. Site Engineering introduces sketching and small calculations; all the chapters are related to terrain. Bauen mit Grün is an overall textbook, with focus on the materials (also soil) and the detailed constructions, seven chapters have some relation to terrain (growth is a focal point). Even though many subjects are of the same kind, the focus and approaches vary. The experience of the author, the regional conditions and the objectives courses the variation of the information and of the selected problems in the textbooks. The interaction between design and knowledge Site Planning defines the design process by being in opposition to the common account of genius, and knowledge, even though it is important is described as a path. Hideo Sasaki

8 Beispiele für die Bewertung von Böden. a) Bodenart nach DIN 4022; b) Bodengruppe nach DIN 18915; c) Wert; d) Allgemeine Ansprache; e) Technische Bearbeitbarkeit; f) Terminliche Bearbeitbarkeit; g) Wasser durchlässig kheit; h) Wasserhalte vermögen; i) Vegetationstechnische Bewertung; k) Was der Planer beachten muss; l) Was der ausführende beachten muss. p125 - 130.
9 Steven Strom and Kurt Nathan, Site Engineering for Landscape Architects, The visual form of grading may be broadly categorized into three types. The three categories are geomorphic, architectonic and naturalistic. p59.
10 Charles W Harris and Nicholas T. Dines, Timesaver standards for Landscape Architecture, Grading may be done for a number of functional and / or aesthetic reasons Figures 320-1 through 320-9 show a range of typical examples. p320-2.

6 Site planning is more than a practical art, however complex its technical apparatus. The aim is moral and esthethical: to make places which enhance everyday life – which liberate their inhabitants and give them a sense of the world they live in. Professional skill – that easy familiarity with behaviour settings, grading, planting, drainage, circulation, microclimates, or survey – is only a path to that result. p1.
writes in a foreword that: “The data and standards it contains demonstrate how and where the profession interconnects with the efforts of many specialists from different sciences and technologies”. Under grading (Harris & Dines, 1998) makes the design process linear: *The grading scheme is a primary determinant in the total design* (Strom & Nathan, 1998) calls the design process a: “a controlled intuitive process.” and emphasize that: “This shaping must not only display a sound understanding of aesthetic and design principles but also ecological sensitivity and technical competency. (Holgersen & Dam) links knowledge to both: “definition of the landscape architectural problem and part of the design process”. In Bauen mit Grün the link between landscape architectural choices and technology is taken as a fact, and different materials and constructions contributes different design.

**Fig. 5:** The relation between design and knowledge depend on the kind of knowledge. The four aspects can help to navigate in the ocean of knowledge when transition to digital design in 3D models starts to develop product data at the early stages of the design process.

### 3.2 Knowledge-based, intelligent landscape modelling

Interpretations of the intelligent 3D-model and terrain in the textbooks indicate a sound structure and a rich source of knowledge. There is however work to do, when the two items has to be combined. The 3D-model has to hold some knowledge very soon in order to construct an intelligent, digital 3D-model, that can visualize, and can have quality assessment, e.g. collision of pipes and three growth. The textbooks illustrate excellently the level of detailed knowledge. Few examples in Bauen mit Grün and Befæstelser express the

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7 The publication of this handbook represents an historic event for the profession of landscape architecture. By scope and organization, it provides a broad practical definition of what landscape architecture is as an applied art and science. The data and standards it contains demonstrate how and where the profession interconnects with the efforts of many specialists from different sciences and technologies. (foreword, Hideo Sasaki)

8 Time Saver Standards, p.320-2

9 Viden om befæstelsernes materialer, afvanding og lagvise opbygning skal hjælpe, når man skal indkredse en problemstilling om befæstelser, og når man gennem skitsering skal finde en løsning. p141.

10 Garten- und landschaftsarchitekt sowie der Unternehmer des Landschafts- und Sportplatzbaues, der diese Objekte als Gesamtwerk ausführt, müssen dabei den Umgang mit diesen Baustoffen und Bautechniken beherrschen. Jeder Baustof bietet ja ein anderes Bild, und die gleiche Situation lässt in dere Re.g.el verschiedene Lösungsmöglichkeiten zu. p2.

Beit aller Freizügigkeit in der Gestaltung sind Planer und Ausführende gebunden an die technischen und physikalischen Eigenschaften der Baustoffe. p2.
level of knowledge e.g. in the outline proposal, that will end up with very specific and detailed knowledge later. Terrain can be seen as a construction complex, a large scale complex equal to a group of buildings.

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<tr>
<th>3D intelligent models</th>
<th>Knowledge-based</th>
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<tbody>
<tr>
<td>Nr.</td>
<td>Subject/ level 3D system</td>
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<tr>
<td>1</td>
<td>Construction entities by form</td>
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<td>2</td>
<td>Construction entities by function</td>
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<td>3</td>
<td>Construction complexes by function</td>
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<td>4</td>
<td>Spaces by degree of enclosure</td>
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<tr>
<td>5</td>
<td>Spaces by function</td>
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<td>6</td>
<td>Facilities by function</td>
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<td>7</td>
<td>Elements by function</td>
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<td>8</td>
<td>Designed elements</td>
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<td>9</td>
<td>Workresults by type of work</td>
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<td>Management process by type of process</td>
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<td>Construction entities lifecyclestage</td>
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<td>Project stages</td>
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<td>13</td>
<td>Construction product by function</td>
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<td>Construction agents</td>
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Complexes are divided into constructions entities such as one building. For terrain this division can be a park. The building is divided into spaces and elements or even designed elements or work results. Similarly the park can be divided into grass meadows, woodland, flower gardens as spaces. The elements can be trees, pavings and lawns. A flower bed can be seen as a designed element and soil improvement can be a work result. Figure 5 shows a complete list of subject in a classification system for a 3D-model based on ISO 12006-2. The list is linked to terrain and the 5 textbooks.

![Fig. 6: A 3D object-based classification system with links to international standards. Terrain transferred in this system can be inspired by the textbooks.](image-url)

![Fig. 7: Terrain in a 3D model similar to the window in figure 1. A grass-meadow was in mind. Notice under products how the first categories have to be open.](image-url)
4 Conclusions & Outlook

The questions in the title can be answered: “Terrain fits the intelligence in the described 3D model.” “The kind of knowledge available is a detailed one. Other kind of knowledge has to be structured for the early stages of the 3D-model.” There is useful experience gathered in a wide range of textbooks.

The classification system has to a higher degree focus on the process, than the textbooks, which mainly has its focus on the detailed construction in the project or the process under landscape construction. The different objectives of the textbooks offer plenty of input with randomized occurrence. The challenge is to conduct the right level of knowledge to the early stages of the process, and to acknowledge that the experience not only come from one book. The separation of information in the earlier stages, e.g. process (DBK, 2005) has to done with substantial insight in the terrain objects. High complexity seen in the textbooks has to be structured as Bauen mit Grün structures the soil in 7 headlines. There are however also in Site engineering and Time-Saver lots of formula, calculation examples and tables that do not fit into the 3D, object classification system. It can however be a valuable digital tool, as an application or a tablet in the landscape modelling program.

The idea of objects in the building is easy to follow. Objects in terrain are not necessarily an evident subdivision. Objects defined as spaces or by function have to some degree already found its way in to Landscape Architecture due to maintenance and park management. Terrain objects can however also be layers under the surface. Objects defined by functions at an early stage in programming and design include unknown information of the site, and while information on the functions are fixed in the program, information about the terrain occurs during the sketching of the proposals.

The transition to an intelligent 3D landscape model will hopefully be followed by both usage of the experience in textbooks and a theoretical study of the landscape design process:

- Split terrain (landscape architecture) into objects. Some objects are evident, some objects are important even though they are hidden in the final project
- Find the objects in textbooks on landscape architecture or - technology, in garden history, and quality standards for park management. The landscape technology textbooks gives often attention to the hidden but important objects
- Take the detailed knowledge as an end point and discuss the information needed in earlier stages e.g. the conceptual design, the outline proposal, and the preliminary project, beware of the 4 aspects: tradition, technology, basic, and unique.
- Use an international (ISO 12006-2; 2001) based 3D-model, funded on IFC (Industry Foundation Classes) and Global Unique Identification.
- Make a large network with all consultants (landscape architects, engineers, architects, city planners) suppliers, contractors, service and management persons when the 3D model is developed
• Continue the theoretical discussion about the design process, and have attention to all the rules of thumb and small calculations in the textbooks, so the landscape architect is controlling the intelligent 3D-model and not the opposite.

5 References

(bips, 2005) bips: construction - IT - productivity – cooperation, Klassifikationsprojektet fase 3 Gunnar Friberg, Power-point presentation, February 2005 <Danish>


(Holgersen & Dam) Søren Holgersen og Torben Dam, Befæstelser, Forlaget Grønt Miljø, 2002, <Danish> 383p.


6 Biography

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