Towards the automatic GIS update of vegetation areas from satellite imagery using digital landscape model as prior information

Christian Heipke, Bernd-M. Straub
University of Hanover
Institute for Photogrammetry and Engineering Surveys
Nienburger Straße 1, 30167 Hannover, Germany
Telephone: ++49-511-762-2482
http://www.ipi.uni-hannover.de

KEYWORDS: automatic, GIS updating, multi-spectral imagery, vegetation.

ABSTRACT: This paper describes a procedure to automatically update GIS vegetation areas from multi-spectral and panchromatic satellite imagery using existing digital landscape models as prior information. The procedure consists of three main steps: (1) automatic generation of spectral signatures for the vegetation areas, (2) classification of the multi-spectral image, and (3) integration of the results into the vector based GIS. Prior to the integration the classification results can be improved in geometric accuracy using higher resolution panchromatic images. The actual decision whether a data base update is necessary, is finally taken by a human operator.

The method was tested using imagery from the Indian Remote Sensing Satellite IRS 1C and the ATKIS BaseDLM. The feature classes arable land, grassland, and forest were investigated. The obtained results demonstrate the feasibility of the proposed approach.

1 Introduction

The technical advances of GIS (Geo Information System) software in combination with the growth in the computer industry leads to an increase of GIS applications. The currentness of topographic data bases is important for potential customers, who want to use and develop special GIS applications. The update rate of topographic maps in Europe of only 6.4 % per annum at the scale 1:50,000, 7.4 % at 1:25,000 and 8.0 % at 1:100,000 [KONECNY, 1996] documents the necessity of developing efficient procedures for updating GIS data. Automatic techniques for updating and refining topographic data bases are still under development [see e.g. VÖGTLE, SCHILLING 1995; PLIETKER, 1997 or WALTER, 1998].

This paper describes a procedure to automatically update GIS vegetation areas from multi-spectral and panchromatic satellite imagery using existing digital landscape models as prior information. The procedure consists of three main steps: (1) automatic generation of spectral signatures for the vegetation areas, (2) classification of the multi-spectral image, and (3) integration of the results into the vector based GIS. If panchromatic imagery of higher resolution than the multi-spectral imagery is also available, an optional geometric refinement of the results derived in the second step can be carried out prior to step (3). The actual decision whether a data base update is necessary, is finally taken by a human operator.

In the next chapter some background on the study is given and the used data sources are introduced. Chapter 3 contains a detailed description of the proposed method. First results are described in chapter 4 demonstrating the potential of the approach. Finally, some conclusions are given in chapter 5.

2 Study background and data sources

2.1 Preliminary remarks

For the present study the ATKIS BaseDLM (ATKIS stands for Authoritative Topographic-Cartographic Information System, DLM for Digital Landscape Model) and imagery of the Indian remote sensing satellite IRS 1C were selected. The entire test area is equivalent to two topographic maps in the scale 1:25,000 (TK 25 No. 4425 and 4525) corresponding to approximately 250 km^2 in the south of the German state of Lower Saxony. The countryside is flat to rolling and contains mostly agricultural features together with some forest.

The choice of using IRS 1C data for refining and updating the ATKIS BaseDLM is not obvious, because given the geometric resolution of 23 m in multi-spectral and 5.8 m in panchromatic mode some objects might not be visible, the required geometric accuracy for ATKIS of 3 m in planimetry can in general not be reached, and some of the required attribute information cannot be extracted from the imagery either [e. g. JACOBSEN 1997; ENGLISCH, HEIPKE 1998]. Consequently, a complete ATKIS updating is out of the scope of this paper.

Nevertheless, it does make sense to use IRS 1C imagery to investigate the amount of change which has taken place since the vector data acquisition, especially for area objects. Also, IRS 1C delivers the highest resolution remote sensing imagery commercially available at the date of writing (May 1999), and there exists an interest in determining how much information can be extracted automatically from this imagery for a vector based GIS such as ATKIS.

2.2 Some terminology

In GIS data modelling is based on a description of different landscape features in a so *called feature class catalogue*. In this catalogue *feature classes* (also called concepts) representing different classes of objects such as roads, buildings, or waterways are described by means of object identifier, and geometric and thematic attributes. *A landscape feature* represents a particular object (also called instantiation of the corresponding feature class). The set of all landscape features is the *landscape model*.

In images different parts can be distinguished based on geometric (location, size, form) and radiometric (colour, texture) information. An *image object* is defined as the smallest homogeneous part in the image discernible from another such part. The *class of image objects* (sometimes called the *class* only) refers to the set of all such image objects as opposed to an individual image object itself. In multi-spectral classification the classes are described by radiometric information only, in general by the mean and standard deviation of corresponding training areas in the different spectral channels.

The geometric and thematic resolution of the feature class catalogue of a GIS varies according to the intended use. In a particular catalogue "arable land" may be a feature class whereas in another catalogue a further distinction into different states of plant growth may be necessary. We focus on the case in which one landscape feature can represent several image objects. In order to store this additional information in a GIS data base the feature class catalogue needs to be refined. For this *refinement* it may be sufficient to introduce an additional attribute for an existing feature class, or a new feature class may need to be created.

In contrast to refinement *updating* refers to bringing up-to-date a landscape model which is outdated, because the landscape itself has changed. Update takes place within the given feature class catalogue and consists in either creating, deleting, or changing specific landscape features. Automatic updating can rely on two different strategies for modelling change: (1) one can try to model the change explicitly, e. g. using so called state transition diagrams [PAKZAD et al. 1999], or (2) statistical assumptions can be made with regard to the expected amount of change. In this paper we take the latter route and assume that "most" of the available vector GIS information is still valid, where "most" implies that areas of change do not significantly influence the description of the training areas in the multi-spectral classification. In this way we are able to extract areas where change has potentially taken place. A human operator must than be called in to decide whether the detected change merits an update of the data base or not.

2.3 Data sources

2.3.1 ATKIS BaseDLM

The ATKIS BaseDLM [AdV 1989, 1995] consists of the following three components:

ATKIS Feature Class Catalogue (ATKIS-OK): This catalogue contains the description of the ATKIS landscape features. It is based on the content of the Topographic Map 1:25,000. The required accuracy for points and lines is approximately 3 m.

Vector data: The landscape features form the two-dimensional landscape model.

DTM: The Digital Terrain Model represents the height information in ATKIS. The DTM is not further used in this study, and is mentioned for the sake of completeness only.

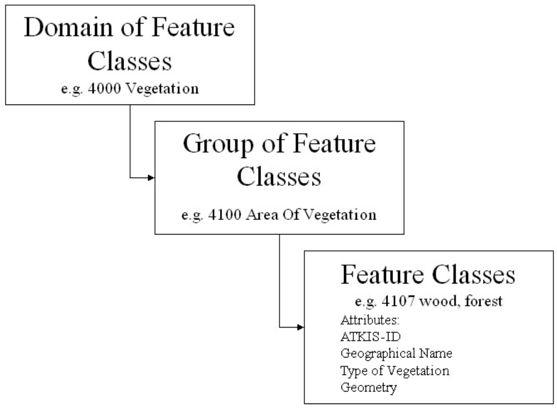

Fig. 1: Organisation of ATKIS-OK

In the ATKIS-OK the landscape is subdivided into seven so called domains of feature classes: geodetic control points, settlement, transportation, vegetation, waters, relief, and administrative areas. Each domain is subdivided into groups of feature classes and further into single feature classes (see Fig. 1). More detailed descriptions of the landscape features are given by attributes. For example, a landscape feature of the feature class forest possesses the attributes geographic name, type of vegetation, object height, etc. Today the ATKIS BaseDLM is available for the entire area of the Federal Republic of Germany [UHDE, 1998].

The described refinement of the data base (see section 2.2) can be accomplished without having to add additional feature classes. If for example arable land is to be divided into several parcels with different states of plant growth, then the existing attribute VEG (type of vegetation) can be assigned to the relevant values.

In this study the ATKIS BaseDLM available from the State Survey Authority of Lower Saxony was used. While it could not be established beyond doubt, we have good reason to assume that these data are current with respect to the year 1997.

2.3.2 Image data

The Indian remote sensing satellites IRS 1C and IRS 1D operate in a polar sun synchronous orbit at a height of 817 km above sea level, see [RADHADEVI et al. 1998] for more details). Each satellite carries three linear imaging sensors, two of which are relevant in this study (see Table 1):

The panchromatic sensor (PAN) provides data with a spatial resolution of 5.8 m and a radiometric resolution of 6 bit. The sensor operates in the spectral range from 500 nm to 700 nm. The images have a ground swath of 70 km, and the inclination angle of the camera is up to ± 26° perpendicular to the flight direction, which leads to a revisit time of up to 5 days. The LISS-III sensor (Linear Imaging and Self Scanning sensor) provides a spatial resolution of 23.5 m and a ground swath of 142 km in the so called channels B2 (green), B3 (red) and B4 (NIR - near infrared). The ground resolution of channel B5 (SWIR - short wave infrared) is 70.5m in a 148 km swath. The signals have a radiometric resolution of 7 bit.

Camera	PAN	LISS-III	
Geometric resolution	5.8 m	23 m (channels B2, B3, B4) 70 m (channel B5)	
Swath width	70 km	142 km	
Spectral range	500-750 nm	Channel B2 Channel B3 Channel B4 Channel B5	520-590 nm 620-680 nm 770-860 nm 1550-1700 nm
Radiometric resolution	6 bit	7 bit	

Tab. 1: Imaging sensors of IRS 1C/D relevant for the study

The layout of the channels and the relation of 1:4 between the spatial resolutions of the multi-spectral and the panchromatic cameras complies with that of the announced high resolution satellites [FRITZ, 1997].

In this study georeferenced images of LISS-III and PAN were used. The LISS images were acquired on April-24-1997, the PAN image on SEP-20-1997. Georeferencing was accomplished via a 2D polynomial rectification. The necessary control points were obtained from an orthoimage of the test area with 0.8 m ground resolution.

3 Automatic extraction and updating of vegetation areas

3.1 Some issues in multi-spectral classification

Supervised multi-spectral classification is a well established procedure in remote sensing. An operator selects training areas in the image, which he can allocate to a certain land-cover, and thus to a certain class of image objects. Per channel the mean and the standard deviation of the grey values within all training areas of one class is considered as representative for the corresponding land-cover. The values of all channels taken together are also called the spectral signature of the corresponding class of image objects. After having selected training areas for the different, every pixel in the whole image can be automatically allocated to the "most likely" class, where "most likely" can be defined in different statistical terms. Therefore, the major task for automating the supervised multi-spectral classification is to automatically generate suitable training areas.

An important aspect for the quality of the classification results is to avoid mixed pixels during the definition of the training areas. Mixed pixels capture the information of more than one object, and disturb the spectral signature of the corresponding class of image objects. They occur primarily at the borders between two image objects or at objects, which are small compared to the spatial resolution. In IRS 1C imagery roads are likely candidates for generating mixed pixels in the LISS-III images. Mixed pixels within training areas

Spatial and thematic information of the landscape stored in a topographic GIS data base, can be helpful in automatically generating the needed training areas [e.g. WALTER 1998]. Of course, this is only possible if (1) the majority of the GIS data is correct, and (2) the landscape features are represented by homogeneous areas in the image (see Fig. 2). The second condition deserves a closer look, because there are landscape features which have a 1:n or a m:n relation to the image objects. In our study these problems occur e.g. for the feature classes *arable land* and *grassland*. In multi-spectral imagery containing green, red, and near infrared channels their corresponding spectral signature can hardly be distinguished. Thus the feature classes have a m:1 relation to the corresponding class of image objects, and it is clear that from the multi-spectral imagery alone no further differentiation in these two feature classes is possible. On the other hand, a landscape feature has a 1:n relation to an image object, if the landscape feature contains e. g. different states of plant growth or different types of vegetation (see Fig. 3). A combination of both cases leads to m:n relations. Therefore, landscape features of one feature class cannot simply be used as training areas for calculating the spectral signature for a class of image objects, but the landscape features need to be checked for radiometric homogeneity prior to the classification.

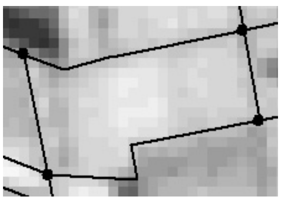

Fig. 2: ATKIS landscape feature containing a homogenous area

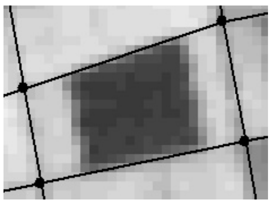

Fig. 3: Multiple image objects within one ATKIS landscape feature

3.2 Automatic generation spectral signatures

In order to be able to automatically generate training areas without running into the problems mentioned above, three steps were carried out after the intersection of the ATKIS BaseDLM and the imagery: (1) A vegetation mask was created, all further processing referred only to this mask. Thus, sealed areas such as settlements, wide roads etc. were excluded from the procedure. (2) The number of mixed pixels was reduced by buffering the polygons of the ATKIS landscape features (Fig. 4). Only pixels lying inside the buffered polygons were used for the further calculation. (3) The pixels, which were assigned as vegetation in ATKIS, were subdivided into two groups A and B. Group A consisted of all pixels of the multi-spectral image related to the feature classes *arable land* or *grassland*. All pixels of the feature class *forest* were contained in group B. Inside each group various classes were allowed. Preliminary spectral signatures of the classes were calculated in a cluster analysis in feature space. We used the well known ISODATA algorithm (Iterative self-organising data analysis technique, RICHARDS, JIA 1999) for this task. Each pixel received an attribute SPECTRAL_SIGNATURE from the range [A_1, A_2, ... ,A_p] or [B_1, B_2,....B_q], with p and q standing for the number of distinguishable classes in A and B. It should be noted that the attribute SPECTRAL_SIGNATURE has only a numerical value. In order to assign a meaning to it a human operator is required.

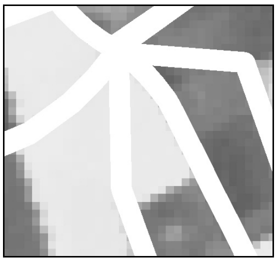

Fig. 4: Buffer around ATKIS polygons used to reduce the number of mixed pixels

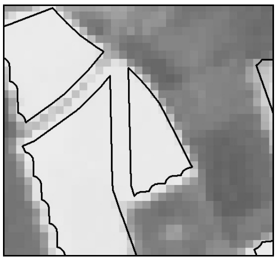

Fig. 5: Automatically generated training areas for one class

If the ATKIS data can be assumed to be up-to-date the preliminary spectral signatures can be used for the subsequent multi-spectral classification of the whole scene. This rather strict condition can be somewhat relaxed to allow for a transition e.g. from forest areas to grassland or arable land (or vice versa) in the time period between ATKIS data collection and image acquisition by introducing an additional step: With the preliminary spectral signatures all pixels in the vegetation mask were assigned to one of the classes [A_i, B_j, NIL]. NIL stands for a class containing pixels not assigned to any of the preliminary spectral signatures. The results were transformed into the vector domain yielding polygons of constant spectral signature. After some simplification (e. g. very small polygons were fused with neighbouring ones) these polygons were intersected with the ATKIS data. The result of this operation consisted of polygons, which belong to a specific ATKIS feature class and possess an attribute SPECTRAL_SIGNATURE. Only the polygons for which the ATKIS feature class was in correspondence with the attribute SPECTRAL_SIGNATURE (e.g. *arable land* or *grassland* and SPECTRAL_SIGNATURE A_i) were further considered. These polygons were again buffered to reduce effects stemming from mixed pixels, and the pixels inside the remaining polygons were used to generate the final spectral signatures for the different classes (see Fig. 5).

3.3 Multi-spectral classification

Using these spectral signatures the whole vegetation mask was classified, resulting in a thematic image with an attribute SPECTRAL_SIGNATURE for each pixel with the possible values A_i, B_i or NIL. The group identifier A or B represents the connection to the ATKIS feature class. Finally, the thematic image was converted into the vector domain and the resulting polygons which represent the image objects to be extracted where again somewhat simplified (see above).

3.4 Integration of the image objects into the vector data base

The integration of the extracted image objects into the vector orientated system ATKIS is described in this section. An important issue in this step is the different geometric accuracy of the two data sets to be integrated. The geometric position of the ATKIS landscape features is on the order of 3 m, whereas the lines delineating the image objects have a geometric accuracy of at best one pixel corresponding to 23.5 m. Therefore, all lines from the multi-spectral classification, which correspond to borders of ATKIS landscape features, should be replaced by the ATKIS lines.

Fig. 6 shows in grey some of the lines delineating the image object resulting from the multi-spectral classification. In Fig. 7 the ATKIS lines surrounded by a buffer superimposed to the lines of Fig. 6 are depicted. Lines within the buffer were assumed to correspond to the ATKIS lines and were therefore deleted.

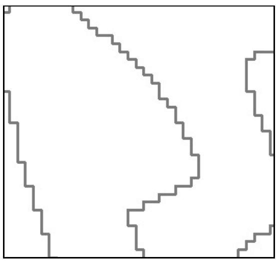

Fig. 6: Lines delineating the image objects

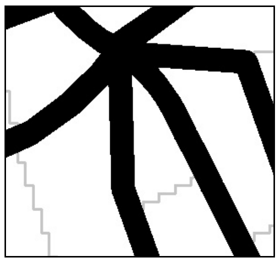

Fig. 7: Same as Fig. 6, superimposed with buffered ATKIS lines.

Next, the remaining lines of the image objects needed to be topologically connected to the ATKIS lines. In order to accomplish this task the two end points of each image object line were snapped to the nearest ATKIS line, and new end points at the geometric intersections between the ATKIS lines and the image object lines were computed (see Fig. 8).

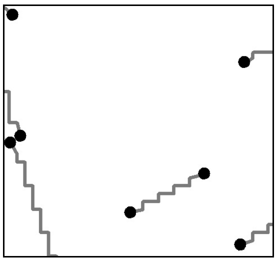

Fig. 8: Image object lines from Fig. 7 with node points

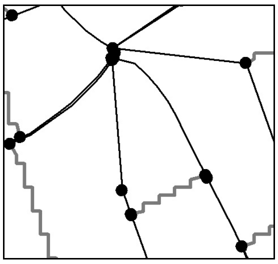

Fig. 9: Refined vector data base

Fig. 10: Valid edges from panchromatic imagery

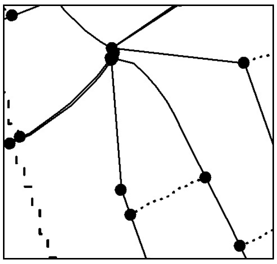

Fig. 11: Newly created landscape features consisting of lines with different geometric accuracy depending on the data source

Finally, the attributes from the ATKIS landscape feature and the SPECTRAL_SIGNATURE from the multi–spectral classification were assigned to the resulting image objects. Additionally, each line of each image object received an attribute GEOMETRIC_ACCURACY corresponding to its origin. For lines stemming from the ATKIS landscape model GEOMETRIC_ACCURACY was set to 3 m, for lines from the multi-spectral classification it was set to 25 m. The image objects were then regarded as new landscape features of a refined vector data base (see Fig. 9).

3.5 Geometric refinement using panchromatic imagery

Before the actual update operation of the old ATKIS landscape model is described (see section 3.6), an improvement of the geometric accuracy of the new landscape features using higher resolution panchromatic images is discussed in this section. There are different possibilities to fuse RGB colour and panchromatic imagery. One very popular one is to resample the colour image to the resolution of the panchromatic image, transform it into IHS space, substitute the resulting intensity channel by the panchromatic channel, and transform the result back to RGB. However, this type of fusion has the disadvantage that a generalisation to a larger number of channels is not possible. Therefore, we have chosen another way of fusing the two data sets. We first process the multi-spectral imagery as described in the preceding sections, and subsequently refine the results using the panchromatic imagery.

The general assumption underlying this step is that there exist corresponding edges in the multi-spectral and in the panchromatic imagery. Since the panchromatic image might be textured without having an equivalent in the multi-spectral imagery, we do not require the area enclosed by the edges to have a constant grey value in the panchromatic image. While visual inspection of the imagery generally confirmed this working hypothesis, it was violated in some areas, in which an edge between different landscape features in the panchromatic image was hardly or not at all detectable. One reason for this violation is of course the limited radiometric resolution of the panchromatic image as compared to the multi-spectral image. Another reason is the different geometric resolution of the multi-spectral image. It is well known that new image objects can be generated or existing image objects can shift their position when they are tracked though scale space [see e. g. Mayer 1998].

Also, two technical conditions have to be fulfilled if our working hypothesis is to be valid: (1) the two images must have been acquired simultaneously in time, and (2) they must be co-registered with sufficient accuracy. The first condition is especially important for vegetation areas during the growing season, a situation we encountered during our investigation. The test material available to us for the described study had a relatively large time difference in data acquisition of five months. In order meet the second condition orthoimages taking into account a detailed digital terrain model should be produced prior to further processing. Since the test area has only a few terrain undulations (see chapter 2), a two-dimensional polynomial transformation was sufficient here.

These remarks were made to emphasise the fact that a geometric refinement of the polygons generated from the multi-spectral imagery is not possible in all cases. The aim of this part of the study thus was to explore the extent to which an improvement could be reached.

For the geometric refinement itself every landscape feature detected in the multi-spectral imagery was mapped into the panchromatic image, and edges were extracted near the feature borders. Edges valid for our purpose were subsequently selected by topological and radiometric constraints similar to the approach presented by [HENRICSSON, 1995]. For the window shown in Fig. 4 the valid edges are depicted in Fig. 10. It is clearly visible that while the detected edges are correct, in a number of areas such edges could nor be detected.

Finally, the valid edges were transformed into the vector domain, and all multi-spectral lines with corresponding valid edges were replaced by the results from the panchromatic image. The related attribute GEOMETRIC_ACCURACY was set to 6 m corresponding to one pixel of the panchromatic image.

Fig. 11 shows the final result of the process. The vector data set contains landscape features with an additional attribute SPECTRAL_SIGNATURE according to the class in the multi-spectral imagery. The borders of the polygons consist of lines with three different values for the attribute GEOMETRIC_ACCURACY depending on the origin of the data: black lines for the ATKIS data, dashed lines for the results of the multi-spectral classification, and dotted lines for the refinements from the panchromatic imagery.

3.6 Updating the GIS-data base for vegetation objects

As described the vector data set is in principle compatible with the ATKIS feature class catalogue, although the geometric accuracy of the newly captured polygons does not meet the ATKIS requirements, no distinction was possible between arable land and grassland (see section 3.1), and of course only vegetation areas were considered. Therefore, the new landscape model can be used for partially updating the ATKIS landscape model which was used as input for the described approach. For detecting possible transitions from one feature class to another one, a simple comparison between the ATKIS feature class and the attribute SPECTRAL_SIGNATURE carried out for each landscape feature in the new vector data set is sufficient. Contradictions between these values lead to an interactive check by an operator. The system shows the landscape objects in question, and the operator can subsequently decide whether or not to modify the ATKIS landscape model.

If besides an update of the original landscape model also a refinement is desired, the newly created landscape model - after interactive checking as described in the last paragraph - constitutes the final results. During the interactive step a semantic label has to be added for the attribute SPECTRAL_SIGNATURE.

4 Experiments and results

The proposed procedure was applied to the test area described in chapter 2, see also Fig. 12. About 80 % of this area is covered with vegetation. According to ATKIS it contained 153.0 km² of arable/ grassland and 49.8 km² of forest. The other 20 % of the scene show settlements. For the classification the three LISS channels B2, B3, and B4 were used. A visual inspection revealed that the ATKIS data and the imagery approximately refer to the same time epoch.

Two different experiments were executed: (1) the given ATKIS data were used as prior information for the procedure, and (2) six km^2 of the arable/grassland of ATKIS were arbitrarily selected and declared as forest (see white mask in Fig. 12), and the procedure was executed again.

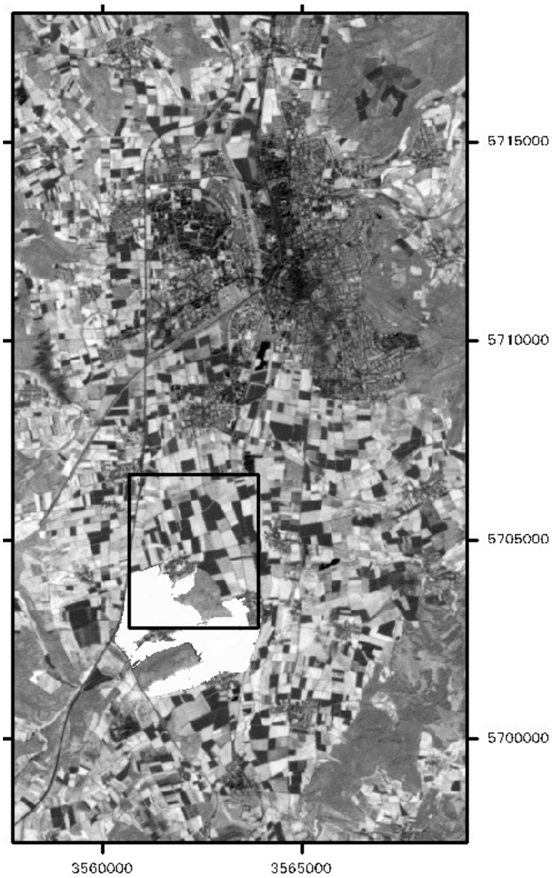

Fig. 12: Overview of the test area. Further results for the window delineated in black are shown in Fig. 13 and 14. For the significance of the white mask in the lower half, see text.

The first experiment represented a sort of base line test for our procedure, and we expected to find very few contradictions when carrying out the cross validation described in section 3.6. The second test simulated the case of outdated ATKIS information, and we expected that the cross validation would return most if not all of the newly created landscape features within these six km^2 for interactive verification.

In both tests two classes were introduced for the arable/grassland in the multi-spectral classification corresponding to the states "vegetated" and "non-vegetated", and one class for forest. The results of both tests are presented in Tab. 2. In the baseline test only 6.1 km^2 (4 %) of the arable/grassland was classified as forest, and 1.3 km^2 (2.6 %) of the forest as arable/grassland. Upon visual inspection of the results three explanations for these inconsistencies were detected: (1) in some areas a change had taken place between the acquisition of the ATKIS and the image data, (2) some areas were misclassified due to a cloud shadow in the image, and (3) some small landscape features were classified incorrectly. The last explanation was mainly found to be true for some small elongated polygons in which the number of pixels was further reduced due to the described buffering. The remaining number of pixels in these polygons was not sufficiently large for a reliable classification.

The results obtained for the second test are nearly identical in terms of area classified as arable/grassland and as forest to those of the first test, see again Tab. 2. This means that the region incorrectly labelled as forest in the ATKIS data was correctly classified as arable/grassland, just as in the first test. During this test it was found that it was essential to distinguish between the preliminary and the final spectral signature to be calculated from the training areas (see section 3.2). Without this distinction the obtained results were significantly worse. Although a larger set of experiments has to be conducted to verify these first results, we have thus reason to believe that our method is able to correctly update outdated GIS data.

ATKIS feature class	**Results obtained from IRS-1C imagery**		
	Feature class	Base line test	Simulated update test
Arable/ grassland	Arable/ grassland	146.9 km^2	148.1 km^2
	Forest	6.1 km^2	4.9 km^2
Forest	Arable/ grassland	1.3 km^2	1.5 km^2
	Forest	48.5 km^2	48.3 km^2

Tab. 2: Numerical results of base line and update test

For a better visualisation of the obtained results they are also presented in terms of figures. Fig. 13 shows a subset of the multi-spectral image overlaid with the borders of the ATKIS landscape features in black and the training areas generated for the spectral signature A_1 in white. It can be clearly seen that there exists a 1:n relation between many image objects and ATKIS landscape features, especially for the feature class arable/grassland.

The results of the presented procedure after automatic classification, geometric refinement and integration into ATKIS are depicted in Fig. 14. The newly created landscape features are displayed as polygons with different grey levels depending on the class determined during the multi – spectral classification. Light and medium grey represents the two spectral classes for arable/grassland, dark grey stands for forest, and white for settlements. The polygon borders consist of lines with different geometric accuracy. Again, black lines represent the ATKIS data, dashed lines the results of the multi-spectral classification, and dotted lines the refinements from the panchromatic imagery. Node points in the vector data are mapped as black circles.

Fig. 13: Subset of Fig. 12 together with ATKIS lines (black) and the automatically generated training areas delineated in white

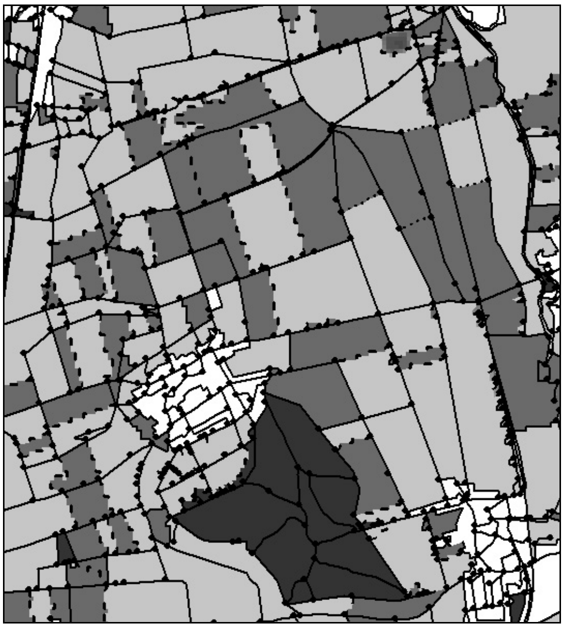

Fig. 14: Final results for the subset of Fig. 12, polygons are filled with light and medium grey for arable land/grassland, with dark grey for forest and white for settlement.

Fig. 15 gives an detailed overview of the upper right corner of Fig. 14 with the panchromatic image in the background showing the success as well as the problems associated with the transfer of the results from multi-spectral classification to the panchromatic image. While a number of edges has been detected successfully, others were not extracted, either due to low contrast or because the approximate location of the lines from the multi-spectral classification was not accurate enough, possibly due to the time difference of five months between the acquisition of the two image data sets.

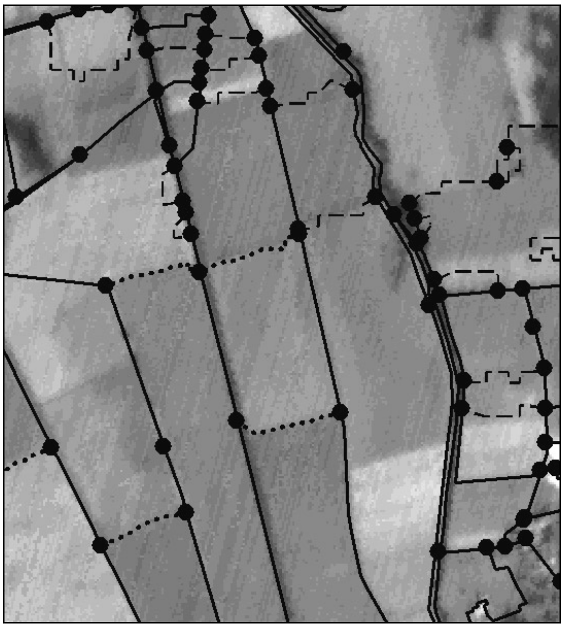

Fig. 15: Zoom into the upper right corner of Fig. 14. The image in the background is a part of the panchromatic image.

5 Summary and outlook

A procedure for the automatic GIS update of vegetation areas from satellite imagery with digital landscape model as prior information was presented. A validation of the method was conducted using data from ATKIS as well as multi-spectral and panchromatic IRS-1C imagery. The obtained results demonstrate the potential of the procedure for the specified task. It will be further refined and tested with the announced high resolution satellite imagery, as soon as they become available.

Open questions include a comparison of the two-step method for integrating the panchromatic images with an approach based on the IHS transformation, further investigations into the refinement and updating potential by increasing the number of spectral classes for the multi-spectral classification, the number of feature classes processed, and the percentage of outdated information. Another important issue which needs to be addressed is quality modelling for both the GIS data and the data derived from the imagery in the geometric and in the thematic domain.

6 Acknowledgements

The presented procedure was developed within the project “Automatic Methods for the Updating of Topographic Data Base with MOMS-02/P Image Data”, financed by the Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center, DLR) under the key number 50QS90111. We are grateful to Landesvermessung und Geobasisinformation, Niedersachsen (LGN) for providing the ATKIS BaseDLM. Also we would like to thank the anonymous reviewers for their valuable comments.

7 References

AdV 1989, 1995: Gesamtdokumentation des Vorhabens ATKIS, Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland.

ENGLISCH, A., HEIPKE, C., 1998: Erfassung und Aktualisierung topographischer Geo-Daten mit Hilfe analoger und digitaler Luftbilder, PFG 3, 133-149.

FRITZ, L. W., 1997, August 1997 Status of new Commercial Earth Observation Satellite Systems, Proceedings, ISPRS Workshop "Sensors and mapping from Space", Vol. 17, 13-27.

HENRICSSON, O., 1995: Inferring Homogeneous Regions from Rich Image Attributes, Automatic Extraction of Man-Made Objects from Aerial and Space Images, Birkhäuser Verlag, Basel, pp. 13-22.

JACOBSEN K., 1997: Calibration of IRS-1C Camera, Proceedings ISPRS Workshop „Sensors and mapping from space“, Institute of Photogrammetry and Engineering Surveys, University of Hanover, Vol. 17, 163-170.

KONECNY, G. 1996: Hochauflösende Fernerkundungssensoren für kartographische Anwendungen in Entwicklungsländern, ZPF (64) 2, 39-51.

MAYER, H., 1998: Automatische Objektextraktion aus digitalen Luftbildern, Deutsche Geodätische Kommision C (494), München.

PAKZAD K., BÜCKNER J., GROWE S., 1999: Knowledge based moorland interpretation using a hybrid system for image analysis, this workshop.

PLIETKER, B., 1997: Automatisierte Methoden zur ATKIS-Fortführung auf der Basis von digitalen Orthobildern, Photogrammetric Week 97, Dieter Fritsch/Dirk Hobbie (Eds.), Heidelberg: Wichmann, 135-146.

RADHADEVI, P.V., RAMACHANDRAN, R., MURALI, Mohan A., 1998: Restitution of IRS-1C PAN data using an orbit attitude model and minimum control, ISPRS Journal of Photogrammetry and Remote Sensing (53) 5, 262-271.

RICHARDS J.A., JIA, X., 1999: Remote sensing digital image analysis, Springer, Berlin.

UHDE, C., 1998: Harmonisierung der Objektartenkataloge, Das Geoinformationssystem ATKIS und seine Nutzung in Wirtschaft und Verwaltung, Ed: Landesvermessungsamt Baden-Württemberg, Stuttgart, 37-55.

VÖGTLE T., SCHILLING K.-J., 1995: Wissensbasierte Extraktion von Siedlungsbereichen in der Satellitenbildanalyse, ZPF (63) 5, 199-207.

WALTER, V., (1998), Automatic Classification of Remote Sensing Data for GIS Database Revision, IAPRS, Vol.32, Part 4, 641-648.