REGION-BASED ANALYSIS OF DIGITAL SURFACE MODELS

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1 INTRODUCTION

The current status in spatial data handling can be characterized in such a way that tremendous efforts have been made to deliver more data in shorter times by using new sensors and the benefits of the internet, while on the other hand a couple of important automatical data processing methods are neither reliable enough nor operational yet.

This general statement is also if not in particular valid for acquiring and processing Digital Elevation Models. On one hand, important developments like radar-interferometric sensors (e.g., the Shuttle Radar Topographic Mission, SRTM) or laser scanners (e.g., the operational systems *TopoSys, TopScan* or *ALTM*) have become available to the market. On the other hand, important tasks along the data processing chain like the normalization of Digital Surface Models (DSMs) or the extraction of object types using elevation information very often do not lead to satisfying and reliable results as obtained with human operators. This is the motivation to present a novel *region-based, multi-scale approach* which can be applied on elevation data for the above mentioned processing tasks. Chapter 2 will describe the underlying methodology in more detail while Chapter 3 will present results using elevation data from laserscanning.

Another reason for unsatisfying processing results is the fact that the full information potential which a human or automatical processing system needs for interpretation purposes is not given if only one data source is considered. For instance, laser scanning methods produce "blind data", i.e. no semantic or image information is associated with the elevation values - in contrast to optical sensors, whereas laser scanners are much better suited for capturing and processing heights, especially in wooded or urban areas. In this context, Chapter 4 will show that the proposed region-based methodology can be transferred and is able to handle multi-sensoral data sources.

2 METHODOLOGY

In contrast to the traditional, point-wise procedure of classification or filtering methods the general idea of the proposed region-based approach (see Figure 1) is that an a-priori *segmentation* is performed in order to detect larger regions showing very similar, homogeneous properties. In analogy to a visual interpretation this region building can be done at various scales in order to obtain the most significant representation of every single terrain feature or object under observation. For the obtained segments which are so far geometrical regions without any meaning a *classification* is performed which in our case uses a fuzzy-logic approach.

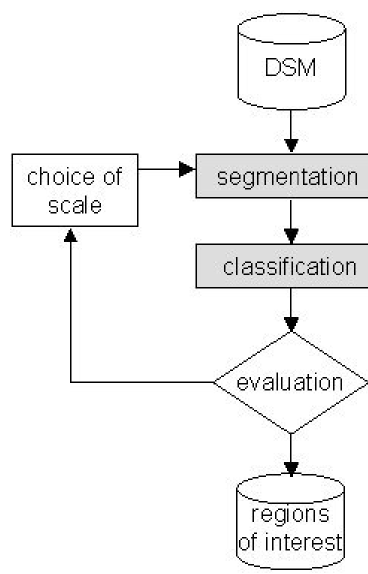

Figure 1. Outline of region-based approach

The **segmentation** of the available elevation data is performed by means of a commercially available software product (eCognition; see also Baatz & Schäpe, 2000). The definition of homogenous regions is based on appropriate parameters that depend on the inputted data source as well as the current application.

The task of extracting the terrain surface from resp. normalizing a Digital Surface Model (DSM) as obtained from laserscanning, radar interferometry or image matching implies the reduction of areas which lie above the surface. We have found that the surface curvature in combination with corresponding gradients represent best the outlines of such regions (for details see Schiewe, 2001b). In order to allow for a variable, application dependent grade of generalisation for the outlines of the regions which have to be reduced, we apply the segmentation at different scales.

As a typical and successful example of an object extraction based on elevation data only we can demonstrate the detection and classification of forest areas (not single trees). Here the homogeneity parameter "absolute object height" which is derived from the normalization process as outlined above differentiates between areas which are clearly above the terrain surface (like forest or buildings) and those which are close to the ground. Secondly, the parameter "height texture" (i.e., the variation of heights within a given window) separates forest areas (with high variations) from areas representing buildings (low variations).

As the extracted, homogeneous regions have no semantical meaning so far, a **classification** of these segments using a fuzzy-logic approach is performed next. As input observations the various parameters of the segments derived at different scales are used. Core task now is the *fuzzification*, i.e. the definition of the membership function of a property (e.g., region to be reduced; object type) related to a segment based on the given observations. Because a generic determination of these functions is impossible, we apply tolerance intervals from logical considerations and a linear function in order to describe the range of partial memberships. Finally, the desired decision is based on a weighted summation of the obtained single membership values.

In the case of the DSM normalization a post-processing step re-classifies island segments which are showing rather low gradients but which are completely surrounded by regions of large gradients (like a roof segment surrounded by wall segments).

In the case of object (here: forest area) extraction we have to use also additional geometrical parameters of the segments: For instance, the definition of a forest area demands for a minimum size (e.g., 500 m^2) and a minimum width (e.g., 10 m).

3 EMPIRICAL TESTS

Various empirical tests are showing the applicability but also the limitations of the general approach as presented above. In the case of normalizing Digital Surface Models it can be noted that due the inherent relatively large number of blunders within elevation models derived from automatical matching based on digital, high-resolution stereo imagery (in our test case from the HRSC-A sensor) neither conventional nor our proposed methodology yield reasonable results (see also Schiewe, 2001a).

On the other hand, for a test site under investigation the region-based normalization based on laserscanning data has shown no errors of first type (omission errors) while the number of errors of second type (commission errors) is below 2% of the total number of segments. Critical regions are small clearings within wooded areas. Figure 2 demonstrates the results. Applying the segmentation and the following classification not only at one, but at multiple scales, reduces the number of commission errors. However, this scaling process must not be performed as far as possible because the number of omission errors would increase and in the extreme case one would end up with an undesired point-wise classification.

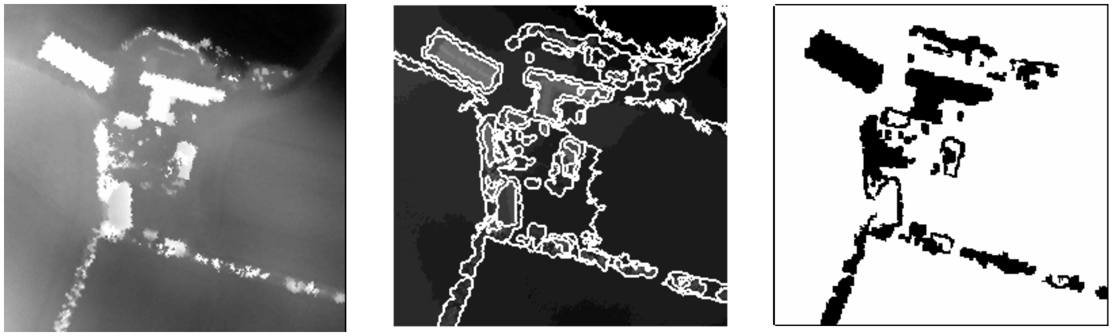

Figure 2. Given DSM (250 m • 250 m; left), results of segmentation (middle) and classification (extracted regions that have to be reduced are in black; right)

For the task of extracting objects (forest areas) from laserscanning data we also found satisfying results: As Figure 3 demonstrates it is possible to separate forest areas from buildings and other objects, and - due to the given size constraints - to separate forest regions from single trees.

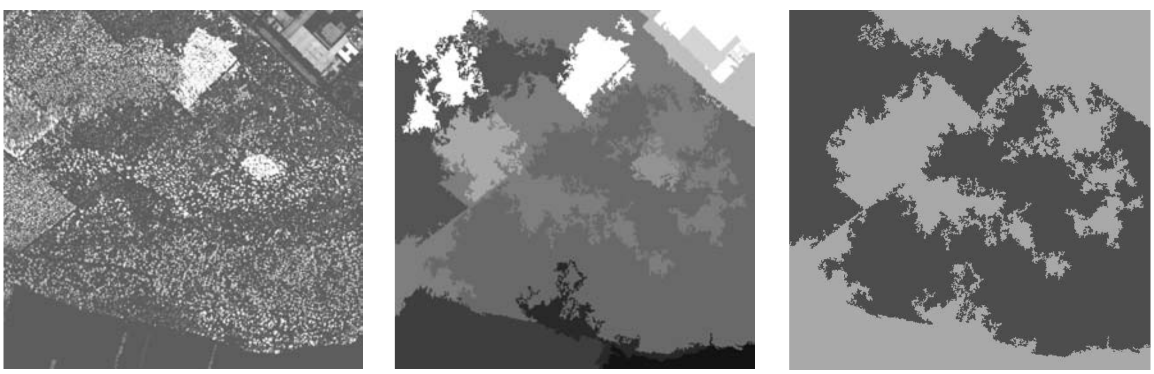

Figure 3. Given DSM (1000 m • 1000 m; left), results of segmentation (middle) and classification (extracted forest regions - not single trees - are in black; right)

4 EXTENSIONS TO MULTI-SENSORAL PROCESSING

As already pointed out there will be a trend towards the acquisition and processing of multi-sensoral data in order to increase the information potential. As an example consider the extraction of forest areas from laser-scanning data only (Figure 3) which is even for a human interpreter a difficult task. In this context we have already shown that the above proposed region-based methodology (and the software in use, resp.) is also able to handle elevation and image data at the same time. Thus it is possible to consider additional homogeneity parameters derived from imagery (e.g. the NDVI or spectral texture for detecting and classifying vegetation on the ground). Corresponding results will be shown during the workshop.

Consequently, *multi-sensor-systems* are under development which will represent a new development stage in the field of photogrammetry and remote sensing. It is planned to present results for an object extraction based on a brand-new, high-resolution and multi-sensoral system (*TopoSys II*) during the workshop which consists of a laserscanner (horizontal spacing of 1 m, vertical accuracy of 0.2 m) and an electro-optical scanner (covering the visible and near infrared range at a pixel size of 0.5 m).

5 CONCLUSIONS

Empirical tests have shown the successful applicability of our region-based and multi-scale approach for normalizing Digital Surface Models and extracting objects from given elevation data. The methodology is able to handle also multi-sensoral data input.

Going one step further, it has to be stated that the presented solutions for the involved processing tasks should not be seen separately. In fact, the traditional linear processing chain - starting with the blunder detection within a DSM, then performing the normalization, and ending up with the object extraction - has to be changed to a linked net of methods which allows an iterative, eventually also backward oriented work flow. For instance, the hypothesis of a certain object type for a given segment is also a valuable information for an improvement within the normalization process (e.g., generally no interpolation of surrounding height values should be applied if buildings are present).

Furthermore, not only regions-based approaches as presented here, but a combination with edge-based methods will become necessary in order to improve the quality of results. Hence, multi-sensoral data input leads to the next challenge which is multi-method processing.

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