TWO STRUCTURE-RELATED STRATEGIES FOR AUTOMATICALLY DELINEATING AND CLASSIFYING HABITATS IN AN ALPINE ENVIRONMENT

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ABSTRACT:

This paper presents a study on automated habitat delineation and classification using very high spatial resolution (VHSR) optical remote sensing data in an alpine environment. Two overlapping study sites, which are situated in the Berchtesgaden National Park (SE Germany) represent a mountainous area, characterized by high habitat diversity. Habitat classification and delineation used to be accomplished manually on aerial photography by experienced interpreters on large areas. Driven by monitoring obligations in the framework of Natura 2000 as well as for reasons of time and economy, there is an increasing demand on regularly updated image data. In parallel, promising advances in automated image interpretation have been made over the last years. The used approach of object-based image analysis (OBIA) resembles the human performance of interpretation, though still with some limitations. Pan-sharpened data from a QuickBird scene were analyzed using two strategies for dealing with high spectral and spatial variability, namely one-level representation (OLR, Lang & Langanke, 2006) and multi-scale segmentation/object relationship modelling (MSS/ORM, Burnett & Blaschke, 2003). The study compares the potential of both strategies in specific settings, (1) boundary delineation of a given set of habitat types via OLR and (2) classification of patches of mountain pine (*Pinus mugo*) using MSS/ORM.

1. INTRODUCTION

1.1 Thematic Background

The Berchtesgaden National Park is one of eleven protected areas within the Alps, which are involved in the European research project group HABITALP (Alpine Habitat Diversity). One of the aims of the HABITALP project is to monitor biodiversity and long-term environmental changes of alpine habitats with CIR (color-infrared) aerial photographs. Since 1980 in an interval of five years manual delineations and classification of habitats have been accomplished by experienced interpreters according to the standardized HABITALP interpretation key (HIK). The latter was developed for land use types in protected alpine areas during the HABITALP project (HABITALP, 2006).

For reasons of time and economy, and in this context more specifically to meet the reporting obligations regarding the conservation status of habitats within the framework of Natura-2000, there is an increasing demand on frequently updated image data (Lang & Langanke, 2006). We assume that automated analysis of satellite imagery will complement the manual interpretation of aerial photographs. Nowadays, satellite sensors offer high spatial resolutions up to 0.61m (panchromatic band) and high radiometric and spectral resolutions. The possibility of applying resolution-merge algorithms increases the potential even more by providing imagery with high spatial, spectral and radiometric resolution. Along with this development promising advances in automated object-based image analysis of remote sensing data for landscape monitoring have been made over the last years (Blaschke et al, 2005; Lang

& Langanke, 2006). By combining methods of image segmentation and knowledge representation such methods try to imitate the human perception and interpretation performance (Lang & Langanke, 2006).

A mere pixel-based classification approach seems to be intrinsically limited to address and classify complex structural classes like habitats in an alpine environment (ibid.). In addition, the pixel- and edged based view usually implies a uni-scale-method, exploring the pixels of only one scale within the image. Uni-scale, pixel based monitoring methodologies have difficulties providing useful information about complex multi-scale systems (Burnett & Blaschke, 2003). Thus, in this project two different region based segmentation / classification approaches were used to identify alpine habitats. Image objects of different scales and levels were extracted by the *region-based local mutual best fitting approach*, which is implemented in the Software eCognition 4.0. Compared to single pixels, image objects have the advantage of being appraisable as meaningful or not, since based on aggregated spectral information and bearing a specific shape (Blaschke & Strobl, 2001). In addition, the topological characteristics of object arrangements (i.e. neighbourhood relations) are known.

The aim of the study is to evaluate the potential of two strategies for representing complex target classes in specific settings. The first strategy, one-level representation (OLR, Lang & Langanke, 2006) we employed for boundary delineation of a given set of habitat types. The second, multi-scale segmentation/object relationship modelling (MSS/ORM, Burnett & Blaschke, 2003) was used for identifying patches with varying coverage of mountain pine (*Pinus mugo*).

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1.2 Study site

To achieve the aim of the study two overlapping test sites situated in the Berchtesgaden National Park (NPB) have been chosen (see figure 1). The first test site (A) comprises a 16 km^2 area in the south-western Klausbachtal. The second site (B) captures a 29 km^2 expanded site around the peak of the Hochkalter massif (rising up to 2607 m a.s.l). Both subsets represent a typical alpine area, characterized by high bio- and habitat diversity and rough relief.
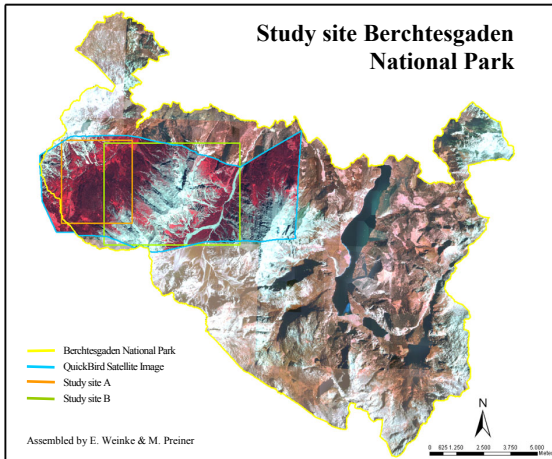

Figure 1: Study sites at the Berchtesgaden National Park

1.3 Data & data processing

We used very high spatial resolution (VHSR) data from a QuickBird scene scanned in August 2005 (see figure 1 and table 1). The imagery we obtained pre-projected in UTM-33 (WGS-84) but with a low spatial accuracy. Multispectral and panchromatic bands were separately orthorectified using the *rational polynomial orthorectification* (RPC) model. Due to the rough terrain, the additional usage of ground control points and the elevation information of a 10m resolution DEM have increased the geometrical correction.

Band	Wavelength Region [ym]	Resolution [m]
1	0.45 - 0.52 (blue)	2.44
2	0.52 - 0.60 (green)	2.44
3	0.63 - 0.69 (red)	2.44
4	0.76 - 0.89 (NIR)	2.44
PAN	0.45 - 0.90 (PAN)	0.61

Tab. 1: Spatial and Spectral Resolution of QuickBird Satellite Imagery

To gain the best possible result out of the panchromatic and the multispectral bands two different *resolution merge* operations were performed: for the OLR-strategy pan-sharpening according to LIU (2000) was chosen. To get a better differentiation among the vegetation coverage a PCA-based resolution merge was used for the MSS/ORM-methodology.

2. METHODS

2.1 Strategy 1 (test site A) - OLR

The first study entails boundary delineation of a given set of habitat types via OLR. OLR means that through iterative segmentation entire habitats are delineated which reflect the appropriate scale domain (see figure 2). By means of this strategy just one single target level is found (Lang, 2002). In the process of generating optimized target levels the basic rule of image segmentation is not allowed to break. As a consequence the image has to be divided into non-overlapping regions so that coarser levels are hierarchically structured in finer sub-levels and vice versa. During the first step, just a small area of interest (AOI) was selected and single habitats were extracted on specific target levels through the OLR-strategy. After this process the quality of the single segmented habitat geometries were checked by visually delineated habitats from CIR-aerial photographs. The detected target levels of the single habitats were applied to the whole first test area. The goal was to identify further habitats in the whole test site which result in the same iteration steps and parameter. Based on existing habitat geometries of the finer level we performed coarser segmentation for delineating habitats on a higher target level (aggregation level). Optional aggregation levels can be identified but the habitat geometries of lower levels should not be disregarded according to the approach of applying a strict hierarchy. This process we call iterative OLR-method.

The produced geometries were compared with the existing visual interpretation using the virtual overlay method (Lang et al., 2006) implemented in LIST (*landscape interpretation support tool,* ibid.), an extension for ArcView 3 GIS. The tool offers a way to prove spatial coincidence of two corresponding habitat geometries. A threshold value can be set for 'spatial overlay strictness (SOS)' to accept overlaps of corresponding, but not fully congruent delineations. By investigating the spatial relationships between boundaries of corresponding habitat delineations, the "fate" of a particular habitat can be determined (cf. Schöpfer & Lang, this volume). This includes comparison of corresponding, though differently delineated habitats. The quality of the single habitats of the different target levels is based on an effective segmentation process and the specific parameters.
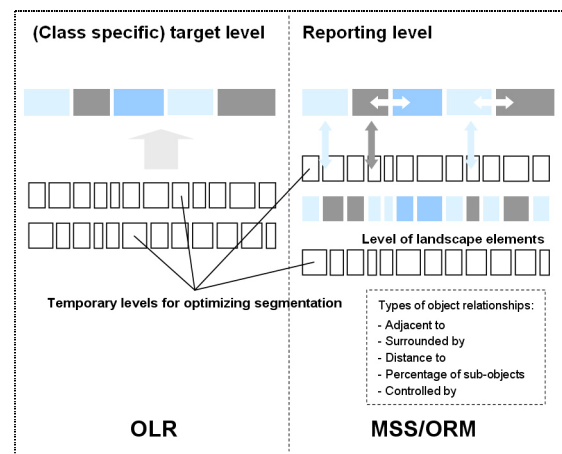

Figure 2: OLR vs. MSS/ORM according to Lang & Langanke (2006)

2.2 Strategy 2 (test site B) - MSS/ORM

Different to the first method for the second case study we applied the MSS/ORM approach (Burnett & Blaschke, 2003). Unlike the OLR method image objects are represented here in at least two scale-levels (see figure 2). According to the *region-based local mutual best fitting approach* (Baatz & Schäpe, 2000) as being implemented in the software eCognition 4.0, hierarchically arranged levels of image objects are generated by adjusting the user-defined homogeneity parameters (MSS). After this segmentation not only the spectral- and shape values of the image objects are known, but also their particular spatial and topological arrangement and therefore their horizontal and vertical relations. These image objects are the new fundament for the following object relationship modelling (ORM). To realize the ORM a hierarchy of complex classes is constructed, semantic rules are created, classification sequences developed and – ideally – user-defined useful objects from the former image object primitives generated.

The main target object of the MSS/ORM case study was mountain pine shrubs, a subtype of the FFH habitat type "Bushes with Pinus mugo and Rhododendron hirsutum" *(Mugo-Rhododendretum hirsuti)*.
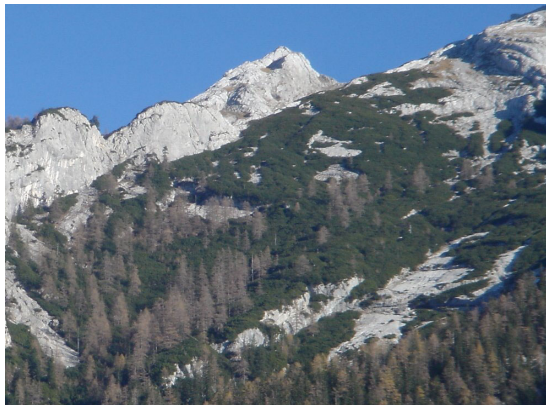

Figure 3: Picture of a typically heterogeneous area within the Berchtesgaden National Park

On the slopes of the Hochkalter massif, these areas covered by *pinus mugo* are arranged particularly heterogeneous (see figure 3). Because of that they had to be represented on up to five different scale levels and differentiated with a complex segmentation/classification process cycle. For this reason we constructed and classified several qualitative sub-classes (*Pure mountain pine stand, Mountain pine with single trees, Mountain pine with trees, Mountain pine with rock, debris or pebbles, Mountain pine with alpine meadow and/or rock, debris or pebbles, Forest with mountain pine, Alpine meadow with mountain pine, Rock, debris or pebbles with mountain pine*) and - to make the internal differentiation of this mountain pine classes possible - a number of additional auxiliary classes (*Forest, Alpine meadow, Rock, debris or pebbles, Firn- or Snowfield,...*).

To meet the objectives of a complete classification we initially defined and classified the homogeneous single objects (e.g. tree, bush, single rock …) and small split objects (e.g. tree - shadowed part, tree - lighted part) according to their spectral and shape values on the finest segmentation level (almost pixel level). Afterwards and contrary to this, we identified the mainly heterogeneous composite objects of the higher scale levels (e.g. *mountain pine with single trees*, *alpine meadows with mountain pine*) using additional semantic information and topological object relations (e.g. *number of trees-objects on a lower segmentation level*).

A special refinement, with an extra segmentation- classification cycle was applied, only concerning the mixed areas and transition zones between mountain pine and wood, alpine grassland or rocks, which had been, up to this time, extracted unsatisfying. To realize that, we merged all of the mixed classes (e.g. *Alpine meadow with mountain pine, Mountain pine with single trees, Forest with mountain pine,...*) into one single class (*Classification-based Segmentation*) and exported it as a *shape* file. After that we re-imported the file as a thematic layer and exclusively segmented and classified it without affecting the already well classified, mostly homogeneous classes (*Forest, Alpine meadow, Pure mountain pine stand, Rock, debris or pebbles, Firn- or Snowfield,...*) (see figure 5). In a final step the two parts were joined and re-assembled on a super level.

3. RESULTS AND DISCUSSION

In test site A the semi-automated segmentation produces similar habitat boundaries like the manual delineation (see figure 4). Alpine habitats with homogenous spectral behaviour (similar reflectance such as grasslands or regular texture, such as mixed forest) were successfully segmented and in many cases the results resembled the habitat geometries provided by an interpreter. However, one striking difference is that the used image segmentation approach does not provide scale-specific delineation as the human interpreter does. In other words, the boundaries of the automatically derived habitats are ultimately following pixel boundaries. Taking this into account we applied for the meadow and pasture habitat an SOS factor of 34% (see figure 4, left) and for the coniferous forest habitat we used an SOS factor of 12% (see figure 4 right). The high buffer distance of the meadow and pasture habitat is justified because in this case the interpreter perceptually included single features (like trees) in an otherwise homogenous grassland habitat matrix, whereas the software segments only the homogenous grassland area. The low buffer distance of the coniferous forest habitat shows that the border delineation of the human interpreter and the image analysis software eCognition are very similar.

☐ Buffer zone
☐ Visual border delineation of CIR- areal photogarphs
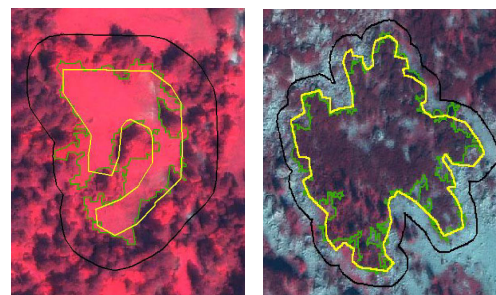☐ Habitat border which results of a segmentation process

Figure 4: Boundary delineation of a meadow and pasture habitat (left) and a coniferous forest habitat (right).

Through the iterative OLR eight aggregation levels with single habitats could be extracted (see figure 5). Each aggregation

level reveals a specific number of habitats with different structural features. Two reasons account for that; a high within-habitat diversity (heterogeneously composed habitats) and the different habitat dimensions.
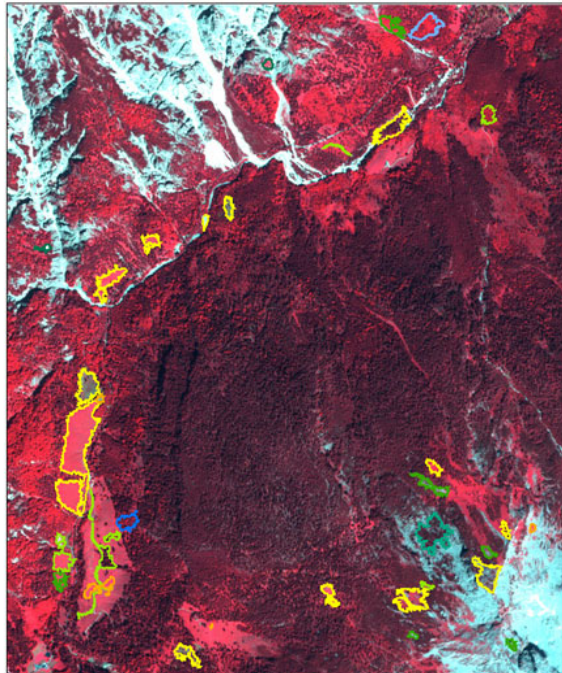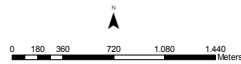

Figure 5: Eight Aggregation levels

The used QuickBird data with enhanced spatial and radiometric resolution is according to this qualified for image segmentation of specific habitats. The OLR segmentation strategy turned out to be suitable for delineating alpine habitats at single representation levels. At these levels one or more habitats can be identified. A number of such target levels can be extracted from the whole scene via the iterative OLR-method and re-assembled on a super level. In general, two different systems were compared. The visual human-perceptive system (interpreter) and the digital image analyses system (eCognition) which provide geometries with non-congruent object outlines even when working in the same scale domain. Whereas the human interpreter works with a high degree of generalization and subjectivity, eCognition strictly applies specific spectral and shape parameters and would not generalize. Using LIST, the different originated geometries could be compared with a specific buffer distance and it could be shown that the segmented results are similar to these of the human interpreter.

Using the MSS/ORM classification strategy in test site B, the mountain pine areas have been identified and classified quite satisfyingly (also compared with the CIR-based delineation made by a human interpreter). Due to the extraction of the qualitative mixture classes especially the ecological relevant, altitude caused transition zones between wood and mountain pines and mountain pines and alpine grassland or rock are clearly recognizable (see figure 6 and 7).
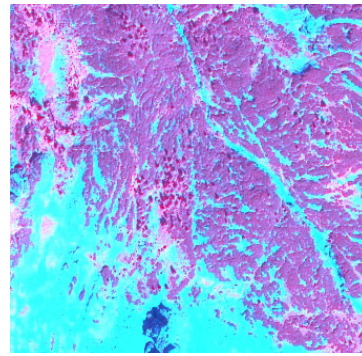
1: blank pan-sharpened QuickBird satellite data (Subset)
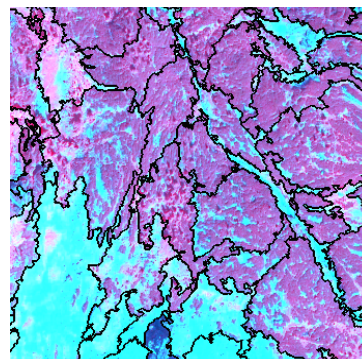
2: Initially segmented image object composition
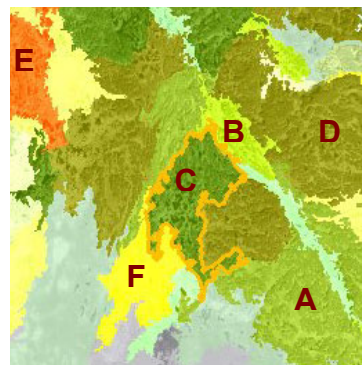
3: Final classification result with user-defined modified useful image objects

Apparent classes:
A) Pure mountain pine stand
B) Mountain pine with alpine meadow and/or rock, debris or pebbles
C) Mountain pine with trees
D) Mountain pine with single trees
E) Forest with mountain pine
F) Heterogeneous class with mountain pine

Figure 6: Extracting process of qualitative sub-classes of mountain pine vegetation within the transition zone.

With the generated classification as a new basis, change detection analyses for assessing or updating already existing geo-data could be accomplished (e.g. using LIST, ibid.). A further application for this habitat classification could be the quantitative and qualitative description of ecological characteristics concerning the distribution pattern of the extracted mountain pine classes, using the *landscape metrics* approach as implemented in the V-LATE Tool (Lang & Tiede, 2003).
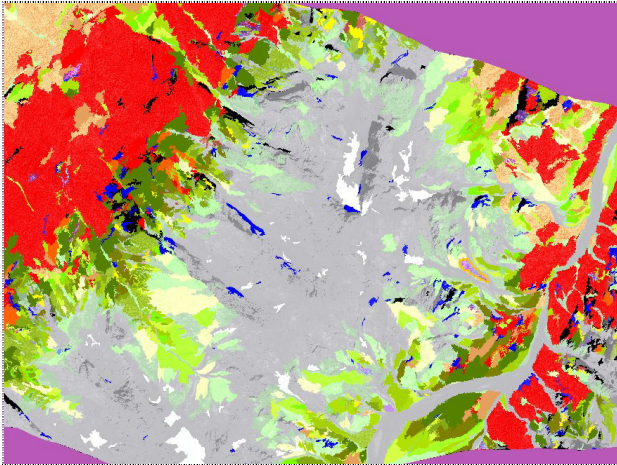
Figure 7: Final classification of study site B.

Problems concerning shadow objects on the pixel level or the illumination-caused spectral similarities of different classes and accordingly spectral differences within one class have been eliminated satisfyingly with the described usage of semantic rules and topological relations. Other problems affect the general usage of eCognition. Unfortunately the processing times increased exorbitantly while with the entire subset size (29 km^2) so it was hardly possible to work consistently.

Despite these limitations the results of the two studies show the considerable potential of the region based approach for automated habitat delineation and classification in mountainous areas. Depending on the thematic intentions and further planned applications either the OLR or the MSS/ORM strategy can provide the desired benefits for extracting (alpine) habitats.

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