New Sensor systems and new Classification Methods: Laser- and Digital Camera-data meet object-oriented strategies

ABSTRACT

Since the advent of digital remote sensing instruments, procedures for analysing their images have relied upon pixel-based methods. Pixels within areas assumed to be thematically homogeneous are analysed independently and consequently do not necessarily give the same classifying results. New object-oriented approaches offer a solution. The new methodology was tested for two very different data sets: Data from the High Resolution Stereo Camera – Airborne (HRSC-A) and intensity data from a Lidar. This paper discusses some of the results. The combined use of multiresolution segmentation and knowledge-based classification showed very promising results for both data types.

ZUSAMMENFASSUNG

Neue Sensorsysteme und neue Klassifikationsmethoden: Laser- und Digitale Kameradaten treffen auf objekt-orientierte Strategien.
Fernerkundungsdaten werden seit der Verfügbarkeit digitaler Sensoren pixelbasiert ausgewertet. Hierbei werden auch Pixel thematisch einheitlicher Regionen unabhängig voneinander analysiert. Dieses Vorgehen erweist sich nicht immer als sinnvoll, insbesondere bei der Interpretation hochauflösender Daten. Neue objekt-orientierte Ansätze zeigen hier bessere Resultate. Dieser Artikel diskutiert Ergebnisse objekt-orientierter Methoden, die auf sehr unterschiedliche Datensätze angewendet wurden: Daten der hochauflösenden Stereokamera HRSC-A und Intensitätsdaten eines Laserscanners. Ziel war die Erkennung von Objekten (Gebäuden) und die Klassifizierung von Landnutzung. Der kombinierte Einsatz von multiskalarer Segmentierung und wissensbasierter Klassifizierung zeigte vielversprechende Ergebnisse für beide Datentypen.

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1 Introduction

The (airborne) Remote Sensing Industry faces a time of important changes driven by new sensor systems, new markets and market demands. New sensor systems offer new possibilities of data acquisition, accuracy and resolution. Airborne laser scanning represents a new and independent technology for the highly automated generation of digital terrain and surface models. In addition to the height measurement the latest laser scanning systems also provide the reflectance signal derived from the intensity of the backscattered pulse echo, thus providing an image additional to the elevation information. Digital camera systems like the HRSC-A series deliver geometrically highly accurate multispectral orthoimages and surface models.

Parallel to this the Remote Sensing Industry faces new market demands. The applications of Geoinformation Technology are expanding very fast especially in non-traditional markets like insurance-, telecommunication- and in-car navigation industries. As a result of that there is a strong demand for reliable, up-to-date geoinformation products readily available at affordable prices. This new market situation also has its influence on the range of products. Application oriented products have to be made available like 3D City Models for Telecom planning or 3D data products to assess the risks and potential costs of inundation.

To cope with these demands, new methods have to be developed to automate the extraction of specific features from these new sensors. Some methodological obstacles are preventing extensive automatic processing: The problem of extracting the desired information directly from remotely sensed data is not solved yet. This is especially the situation for high resolution airborne remote sensing data. New object oriented approaches can offer solutions.

This paper highlights some results of studies where new methods met with new sensors. A new object oriented classification approach was applied to high resolution data sets from the High Resolution Stereo Camera (HRSC-A). An approach for automated house detection and updating of vector data sets is discussed, using multiresolution segmentation and a knowledge-based classification technique. The approach and concepts have been tested for updating the Dutch 1:10.000 Top10Vector database. Secondly the new interpretation concept has also been tested for the analysis of laser intensity data.

2 New Challenges: the Interpretation of High Resolution Data

Automated procedures to interpret high resolution data (pixel sizes up to 15 cm) are confronted with a number of problems:

- the lack of adequate analysis tools
- difficulties of differentiation between features
- complexity of the task
- some desired map features can only be detected by human interpretation and knowledge (e.g. borders, different usage of areas)

The level of detail the data shows limits the success of pixel-based classification, each pixel is related not to the character of object or area as a whole, but to components of it and a lot more classes have to be detected (Smith & Hoffmann 2000). It was found that using only multispectral information for classification does not lead to precise and consequent interpretation results of urban land use (Fung & Chan, 1994; Barnsley & Barr, 1996; Gao & Skillcorn, 1998) because the differentiation between urban object classes is done not only with the help of spectral information, but also with spatial information of the image data. The same colours in a data set might show different objects (e.g. in some areas roofs and streets are built of very similar materials), the expressiveness is ambiguous. Only the combination with spatial information leads to unambiguous identification (Strathmann 1988). Investigations also showed, that spectral classification of higher resolution data (TM and SPOT data sets in comparison with MSS data) does not automatically lead to higher classification accuracy (Johnsson 1994, Toll 1984), because higher spatial resolution mostly widens the variance of classes, thus leading to misinterpretation. Finer spatial resolutions actually reduced classification accuracy for certain land cover types. The coarse spatial resolution of the Landsat MSS smoothed out spatial complexity within heterogeneous land cover types, such as urban. It was found that although finer spatial resolutions reduced the proportions of mixed pixels, the number of detectable classes increased and became less separable spectrally (e.g. Bruniquel-Pinel & Gastellu-Etchegorry 1998).

Using contextual (e.g. elevation information, thematic GIS-layer) data for interpretation showed to be very helpful for image data analysis. Vector and raster maps have been used to help segment images into units and to assist in the classification of these images, but only the recent development of integrating remote sensing and GIS made it possible to combine raster images and vector data. The combined use of remotely sensed data and GIS became a major area of applications research (e.g. Smith et al. 2000, Aplin et al. 1999).

However it is obvious that new approaches are required to overcome some of the fundamental problems.

3 New Methods

Such a new approach is offered by the software package eCognition The procedure is based on the so called 'Fractal Net Evolution' approach which is a method to describe complex semantics within largely self constructing and dynamic networks. Basic part is a new patented technique for object segmentation. It extracts image object-primitives in variable resolution into fine or coarse structures. Semantic information necessary to interpret an image is mostly not represented in single pixels but in meaningful image objects and their mutual relations. Beyond the pure spectral information, image-objects are characterised by a number of additional features such as texture and form which can hardly be exploited using pixel-based approaches. This technique has been adapted to find image objects in textured data, such as SAR images, high-resolution satellite imagery, airborne data or medical images (Baatz & Schäpe 1999). The classification strategy consists of three main points: Object orientation, representation of the image information in different scales simultaneously and description, processing and analysis of image information by means of semantic networks.

In a first step a hierarchical network of image objects is built which allows to represent the image information content at different resolutions (scales) simultaneously. Each image contains different semantic levels at the same time. By operating on the relations between networked objects, it is possible to classify local object context information. In a second step the image objects will be classified by means of fuzzy logic, either on features of objects and/or on relations between networked objects operating on the semantic network.

4 Example 1: Detecting buidings from HRSC Data: An approach with ecognition

The feasibility of the new methodology has been tested in a project that was aimed at automated detection of houses from High Resolution Stereo Camera data. The project was a joint activity between the Topographical Service of the Netherlands (TDN), DLR (Berlin, Germany) and TerraImaging B.V. (Amsterdam). The automatic house detection is just the first step at the final goal: a further automatic updating of the 1:10.000 Topograpical database of the Netherlands.

4.1 The High Resolution Stereo Camera – Airborne (HRSC- A)

The HRSC-A data set of the city Nijmegen was acquired at November 4th 1999 fom a flight altitude of 3000 m, pixel size (nadir): 15 cm. The multispectral data sets were resampled to the original resolution of the DSM of 50 cm. The vector data set of Topographic Service dates from 1998, it was converted from vector to raster format (resolution 50 cm).

The High Resolution Stereo Camera – Airborne (HRSC-A) digital photogrammetric camera and its processing software provides the geoinformation industry for the first time with an entirely digital and fully auto-

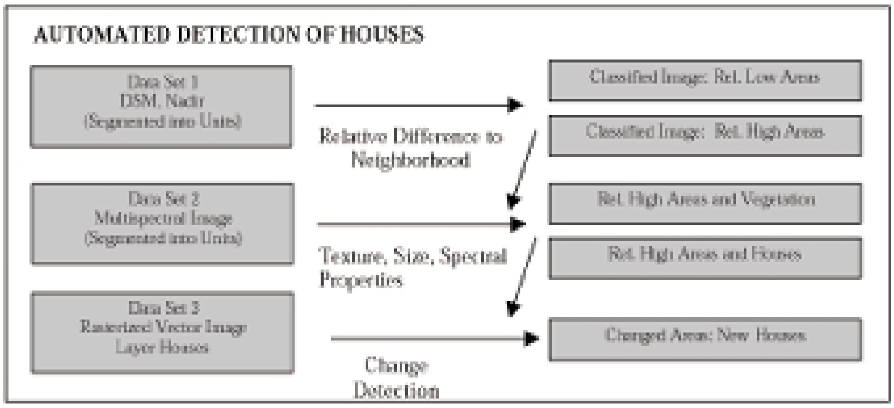

Fig. 1: Strategy for automated detection of houses

matic process to produce highly accurate digital image data. The airborne camera, originally developed for Mars Missions by the Institute of Planetary Exploration of German Space Centre DLR in Berlin-Adlershof, combines high resolution, photogrammetric accuracy and all-digital acquisition and provides both multispectral and elevation information. The multispectral, multiline (9) and multi-stereo (five different stereo bands) pushbroom instrument provides digital ortho-images and digital surface models with an accuracy of 10–20 cm (Wewel & Scholten 1999), the pixel resolution is 15 cm (3000 meter flight altitude).

Since the first airborne experiments (May 1997) the HRSC-A system has been used for different applications ranging from telecom network planning and cartography to environmental monitoring and internet marketing. In co-operation with DLR, ISTAR (France) and TerraImaging (The Netherlands) are exploiting the potentials of the camera data for Telecom Network Planning (Renouard & Lehmann 1999), GIS Applications, 3D-modelling, Environmental Monitoring, Mapping/map updating (Hoffmann & Lehmann 2000) and Visualisation.

4.2 THE APPROACH OF DETECTING BUILDINGS

The approach consists of four parts: Multiresolution segmentation of the image, dividing the image in high and low areas, dividing high areas in buildings and areas other than buildings (vegetation) and finally combining the rasterised vector data set with the classified image extracting areas with new houses. The basic information for interpretation was supplied by the Digital Surface Model. For this approach three properties of houses were used: They are higher than the surrounding areas, they have a minimal and maximal size, and they generally have smooth texture (compared to vegetation) *(see Fig. 1)*.

A basic part of the procedure is an object segmentation which is able to find image objects in any chosen resolution (fine or coarse structures). The algorithm is based on the assumption that image objects are characterised by colour and spatial continuity. The hierarchical structure represents the information of the image data in different resolutions simultaneously. Each object 'knows' its context, its neighbourhood and its sub-objects. Thus it is possible to define relations between objects, e.g. 'relative border length to other classes' and use this additional context information for classification.

The size of image objects is defined using the “object scale parameter” that determines the object resolution, for segmentation all or single bands can be used. In order to reduce processing time, in first tries only the was used for segmentation, but the geometric shapes representing houses appeared unrealistic. The combination of DSM and nadir image showed much better results *(see Fig. 2)*.

eCognition allows a knowledge-based classification, using a set of rules, including spectral and textural information, form, neighbourhoods, logical expressions and many more. Classification is done based on fuzzy logic. The advantage of fuzzy-logic is the possibility to integrate most different kinds of features and to connect them by means of (fuzzy-) logical operators. Thus complex class descriptions are possible. Each single step of classification can be retraced for each image object in detail. The classificators used for the class descriptions are nearest neighbour or membership functions (Baatz & Schäpe 1999).

The data set was first divided in relatively high and relatively low areas, this information was provided

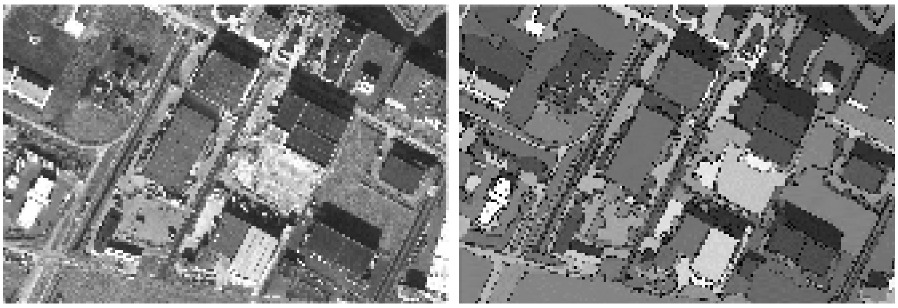

Fig. 2: Result of segmentation: original nadir data set (left, resolution: 50 cm), and segmented image (right)

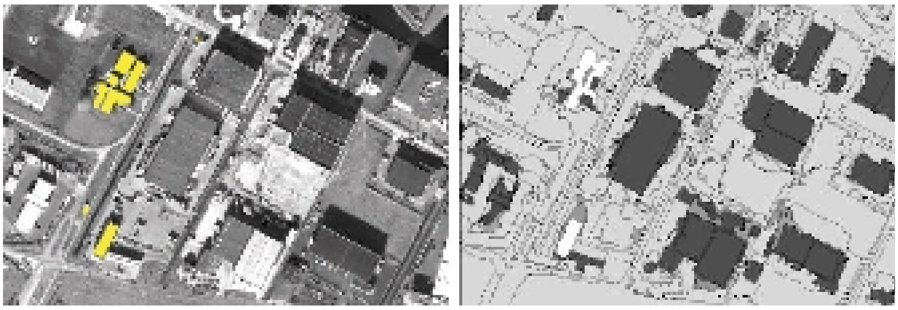

Fig. 3: Nadir image with rasterised vector data set (white) (left) and house detection (white: houses in the vector data set, light grey: low areas, dark: new houses, dark grey: low classification probability (shadows)

by the DSM. In a next classification step the detected high objects were divided in buildings and other high objects (generally vegetation). For this differentiation the different texture properties of vegetation and houses were defined. Another approach to differentiate between vegetation and non-vegetation is using an additional channel with the result of the Normalised Difference Vegetation Index (NDVI).

The next step combines the classification result for houses and the vector data set. Input Data was the rasterised Top10Vec and the classified image (buildings). Both layers were compared, highlighting only the new houses *(see Fig. 3)*. This result can be exported and implemented into the vector data set.

4.3 DISCUSSION OF RESULTS, PROBLEMS AND LIMITATIONS

The combination of high resolution imagery, high resolution elevation information and a new object-oriented approach showed promising results for automated updating of data sets. All houses of the test area could be found, using the spectral, geometric and textural properties of the image objects. Due to the fact that only few parameters were used, the approach proved to be stable. The additional information from the DSM showed to be very important for interpretation.

The quality of the classification and the proposed approach mainly depends on the quality of the Digital Surface Model. A limitation is the difficulty to process precise DSM in urban areas, especially in zones with narrow streets and in shady areas. Using the DSM for object segmentation is like generalising the image, e.g. single houses often are combined to house clusters, especially if there are only narrow spaces between individual structures. Small structures might disappear and make detection of single houses impossible.

There are limitations detecting low houses. And it might be difficult to detect high houses that are surrounded by high vegetation. Depending on the accuracy of the segmentation the exact shape of houses was not always depicted. Huge buildings that were segmented in many units were difficult to extract, additional parameters (relative border to houses e.g., plus high absolute DSM-value) had to be found.

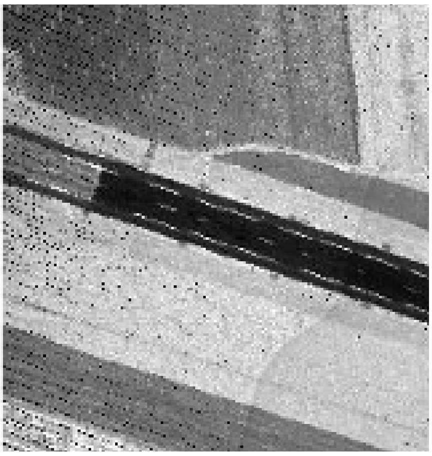

Fig. 4a: The subset shows the runway of an airport

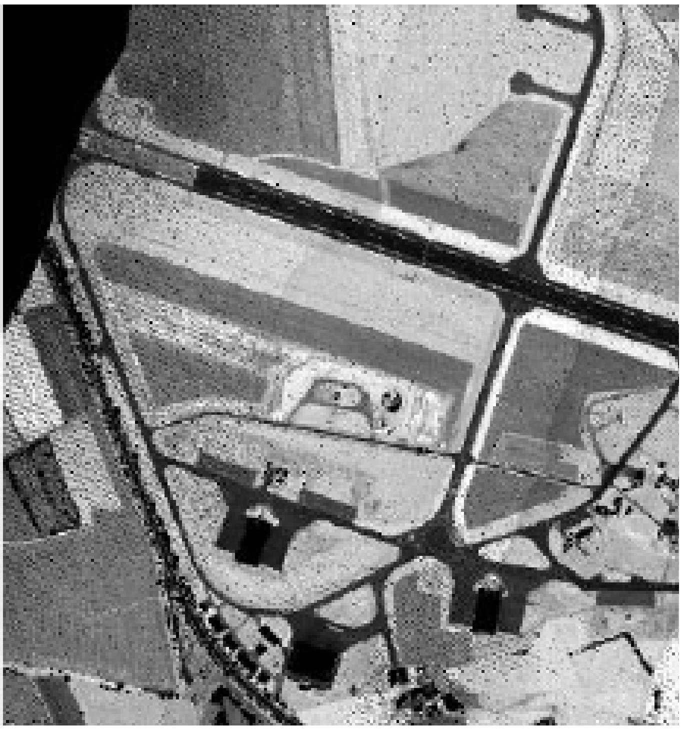

Fig. 4b: : Lidar intensity data mosaic of adjacent flight lines

5 Example 2: Classification with Lidar intensity data

Airborne laserscanning has proven to be a suitable tool to provide highly accurate elevation data fast and at relatively low costs. The technique is used for the determination of digital surface models and digital terrain models. Several countries use laserscanning technology to update or create nationwide elevation models. The main application fields are water management, coastal zone management, 3D-visualisation, mapping, Telecom planning, 3D city modelling and powerline mapping. Until now the classification of the lidar data has been focused on the distinction between ground and non-ground points, thus resulting in terrain models and surface models as basic products. Sophisticated software has been developed to achieve this automatically.

Further thematic interpretation of lidar data sets showed to be difficult due to the lack of (multispectral) image information. Combining different data sets (e.g. laser data and aerial photographs) showed poor results because of the difficulties of co-registration of the data sets, the availability of similar data sets (same acquisition time and acquisition parameters) was another problem.

The latest generation of laserscanners supplies the user with an additional observable: the intensity information of the reflected signal. Since most laser scanners operate in the 1040 to 1060 nm wavelength, the intensity of the reflected signal is related to the surface the laserpulse is

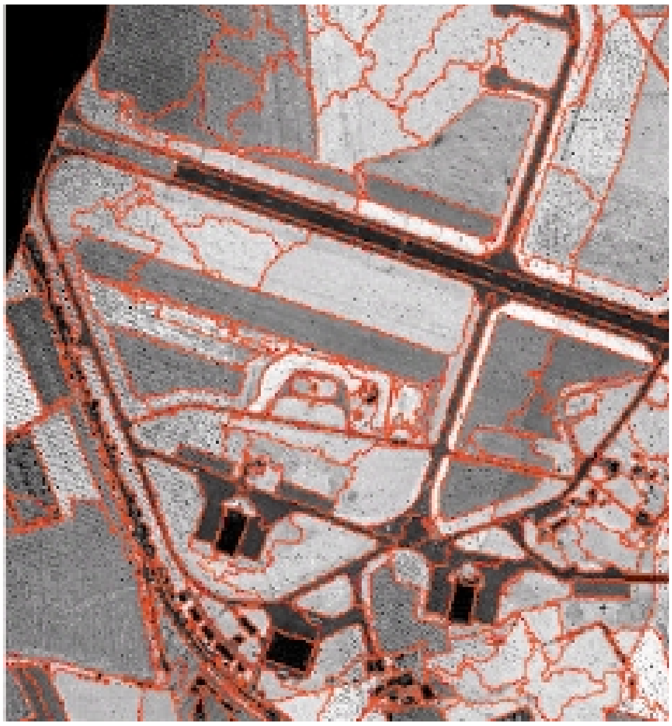

Fig. 5: Segmented intensity data set

reflected from. So intensity could help to perform a further thematic interpretation of the terrain mapped, offering the advantage of a digital image together with the highly accurate coordinates in x, y and z for every image element *(see Fig. 4)*.

The aim of this study was to classify the intensity data with the described object-oriented method, using again image segmentation, supervised classification technique and knowledge-based hierarchical classification technique using fuzzy logic expressions. Some preliminary results will be discussed.

The intensity data set (point data) was processed to a raster file with a 2m resolution and imported to eCognition. The classification procedure started with an image segmentation, this time just based on the single intensity band. Due to the coarse structure of the intensity data (compared to the high resolution camera imagery) the segmentation showed a good result, leading to unambiguous segments. Although not every pixel carries an intensity information (due to dropouts) the segmentation process proved to be stable (see Fig. 5).

After segmentation a supervised classification was performed, using samples for the different classes (roads, vegetation, houses, fields). Using a nearest neighbour classifier the defined set of classes could be separated (see Fig. 6), the result could be improved by using the elevation information for analysis. A future task will be a further investigation of parameters (texture etc.) to diversify the classification result.

6 Discussion of Results

First results of the automatic detection of man made features from the combined usage of laser elevation and intensity data show convincing results. Although the intensity data set was just a monochromatic image an unambigious classification result could be achieved. Using the combined information from height measurement and intensity data also shows the potentials of integrated laserscanning and image sensors.

For segmention of the laser data one single band is sufficient as already shown with the digital camera data set. The histogram matching of different flight lines has to be improved in order to get a homogeneous base data set, the intensity data image also has to be normalized. A limitation for the interpretation is the fact that the measurement of the return signal is relative. The return intensity is based on several factors such as flying height, atmospheric conditions, directional reflectance properties and the reflectivity of the return target.

7 Conclusions and Outlook

The examples prove that object-oriented approaches can result in powerful solutions for the interpretation of high resolution data. This is especially true for 3-dimensional datasets, since high resolution elevation information will enhance and facilitate the analysis. It is anticipated that these new methods will facilitate a flexible and cost-effective production of those products demanded by the emerging users of geoinformation technology. This will undoubtly further strengthen the position of the new airborne sensors as suppliers of up to date, user-demand driven 3D geoinformation products.

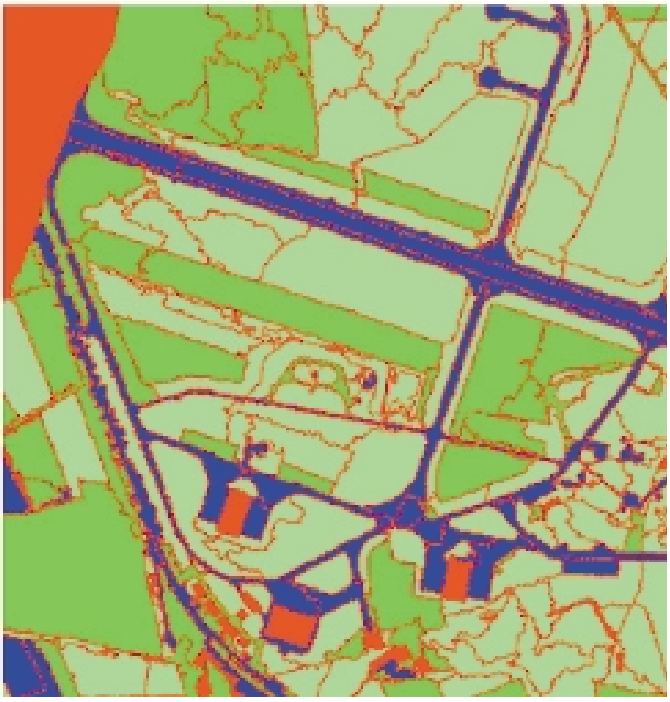

Fig. 6: Classified image

Acknowledgements

This research was done in co-operation with “De Topografische Dienst” Holland. The authors like to thank for the supplied data sources and for fruitful discussions about the implementation of the updating approach.

8 References

APLIN, P., ATKINSON, P.& CURRAN P.J. 1999. Fine Spatial Resolution Simulated Satellite Sensor Imagery for Land Cover Mapping in the United Kingdom, Remote Sens. Environ. 68, pp. 206–216.

BAATZ, M. & SCHÄPE, A. 1999. Object-oriented and multi-scale image analysis in semantic networks. Proc. 2nd International Symposium on Operationalisation of Remote Sensing Conference and Exhibition, CD.

BAATZ, M. & SCHÄPE, A. 2000. Multiresolution Segmentation an optimization approach for high quality multi-scale image segmentation. Strobl, J., Blaschke, T. & Griesebner G. (Hrsg.): Angewandte Geographische Informationsverarbeitung, Beiträge zum AGIT-Symposium Salzburg 2000, Karlsruhe.

BARNSLEY, M. J. & BARR, S. L. 1996. Inferring urban land use from satellite sensor images using kernel-based spatial reclassification. Photogrammetric Engineering & Remote Sensing, 62, pp. 949–958.

BRUNIQUEL-PINEL, V. & GASTELLU-ETCHEGORRY, J. P. 1998. Sensitivity of texture of high resolution images of forest to biophysical and acquisition parameters. Remote Sensing of Environment, 65, pp. 61–85.

FUNG, T. & CHAN, K. C. 1994. Spatial composition of spectral classes: A structural approach for image analysis of heterogeneous land-use and land-cover types. Photogrammetric Engineering & Remote Sensing, 60, pp. 173–180.

GAO, J. & SKILLCORN, D , 1998. Capability of SPOT XS data in producing detailed land cover maps at the urban-rural periphery. International Journal of Remote Sening, 19 (15) pp. 2877–2891.

HOFFMANN, A. & LEHMANN, F. 2000. Vom Mars zur Erde – die erste digitale Orthobildkarte Berlin mit Daten der Kamera HRSC-A. Kartographische Nachrichten , 50 2/2000.

JOHNSSON, K. 1994. Segment-based land use classification from SPOT Satellite data. Photogrammetric Engineering & Remote Sensing, 60(1), pp 47–53.

RYHERD, S. & WOODCOOK, C. 1996. Combining spectral and texture data in the segmentation of remote sensed images. Photogrammetric Engineering & Remote Sensing, 62, pp. 181–194.

RENOUARD, L. & LEHMANN, F., 1999. High Resolution Digital Surface Models and Orthoimages for Telecom Network Planning. Photogrammetric Week, 99, eds. D. Fritsch and D. Spiller. Wichmann, Heidelberg, , pp 241–247.

SMITH, M. & HOFFMANN, A. 2000. Parcel-based approaches to the classification of fine spatial resolution imagery: Example methodologies using HRSC-A data. IAPRS Vol. XXXIII Amsterdam 2000.

SMITH, G.M., FULLER, R.M., HOFFMANN, A. & WICKS, T., 2000. Parcel-based approaches to the analysis of remotely sensed data. Proceedings of the Remote Sensing Society Conference, Adding Value to Remotely Sensed Data, Remote Sensing Society, Nottingham, CD-ROM.

TOLL, D.L., 1984. An evaluation of simulated TM-data and Landsat MSS data for determining suburban and regional land use and land cover. Photogrammetric Engineering & Remote Sensing, 50 (12) pp 1713–1724.

WEWEL, F. & SCHOLTEN, F. 1999. High Resolution Stereo Camera (HRSC): Multispectral Data Acquisition and Photogrammetric Data Processing. In: Proc. 4th International Airborne Remote Sensing Conference and Exhibition, Vol. I, pp 263–271.