AUTOMATIC CHANGE DETECTION IN GIS DATABASES BASED ON CLASSIFICATION OF MULTISPECTRAL DATA

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ABSTRACT

Digital spatial data underlay strong temporal changes. In order to update these changes, the data are checked manually by operators for their correctness by superimposing them with up-to-date orthophotos. This is also the procedure which is applied with ATKIS data. ATKIS is the German topographic cartographic spatial database [1] and presently contains more than 60 different feature types for the whole area of Germany in the scale of 1:25,000 (beside this scale there are further levels of data aggregation in the scales 1:200,000 and 1:1,000,000 which were not used in this work). The ATKIS data are the basis for a large number of applications in very different fields, like environmental planing, street information systems, forest monitoring and a lot more. In order to eliminate the bottle-neck of manual updating, a software was developed at the Institute for Photogrammetry (ifp) for the automatic detection of updates in ATKIS data. In this paper the used approach is presented and the results are discussed.

1 AUTOMATION OF UPDATING OF GIS DATA

Currently, the revision cycle of ATKIS data is one year for the street network and five years for all other object classes. Shorter revision cycles are at present unrealisable for two reasons. On the one hand the manual inspection of the data is very cost- and time-consuming and on the other hand aerial photographs are only flown in 5 year cycles so that no up-to-date data are available.

However, a decisive turn can be seen by the data availability. With new satellite systems, it will be possible in future to provide up-to-date high resolution orthophotos in short time periods and high quality. At September 24th, 1999, the optical high resolution satellite *IKONOS* of the company *Space Imaging* (http://www.spaceimaging.com) was brought successfully into the orbit. Further systems as for example *Quickbird* of the company *EarthWatch*, *OrbView 3* and *4* of the company *ORBIMAGE* or *EROS A* and *B* of the company *West Indian Space* will follow shortly (see also [7] and [8]).

The process of updating of spatial data can be subdivided into three steps (see figure 1). In the first step, changes of the landscape must be detected. This can be done for example through a comparison of GIS data with a up-to-date orthophoto or through field inspection. This is a work- and time-consuming process which is at current only barely automated. Furthermore the manual comparison of GIS data and orthophotos requires high concentration and is error-proned.

In the second step, further data sources must be used in order to add further attributes which cannot be detected in the orthophoto. This can be for example street names, ownership attributes or administrative boarders which have to be retrieved from very different data sources. In order to be able to work here effectively an optimisation is necessary that assures a fast information flow. This optimisation is strongly dependent on legal and organisational responsibilities of the data producers and will not be further discussed in this article.
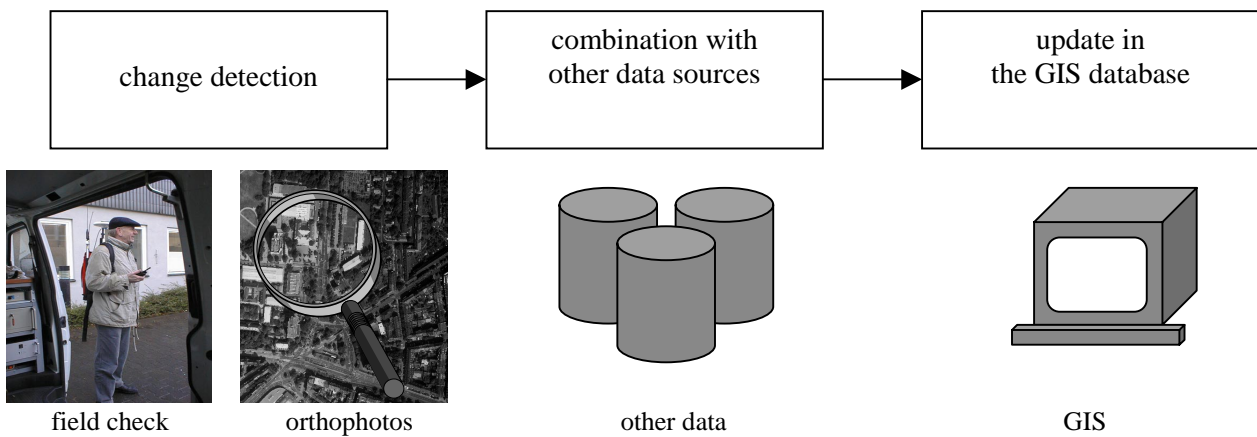
Figure 1: Different steps of updating of GIS data

In the last step, the changes with all additional information have to be stored into a GIS database. This operation step can be automated at least in part. Consistency checks can be done with automated checking programs which assure high quality data sets. Many functionality's for this purpose are already integrated in commercial GIS products and further application-specific procedures can be programmed by the users.

The first step of this process – the detection of changes – requires the largest amount of work. In the following an approach is introduced which enables the fully automatic detection of changes in GIS by using of multispectral remote sensing data.

2   CONCEPT

The approach for change detection is fully automatic and can be subdivided mainly into two steps (see figure 2). In a first step the remote sensing data have to be classified pixel wise into different land use classes. This is done by a supervised maximum likelihood classification. The problem for an automatic approach here is the supervised part of the classification algorithm. Normally this part involves the work of a human operator and requires a lot of experience because the quality of the training areas is a crucial factor for the quality of the classification result. As the digitising of the training areas is time intensive and new training areas have to be digitised for every new data set (because of atmospheric effects, different spectral diffusion depending on the sunlight, different spectral characteristics of vegetation depending on season or soil, etc.), a method is needed to derive the training areas in an automatic way. Having assumed that the number of wrongly collected GIS objects and the number of changes in the real world are substantially less than the number of all GIS objects of the data set, the training areas can be derived automatically from the already existing GIS data. The higher the quality of the training areas the better will be the result of the classification. Therefore, the object geometry is not used as stored in the GIS database - a pre-processing has to be performed first [12].

After the classification it must be decided which of the GIS objects do not match the remote sensing data. These can be objects where a change in the landscape has occurred or objects, that were not collected correctly. All GIS objects are subdivided into three classes. The first class contains all objects which could be detected with a high certainty in the remote sensing data, the second class contains all objects which are detected only partly and the third class contains all objects which could not be detected at all.
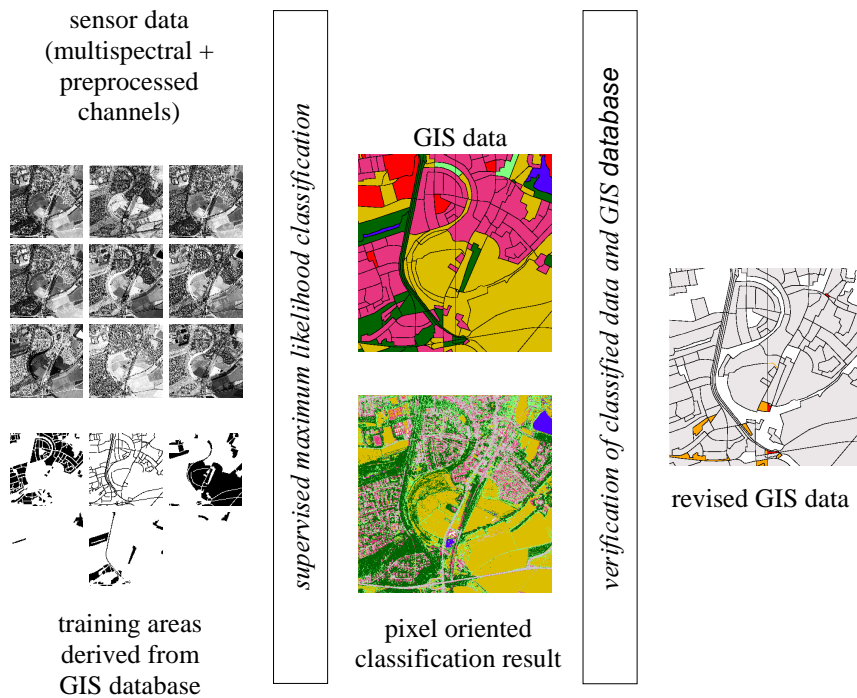
Figure 2: Overview of the automatic approach for GIS change detection

The approach is implemented in a software package based on UNIX and X-Windows. Figure 3 shows a selection of different windows of the program. The software was implemented in such a way that all parameters of the approach can be changed interactively by the user and stored as a project. Additionally a visualisation component is available to explore the results interactively on the screen. The software is designed in such a way that there exists no limitation regarding the geometric resolution, the size of the images or the definition of the spectral bands. This enables the examination of data from very different sources.

3 POTENTIAL OF AUTOMATIC APPROACHES

Not all object classes can not be distinguished alone by their spectral and textural characteristics without addition of further information sources. Examples are the object classes wood and grove or residential area, industrial area and area of mixed use. Even a human operator is very often not able to distinguish these object classes without additional information. In addition, it is still added that the definition of these object classes in the ATKIS object catalogue can be ambiguous and the object classes are often not clearly delimitable from each other. Therefore, object classes of this kind are combined together to one of the five different spectral classes: greenland, forest, settlement, water and streets (see also [9]).

4 INPUT DATA

The developed approach was tested with data from different sources. Results with data from the Indian Remote Sensing Satellite IRS-1C [11], the MOMS-2P camera system [10] which was used on the Russian MIR station, the Digital Photogrammetric Assembly (DPA camera system) [2, 5] and from scanned analogue orthophotos can be found in [3, 4, 12, 13]. The quality of the results is dependent from three different factors: the geometrical resolution, the radiometrical resolution and the definition of the spectral bands.

In order to get interpretable and reliable results, a geometric resolution of 2 meter is sufficient for data in the scale 1:25,000. The problem of lower resolution data is that objects which are marked by the program as *not found* are very often not clearly visible in the image and therefore the results cannot be verified by an operator (see also [12, 13]). Higher resolution leads to better results especially in urban areas, but at the same time to a strong increase of the computing time.
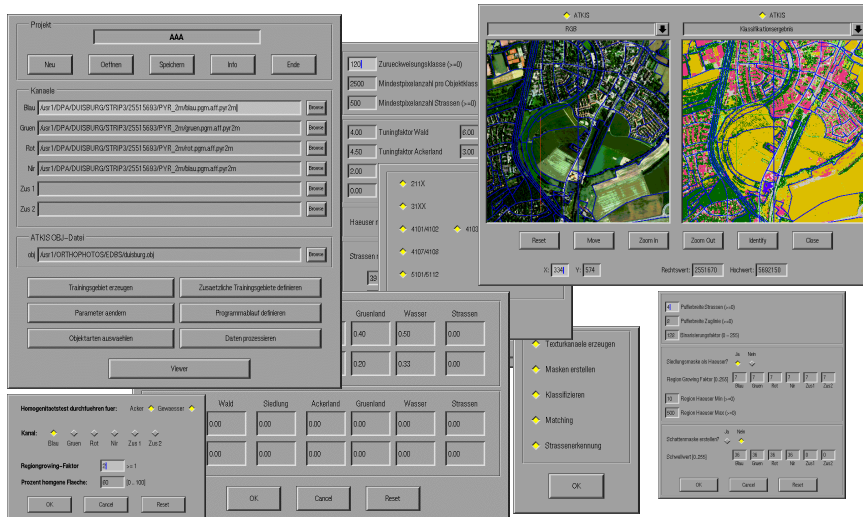
Figure 3: Software package

A radiometric resolution of 8 bit is sufficient for the classification to separate the different land use classes and is provided by most of the existing sensors. More important is the definition of the spectral bands of the sensor. A reliable classification of areas with strong shadow is only possible if a channel in the near infrared is available (see also [12, 13]).

In general it can be said that the higher the amount of information in the input data the better are the classification results. A very high information content can be achieved by integrating data with very different characteristics. This can be done for example by the combination of multispectral and laser data. Laser data improve the classification result significantly because they have a complementary "behaviour" as multispectral data. With laser data the classes greenland and street can be separated very good from the classes forest and settlement because of the different heights of the pixels above the ground whereas in multispectral data the classes greenland and forest can be separated very good from the classes streets and settlement because of the strongly different percentage of chlorophyll.

The results presented in the following were computed with scanned CIR orthophotos plus laser data with a ground pixel size of 2 meters.

5   CLASSIFICATION RESULTS

Figure 4 shows a classification result at an example. Forests are recognised being homogeneous and well detectable. Agricultural areas show sometimes inhomogeneities because of planting structures, but nevertheless they can be detected also very well. The land use class which could be detected best is water. The land use class settlement cannot be recognised as homogeneous uniform areas, but it is subdivided into several classes. It can be seen that pixels are only recognised as settlement areas if they represent house roofs. The other pixels are classified as streets, forest or agricultural area depending on the "ground truth". The reason for this result is the high resolution of 2m.

6   MATCHING RESULTS

In order to detect field changes, the classification result has to be compared with the ATKIS data. All ATKIS objects are subdivided into three different classes. The decision to which class an object belongs is made by measuring the percentage of pixels which are classified to the same object class as the object itself belongs to. Optionally the form and the homogeneity of the correctly classified pixels in the object are used. Very small or narrow objects are evaluated less strict than normal objects.

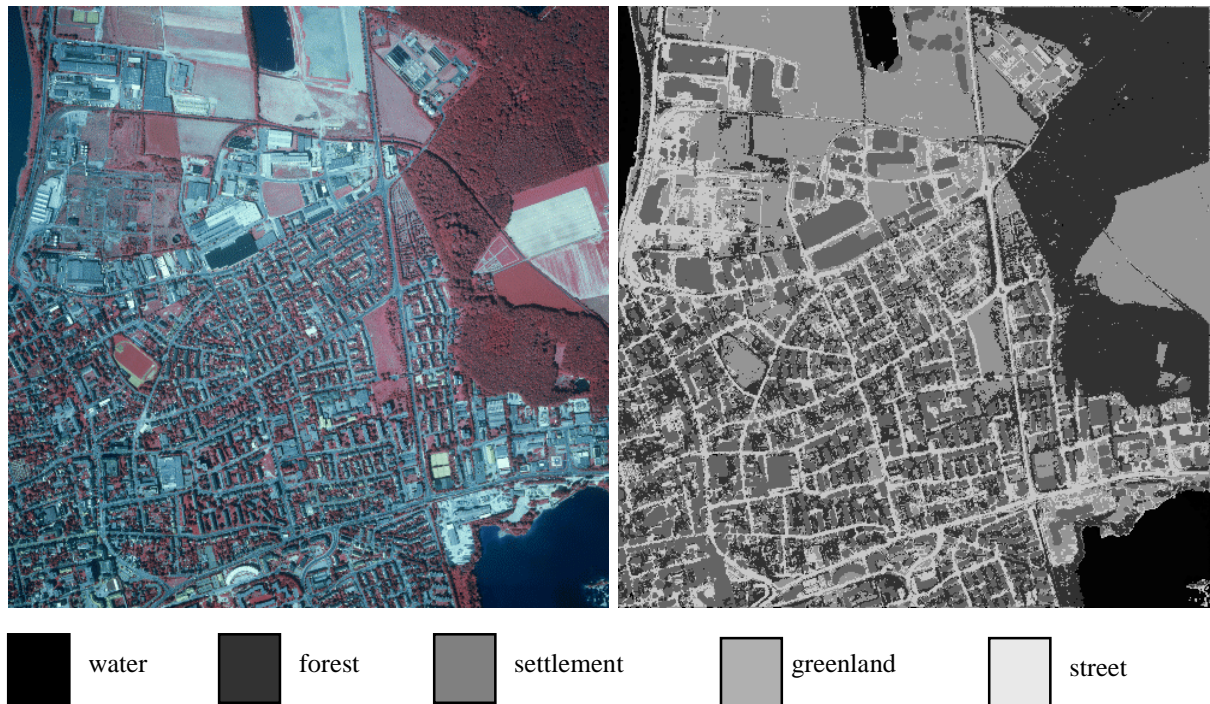| ■ water | ■ forest | ■ settlement | ■ greenland | □ street |

Figure 4: Classification result

Figure 5 shows by an example the measurement of the homogeneity and the form. The light grey rectangle represents an ATKIS object and the dark grey areas represent the pixels which are classified to the same object class as the ATKIS object. With the weighted sum of all three measures the objects are subdivided into the classes *full verified, partly verified* and *not found*.

Figure 6 shows an example of objects which could not be verified by the matching. The two objects which are superimposed in black on the image were collected as greenland in the ATKIS database. It can be seen that meanwhile a settlement area was built up. The result of the matching is that these two objects cannot be found in the image because of the low number of pixels that were classified as greenland.
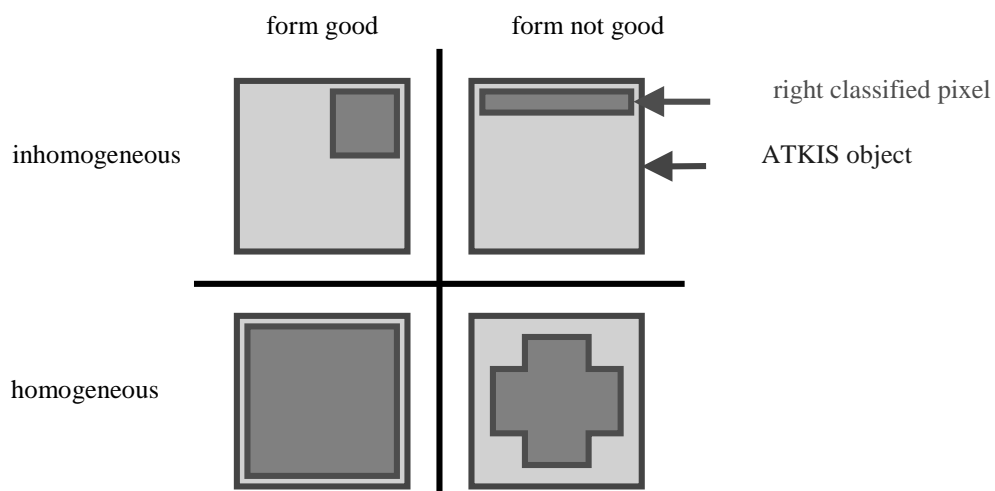

Figure 5: Measurement of the homogeneity and the form

greenland

cir image

forest

settlement

greenland

street

classification

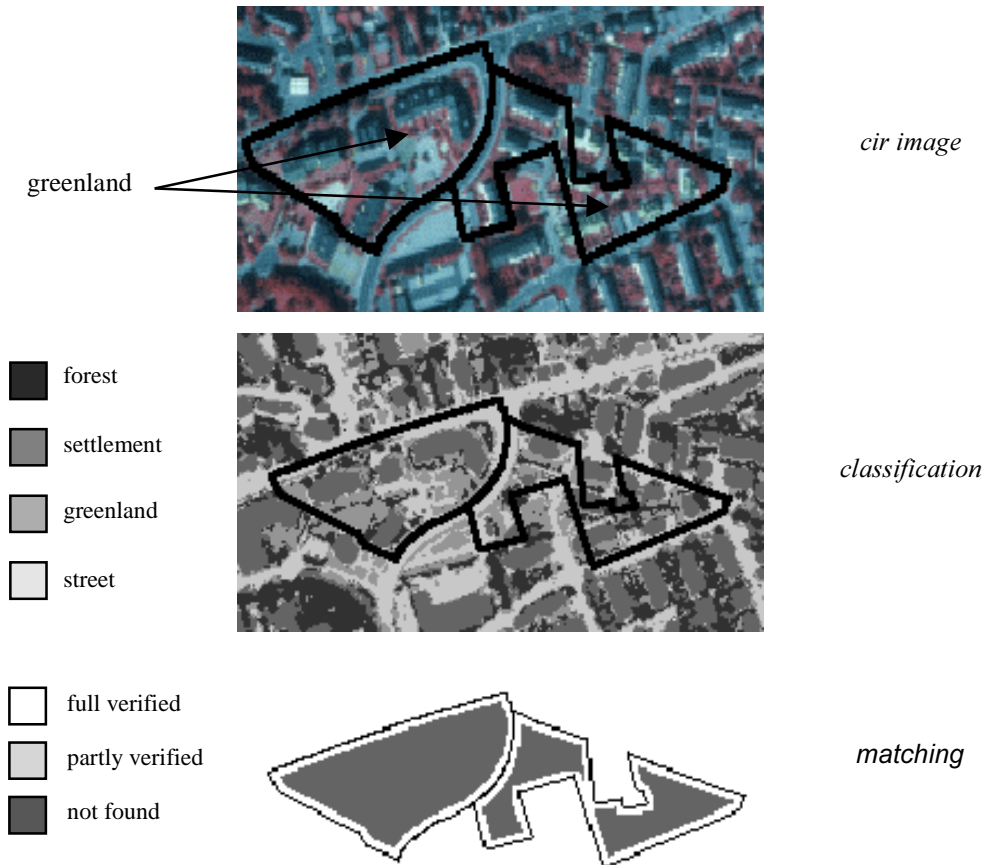full verified

partly verified

not found

matching

Figure 6: Matching example 1

Figure 7 shows an object that was collected as an agricultural area. But this object contains also a house and some paved areas which are represented in the classification result as settlement and street. The result of the matching is that this object can be verified only partly because the percentage of right classified pixels is too low and they are not distributed homogenous in the object.

7 SUMMARY

In this paper an approach is introduced which enables the automatic detection of changes in GIS databases by using remote sensing data. The approach is implemented in a software package under UNIX and X11 Windows. The program was designed in such a way that it is possible to use data from very different sources as an input. The best results can be achieved with the combination of multispectral and laser scan data. If these two data sources are available, a geometric resolution of 2m is sufficient to verify objects in the scale 1:25.000.

Whereas the classification is very robust, problems can appear by the matching process. The reason for this is, that ATKIS objects are not only collected from orthoimages but also from cadastral maps. Therefore the acquisition of object borders is often done according to ownership structures and not according to detectable structures in the image. Additionally the object classes are defined in the object catalogue in such a way that very inhomogeneous objects can appear. An example for this statement can be seen in figure 7. The greenland object does not only contain greenland areas but also a farm house and some paved areas. This object is collected correctly according to the ATKIS object catalogue but it is so inhomogeneous that it cannot be verified by the matching.

cir image *classification* *matching*

greenland

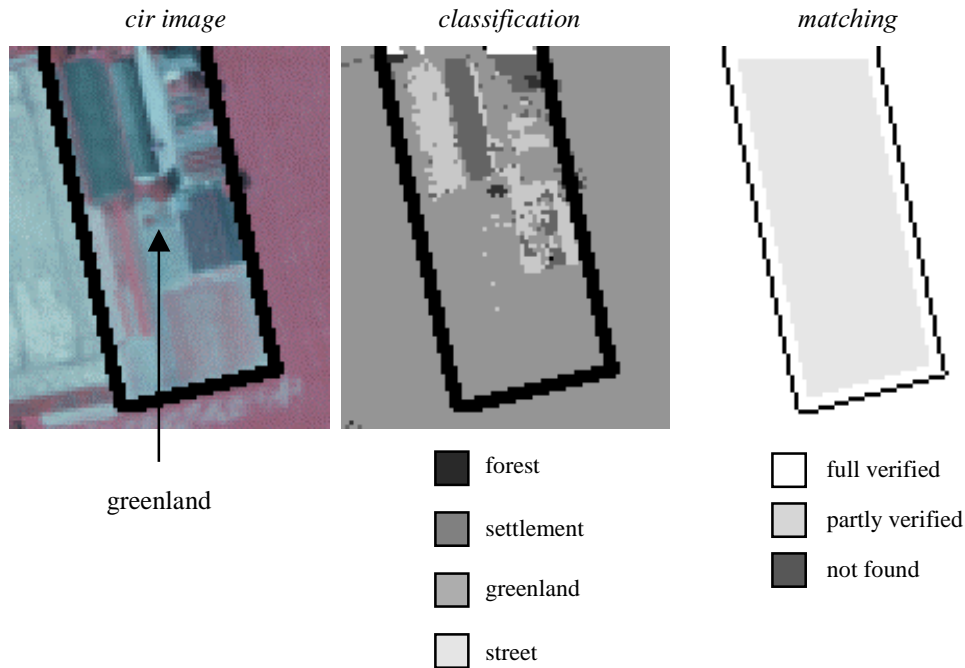| | forest | | | full verified |
	settlement			partly verified
	greenland			not found
	street			

Figure. 7: Matching example 2

A solution for this problem would be to store the classification result for all objects in a data base. If an object could not be verified, the program can look into the database and compare the current classification result with an older one. If the two classification results are similar and an operator had already confirmed earlier that the object is correct digitised, it could be assumed that the object is still correct.

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REFERENCES

1. Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland (AdV): Amtlich Topographisches-Kartographisches Informationssystem (ATKIS) Bonn (1988).
2. Haala, N., Stallmann, D., Staetter, C.: On the use of multispectral and stereo data from airborne scanning systems for DTM generation and landuse classification in: ISPRS Commission IV Symposium GIS – Between Visions and Applications, Vol. 32, Part 4, 203 – 209 (1998)
3. Haala, N., Walter, V.: Classification of urban environments using LIDAR and color aerial imagery in: Fusion of sensor data, knowledge sources and algorithms for extraction and classification of topographic objects, 3 - 4 June, Valladoid, Spain (1999)
4. Haala, N. Walter, V., Staetter, C.: Analysis of multispectral data from airborne pushbroom systems for DTM generation and landuse classification, in: Proceedings of the Fourth International Remote Sensing Conference and Exhibition / 21st Canadian Symposium on Remote Sensing, Ottawa (1999)
5. Hahn, M, Stallmann, D., Staetter, C.: The DPA-Sensor System for Topographic and Thematic Mapping, in: International Archives of Photogrammetry and Remote Sensing (ISPRS), Vol. XXXI, Part B2, 141 – 146, Vienna (1996)

6. Hahn, M., Staetter, C.: A scene labeling strategy for terrain feature extraction using multisource data, in: International Archives of Photogrammetry and Remote Sensing (ISPRS), Vol. XXXI, Part B4, pp, 823 – 828, 1996, 435 – 441 (1998)

7. Jacobsen, K.: Status and Tendency of Sensors for Mapping, Proceedings of the International Symposium on Earth Observation System for sustainable Development, Bangladore, India, Vol. XXXII, Part I of International Archives of Photogrammetry and Remote Sensing (ISPRS), 183 – 190 (1998)

8. Kilston, S.: Capabilities of new Remote Sensing Satellites to support sustainable Development, Proceedings of the International Symposium on Earth Observation System for sustainable Development, Bangladore, India, Vol. XXXII, Part I of International Archives of Photogrammetry and Remote Sensing (ISPRS), 124 - 131 (1998)

9. Petzold, B.: Revision of topographic databases by satellite images – experiences and expectations, proceedings of the seminar on remote sensing and image analysis techniques for revision of topographic databases, National Survey and Cadastre – Denmark (2000).

10. Schiewe, J.: Cartographical Potential of MOMS-02/D2 Image Data in D. Fritsch and D. Hobbie (Eds.) Photogrammetric Week '95, Wichmann Verlag, 95 – 106 (1995)

11. Srivastava, P, et. al.: Cartographic Potential of IRS-1C Data Products, in: International Archives of Photogrammetry and Remote Sensing (ISPRS), Vol. XXX1, Part B4, 823 – 828, (1996)

12. Walter, V.: Automatic classification of remote sensing data for GIS database revision, in International Archives of Photogrammetry and Remote Sensing (ISPRS), Vol. XXXII, Part 4, 641 – 648, (1998)

13. Walter, V., Fritsch, D.: Automatic verification of GIS data using high resolution multispectral data in: International Archives of Photogrammetry and Remote Sensing (ISPRS), Vol. XXXII, Part 3/1, 485 – 489 (1998)