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Segment-based analysis of high resolution satellite and laser scanning data

Marco Neubert[1]

Abstract

After the presentation of new approaches of image analysis for remote sensing data at the symposium of Computer Science for Environmental Protection 2000 in Bonn, Germany (Blaschke et al. 2000, Bock/Lessing 2000), now first user experiences using this method were achieved. Based on high resolution satellite imagery of the IKONOS-2-Sensor (1 m ground resolution) and laser scanner elevation data, knowledge about the classification process, the implementation and about data handling of the software system eCognition (Definiens Imaging, Munich, Germany) were gathered.

1. Introduction

Remote sensing data become more and more important for different environmental tasks. Satellite data even allow monitoring independent of accessibility of the surveyed areas.

With the data of the commercial IKONOS satellite high quality non-aerial remote sensing data with a geometric resolution of 1 m in the panchromatic and 4 m in the four multispectral channels are available for the first time. Thus, they are entering a field of application, which was reserved for aerial photographs so far. Furthermore there are high resolution elevation models from laser scanner data available with a resolution of 1 m. The combination of this two new high resolution datasets allows a more secure land cover classification of the imagery.

On account of the expanding resolution of imagery and scanner data admittedly the complexity of reproduction of the earth's surface is increasing. Thereby difficulties of processing (amount of data) as well as problems of image analysis using conventional methods are arising. Essential for the future of remote sensing are new, not only pixel- and grey-value-based classification approaches, such as image segmentation, neural networks etc.. Referring to this the segment-based software eCognition 1.0 is the most discussed approach at the moment.

[1] Institute for Ecological and Regional Development, Weberplatz 1, D-01217 Dresden, Germany, Email: M.Neubert@ioer.de, Internet: http://www.ioer.de

Figure 1
Test site Saxon Switzerland (© SpaceImaging EU SA) and the location in Germany.

2. The test site

As shown in figure 1, the test site Saxon Switzerland is located in eastern Germany, in the east of the German federal state of Saxony, south east of Dresden and has a dimension of 3.4 x 3.4 km. The rural area is characterised by an erosive landscape (belonging to the Elbe sandstone mountains) which evolved during the cretaceous age. It is characterised by rocks of cretaceous sandstone, deep and narrow valleys, the floodplain of the river Elbe, table mountains and gorges. Parts of the study area are protected as National Park. The shape and structure of this unique landscape is represented by sandstone and alternating forested and open areas.

3. Data and methods

3.1 IKONOS – Very high resolution satellite imagery

Since the beginning of 2000 data of the IKONOS-2 satellite sensor is available and delivers a geometric resolution of 1 m in the panchromatic (PAN) and 4 m in the four multispectral (MS) channels (SpaceImaging 2001). This investigation was done using a resolution merge (principle components method) to combine the sharpness of the PAN and the spectral information of the MS bands. The image was acquired on August 1st 2000.

The quality of imagery has to be rated as very good, if there are no atmospheric effects. In the panchromatic images, the contrast is such that the white lines of sports-field and road markings are clearly recognizable. At 11 bit, radiometric reso

lution is very high. Using a predefined ellipsoid (WGS84) and a map projection (e.g. UTM), even the used most basic CARTERRA Geo product is pre-rectified. Data are then essentially fit for use in Geoinformation Systems (GIS ready) (Meinel/Reder 2001, Meinel/Neubert/Reder 2001a).

The new high resolution imagery makes some problems in respect of data amount and the grade of details contained (e.g. different roof materials). Simultaneously the problem of mixed pixel known from low resolution satellite data is minimised. A big disadvantage is the acceptance of cloudiness up to 20 % by buying IKONOS data which are high priced anyway. The ability of sensor tilt cuts the repetitions rate to as little as one to three days, but this leads to inclinated views and effects of tilting of buildings. On the other hand this fact allows to produce stereo images.

At the moment the ortho-rectification of IKONOS data is only practicable using the software Geomatica OrthoEngine of PCI Geomatics (Richmond Hill, Canada). It will be possible with new ERDAS (Atlanta, US) Imagine 8.5, too. For exact ortho-rectification which is important especially in mountainous areas a high resolution DEM is necessary. The rectification is needed for using and overlaying additional geodata. In this case the ortho-rectification was done with the PCI tool and an accuracy (RMS) of 2.39 m for the whole scene (11 x 11 km) was reached therewith.

Some further companies are going to start new commercial high resolution satellite sensors in the near future and become new competitors of SpaceImaging's IKONOS-2 (see figure 2). Maybe this will have positive effects for the information politics of the operators (respective sensor models) and for the pricing of the data, what will make the data more competitive against aerial photographs.

Company	Sensors name	Advertised launch date	Resolution specifications		
			Panchro-matic band	Multispec-tral bands	Other bands
ImageSat	EROS A1	Dec. 2000	1.8 m		
Orbimage	OrbView-4	Jul. 2001	1 m	4 m	8 m/20 m HS
Earth Watch	QuickBird 2	Oct. 2001	0.7 m	2.8 m	
Orbimage	OrbView-3	3Q 2001	1 m	4 m	
Spotimage	Spot 5	Mar. 2002	2.5 m	10 m	20 m SWIR
ImageSat	EROS B1-B6	2Q 2002	0.82 m		
NASDA	ALOS	2003	2.5 m	10 m	
RapidEye	RapidEye	2003/2004	6.5 m	6.5 m	6.5 m

Figure 2
Overview of planned high resolution satellite sensors in the near future (without analogue and radar sensors)

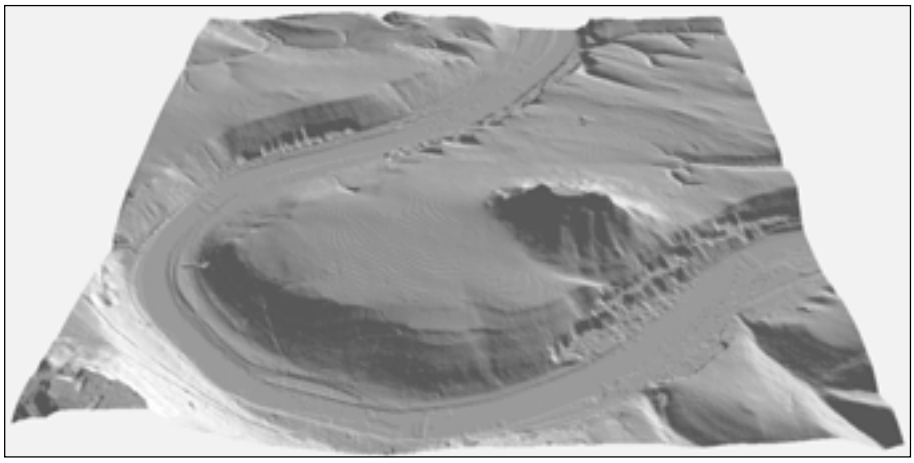

Figure 3
3D-view of the test site using the laser scanner elevation data.

3.2 Laser Scanning elevation data

Aside from the high resolution satellite imagery there are high resolution elevation models from laser scanner data with a resolution of 1 m and an altitude precision of 10 to 20 cm available (Csaplovics/Wagenknecht 1999). The used elevation data was normalised to the terrain (digital terrain model, DTM, see figure 3).

3.3 Image analysis using eCognition

The image analysis was done using the new segment-based classification approach of the software eCognition by Definiens Imaging (Definiens Imaging 2001, Baatz/Schäpe 1999, 2000). The software enables to overcome problems of conventional pixel-based approaches. It is based on the segmentation of homogeneous image areas (see figure 4) and offers valuable tools for classification.

Remote sensing data cannot be processed itself using eCognition as the software is only an image analysis program. Thus, an additional image processing system is required.

The software is based on the so-called 'Fractal Net Evolution' technique which is a method to describe complex semantics within a largely self-constructing and dynamic network. The 'Multiresolution Segmentation' allows to extract image object-primitives in variable resolutions into fine or coarse structures.

By the segmentation - as the first step - a hierarchical network of image segments is created which represents the semantic image content at different scale level. The

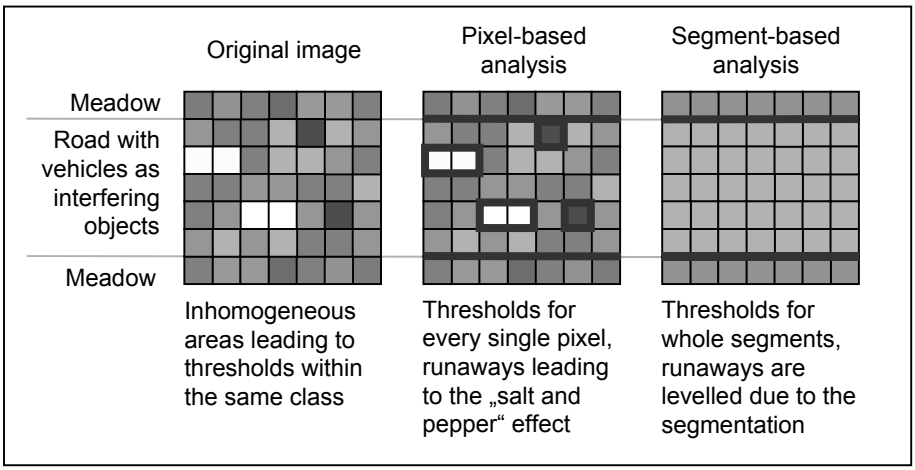

Figure 4
Idealized example to compare pixel- and segment-based approach.

segmentation algorithm is working with a region growing process starting from initial points using the fact, that a pixel is a member of the same class like its neighbour with a high probability. Creating segments, the number of elements to classify is much reduced and the amount of data is significantly decreased at the same time. Furthermore it avoids the "Salt-and-Pepper" effect invariably associated with pixel-based approaches (Blaschke 2000a, 2000b). To achieve the best segmentation for a given image, it is essentially necessary to run tests until the appropriate segmentation parameters have been found.

In the second step – the classification itself – a knowledge based so-called 'Class Hierarchy' is built. Thereby the process of classification can be done either by means of fuzzy logic membership functions or by selecting training areas (nearest neighbour classifier). For classification it is possible to use not only the average grey values but also context information like relations to neighbouring lower or higher-order image segments as well as formal properties (e.g area, shape).

The infant software – on the market since the end of 2000 – is not free of disadvantages. Thus, consistent data subsets are needed and only raster data of the same resolution could be analysed. Furthermore there is no way to include additional layers during the analysis and there is no possibility to use vectors for import or export. In addition to this the handling of huge datasets is not practicable at the moment.

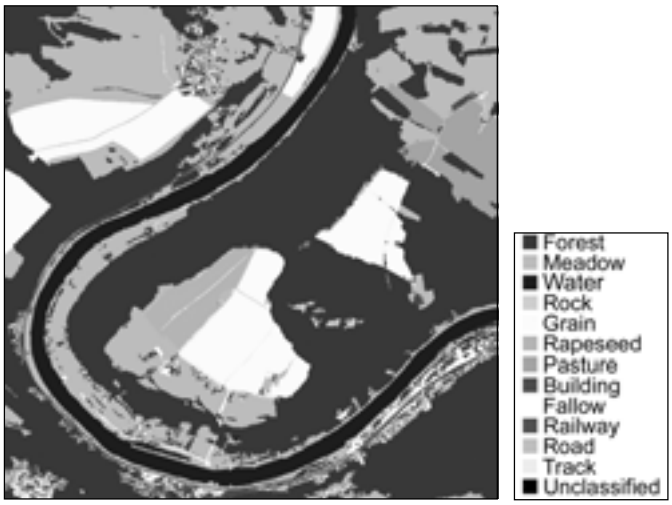

Figure 5
Classified image with 12 land cover types.

4. Results

The classification of land cover and land use types is a main goal of remote sensing. Figure 5 shows the result of the classification using the software eCognition. It was possible to detect 12 land cover types, even different kinds of agrarian cultures. To differentiate coniferous, deciduous and mixed forest was not realisable due the unfavourable atmospheric conditions. The classified image shows a very homogeneous result. The accuracy was checked visual and has to be rated as very good.

The use of a DTM was not very valuable – for classifying land cover a surface model (DSM) would be better, because it allows to classify buildings and vegetation. The DTM was helpful for detecting rocks and to exclude some classes (e.g. railroad only in the Elbe valley). Some other indices derivated from elevation data like slope and aspect could be useful for the classification.

Within the analysis of an other test site – a rural area of the city of Dresden – an overall classification quality of about 90 % was reached (Meinel/Neubert/Reder 2001a, 2001b). Comparing to pixel-based analysis it was possible to differentiate more classes and to classify more land use oriented (e.g. sports field). Furthermore eCognition yields a more homogeneous result and a smaller portion of unclassified areas was remaining. In this investigation additional geodata were used (digital block map) for a better segmentation.

5. Aspects of application

Spatial data from remote sensing platforms can deliver actual information of land cover fast and cost-efficient. Thus, they have a great importance for natural conservation, landscape planning and monitoring land cover and land use. It is known, that remote sensing is predestinated for environmental and landscape monitoring. The limits of scale were decreasing by means of the high resolution data. With the IKONOS data the development of land use and vegetation as well as landscape structures are observable with an exactness of one meter and it is useable up to a scale of 1 : 5,000. Potentials for using remote sensing data for the European Natura 2000 Directive (monitoring of Flora-Fauna-Habitat-areas – FFH) are under investigation. Change detection could be realised between two satellite images or by a comparison of a classified image with existing datasets
Potential applications are imaginable in the following points:

- Use as GIS-dataset (overlay with other spatial data),
- Visualization (satellite image maps, 3D-Visualization),
- Forest- and biotope monitoring, monitoring of natural conservation areas,
- Update of land use datasets, maps and tree cadastres,
- Mapping urban structure types and soil-sealing,
- City information systems, City marketing,
- Tasks of planning and assessment (working maps, characterisation of structures).

6. Conclusion

With the high resolution satellite data of IKONOS new application potentials of remote sensing become utilizable. In future there will be an increasing geometrical resolution of remote sensing data, especially through the airborne scanners like HRSC-A with 0.15 m resolution. For using this data new approaches have to be developed – this is in process currently. The here presented software eCognition is a first good, upgradable approach with some enervations at the moment but with a high potential too. With eCognition 2.0 it will be possible to use some new features, like edge detection, edge enhancement, support of vector data and some additional segment properties. The adding value of using the high priced IKONOS data is more valuable in urban than in rural landscapes. But for some applications in rural areas the high resolution data will be useful, e.g. biotope monitoring.

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