AUTOMATED VERIFICATION OF A TOPOGRAPHIC DATASET USING IKONOS IMAGERY

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Working Group IV/3

KEY WORDS: Automation, Change Detection, GIS, Quality, Updating

ABSTRACT:
Quality of an authoritative topographic reference dataset is important since it is the basis for many applications. Verification of such data is classified as being part of quality management in this paper. The main topic is the automated verification of the German topographic reference dataset ATKIS using orthorectified IKONOS imagery. The objects from the dataset are compared to an up-to-date orthoimage in order to obtain information on their quality. The main objects of interest are roads, built-up and vegetation areas. As it is assumed that most of the objects in the database are correct, the strategy is to use the objects of the ATKIS DLMBasis as a starting point. Automatic image operators being able to detect the objects of interest use prior knowledge from the dataset, such as geometrical information. By this means inconsistencies between the ATKIS objects and the image features can be detected. To organise the verification of the data independently from its capture, a semi-automatic working environment has been installed. In the interactive step the human operator just has to focus on the objects not being accepted in the automatic run. In this paper we introduce the whole system, we then focus on an envisaged extension towards the verification of additional object classes, for example the differentiation between deciduous and coniferous forests or between cropland and grassland. To realise this extension, radiometric as well as structural features are defined. Concepts and examples for the implementation of the extensions are presented.

1. BACKGROUND

About 80% of all decisions in private and public life rely on geo-spatial information. Examples for authoritative geo-spatial topographic reference data are the German „Amtliche Topographisch-Kartographische Informationssystem (ATKIS)“ and the „Digital National Framework (DNF)“ in the UK.

This paper deals with the automated verification of the German topographic reference dataset. The existing project WiPKA, where substantial object types are already verified automatically is introduced and extensions towards the verification of additional object classes are proposed.

The most important components of ATKIS are object-based digital landscape models (DLM) encompassing several resolutions. The ATKIS DLMBasis, i.e. the ATKIS data offering highest resolution, is produced by the 16 surveying authorities of the federal states of Germany and is delivered to the German Federal Agency for Cartography and Geodesy, BKG. Here, at the Geodata Centre, the ATKIS DLMBasis is checked with respect to logical and geometrical consistency and integrated into one homogeneous data set for the territory of the Federal Republic of Germany.

In addition to the well established, fully automatic inspection of logical and geometrical consistency of the ATKIS dataset, BKG strives for the increase of quality control with respect to reality, i.e. the verification and update of the existing data using reference information from remotely sensed imagery.
By verification the geometric accuracy as well as the correctness of attributes (if observable in the images) are assessed. The completeness and temporal correctness is only partly considered, as only commission errors are identified. During a following update process, new or modified objects not included in the database are identified. By this means also completeness and temporal correctness are fully considered.

Since the BKG has the task to produce a homogenous ATKIS data set for the whole of Germany, it is interested in an efficient and independent verification of the data, in combination with an automated indication of changes in the landscape, compared to the current ATKIS data.

Therefore, the BKG has initiated the project WiPKA[1]. WiPKA is a project carried out in parts by IPI and TNT to develop a system for automated quality control comparing airborne or spaceborne orthoimages and the ATKIS DLMBasis (Busch et al, 2004).

The approach implemented in this system is shortly introduced in the next section. The main focus of this paper is on the extension of the approach regarding the verification of additional object classes, since up to now only five classes, besides the road network, from the DLMBasis are considered. The concepts for these extensions are described in the third section, whereas the fourth section shows some examples. Finally conclusions and an outlook are given.

2. WIPKA-PROJECT

Since in practice the comparison between a model of the world, i.e. the DLMBasis in this case, and the real world, e.g. remote sensing images, still is far away from being carried out completely automatically, the WiPKA system is implemented as an interactive procedure based on ArcGIS on the one hand and on automated image analysis methods on the other hand.

[1] Wissensbasierter Photogrammetrisch-Kartographischer Arbeitsplatz (Knowledge-based photogrammetric-cartographic workstation)

The knowledge-based image interpretation system GeoAIDA (Bückner et al., 2002) and various methods for feature extraction are the core of the automated procedures. These programs run separately in batch mode delivering results that are imported to the interactive working environment. While the final decision about errors is reserved to a human operator, the strategy is to reliably detect as many coincidences of ATKIS objects and objects detected in the orthoimages as possible. By filtering these correct situations, i.e. to generate *acceptance* decisions, the human operator can concentrate on the objects where the automated procedure failed, i.e. on objects having been *rejected*. The workflow as implemented in WiPKA is sketched in Figure 1.

The comparison utilises orthoimages of recent date which are considered as an up-to-date reference of reality and can be used to assess completeness, correctness, positional and temporal accuracy. The main interest concerns objects where most changes arise and that are important, namely the road network, built-up and vegetation areas.

The focus in this paper is on the knowledge-based algorithms for the verification of area objects using IKONOS imagery. For details on the road verification refer to (Busch et al, 2004) and (Gerke et al., 2004).

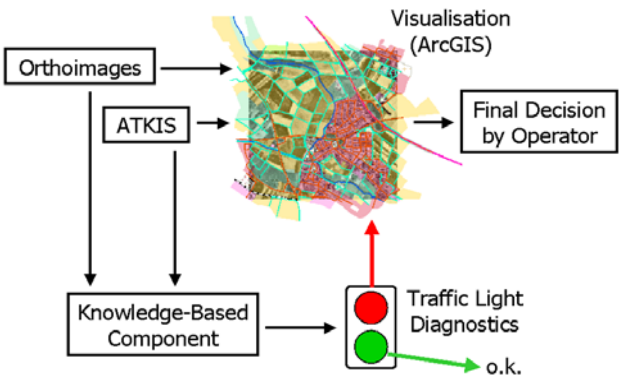

Figure 1: Workflow implemented in WiPKA

2.1 Knowledge-driven verification of area objects

In the ATKIS object catalogue instructions for the capture of landscape objects are defined. The verification of objects stored in the database includes the validation of the compliance with the prescribed semantics, i.e. which type of landcover or which object classes are allowed or mandatory for which ATKIS object. Moreover, the check of the geometric accuracy is subject to the verification: a positional accuracy of at least +/- 3m is required.
Up to now the ATKIS area classes settlement, industrial area, cropland, grassland and forest are automatically verified.

The verification is applied per object in the following manner: The basic assumption is that the given ATKIS area object is correct, i.e. it maintains the required accuracy and the existing landcover and objects comply with the object catalogue. In a first step (top-down, model-driven), evidence is collected from the given orthoimage, only the region in the image as defined by the ATKIS object is of interest. In the current development status, the evidence consists of two complementary sources of information. The first is given by an algorithm which segments and classifies the region of interest into four classes. This supervised texture classification algorithm is able to reliably classify settlement, industrial, crop-/grassland (one class) and forest areas. The second source of evidence consists of an object detection operator which finds single buildings in the image.

In the subsequent bottom-up (data-driven) phase, the evidence per ATKIS object is combined in order to derive an acceptance or rejection decision. A so-called assessment catalogue defines mandatory or allowed coverage of a given ATKIS object with the classified segments or buildings. For example, a given cropland object needs to be covered to at least 80% by cropland-segments, and buildings are not allowed. If the requirements defined by those rules are not satisfied, the respective ATKIS object is rejected, otherwise it is accepted.
The mandatory assignments between ATKIS objects, segments from the texture classification and the buildings from the object detection algorithms are shown in Figure 2. The lower box represents the ATKIS objects, lined up in a hierarchical (part-of) scheme. The assignments are given by the straight connectors between the object classes, for instance an ATKIS settlement area needs to contain one or more houses and needs to be covered by settlement segments obtained from the classification algorithm.

Supervised texture classification The algorithm applied for the texture classification is described in (Gimel'farb, 1997). In this research work, Gibbs random fields are used for modelling pixelwise and pairwise pixel interaction. This approach has shown to be an adequate means to describe texture properties. The specific Gibbs-potentials for these models are obtained from difference grey value histograms. The optimal potentials are learned from given samples applying a maximum likelihood estimation. A segmentation and labelling of a given image consists in finding piecewise homogenous regions by a MAP estimation which involves simulated annealing. Further details on the adaptation of this algorithm are given in (Busch et al., 2004).

Object detection The detection of houses and industry halls is based on the combination and mutual verification of shadow and roof hypotheses. First, hypotheses for shadows and roofs are generated using two different image segmentation operators. Shadow hypotheses of buildings are derived with a threshold decision in the image. Additional shadows, e.g. near a forest, have a limited size, so those shadows can be excluded. Roof hypotheses are generated using the so-called colour structure code (Rehrmann and Priese, 1998). Only roof hypotheses of a plausible size are selected, additionally the compactness and orthogonality of roof labels are validated. In the last step the grouping of instantiated shadow and roof labels to validated buildings is performed. The neighbouring position of a shadow to a roof is checked based on an illumination model. The resulting building hypotheses are divided into houses and industry halls using the area of the objects as criterion. Further details on this algorithm are available in (Müller and Zaum, 2005).

2.2 Results

The results obtained with this approach using orthoimages derived from aerial imagery are discussed in (Busch et al., 2004). The ongoing assessment of the method when IKONOS imagery is used shows similar results, namely that about 2/3 of the DLMBasis objects are correct and are accepted by the algorithm. Another 3 to 6% are accepted though being incorrect. These false positive decisions are mainly related to too weak rules in the assessment catalogue. The enhancement of this catalogue is subject to ongoing tests.

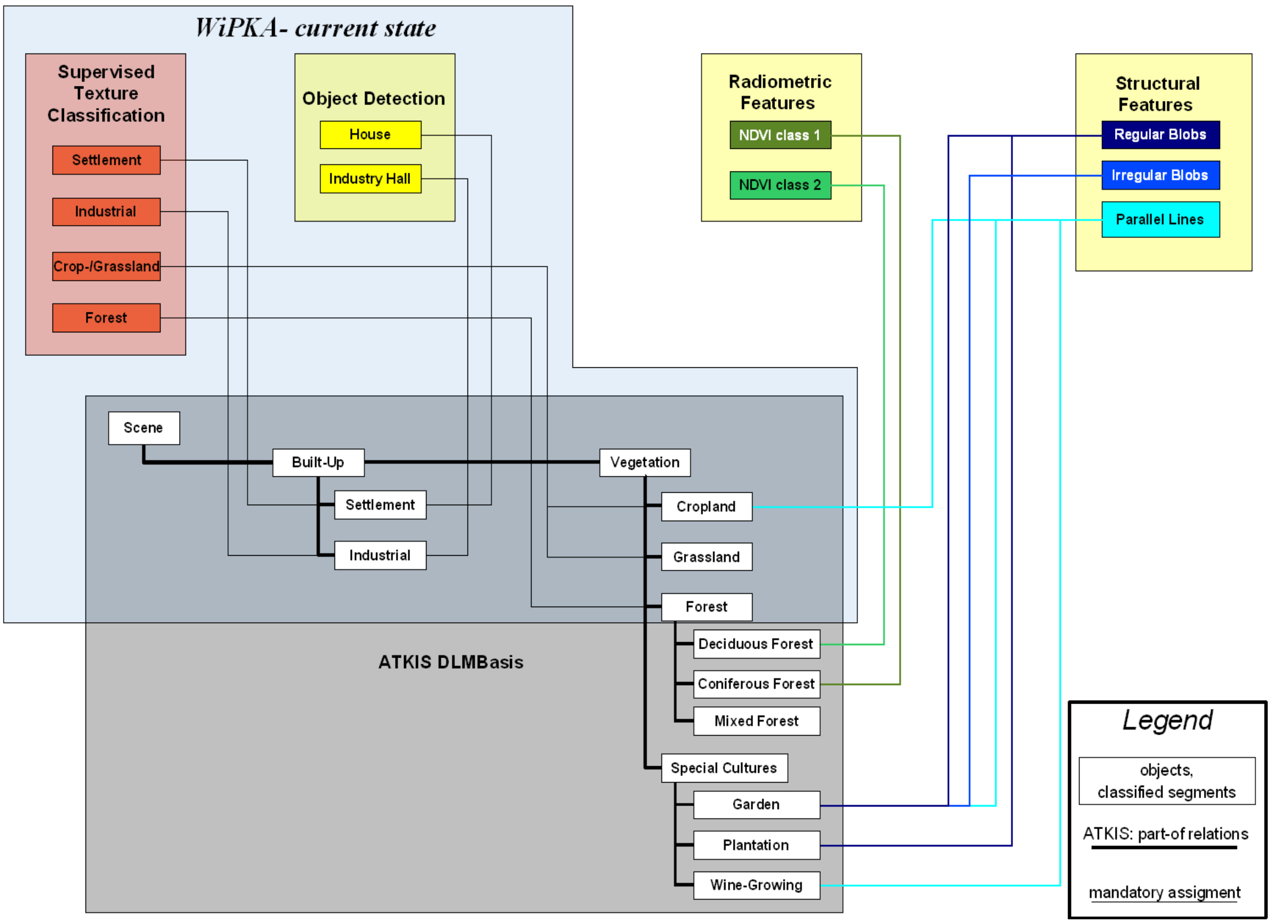

Figure 2: Assignments between ATKIS objects, segments from the texture classification, the buildings from the object detection algorithms, and radiometric and structural feature classes

3. VERIFICATION OF ADDITIONAL CLASSES

The most salient landcover types can be automatically distinguished within the present system. The current task is to reach an increased grade of automation. The verification of the following object classes is therefore subject to our ongoing efforts: the discrimination between deciduous and coniferous forest, the discrimination between crop- and grassland and additionally the verification of garden, plantation and wine-growing areas. The aspired extension of the approach towards the verification of additional object classes requires an enhanced object and feature extraction scheme.
Like the existing approach, these extensions and the respective proposed algorithms are primarily related to typical landscape scenes in Germany. However, the methods described below may be easily transferred to other regions.

3.1 Approach

The currently implemented object extraction and segmentation algorithms can not solely be used for the verification of the additional objects. The texture classification algorithm needs an adequate number of samples within the training phase in order to yield a reliable result. This requirement is normally not satisfied for object classes such as garden or plantation: often only a few instances of those classes can be found in a given scene. The evidence delivered by the algorithm to building extraction does not help to discriminate for example between cropland and grassland. Moreover, a reliable differentiation between deciduous and coniferous forests is normally not feasible with the texture segmentation approach.
Due to these reasons the incorporation of features which describe explicitly the appearance of the respective objects in the imagery is required. Therefore we propose to use explicit radiometric as well as structural features (see again Figure 2).

Remote sensing satellites, such as IKONOS, but also digital frame cameras for airborne image acquisition offer a channel which covers the near infrared spectrum. With this additional information it is possible to calculate vegetation indices such as the Normalized Difference Vegetation Index (NDVI), which is utilised as radiometric feature. Particularly, the differentiation between NDVI range classes inside vegetation areas carries the promise to enable a separation of distinct vegetation types. The use of the NDVI for the differentiation between forest objects is described below, whereas the adequate segmentation of NDVI images, is subject to the next subsection.

Structural features are compared to textural features in (Gimel'farb, 1997, p. 3): „The structure is defined in a broad sense as a mutual relation of the elements of the whole object or a fabric or framework of putting them together". On the other hand "the texture relates to a specific structure of visual or tactile surface characteristics of particular objects such as natural woven ones." Examples for structural features are the

lines a machine leaves behind in the cropland, or trees in a plantation which are arranged in a specific, regular order or wine growing up in lines.
In the approach proposed here, the structural features *regular blobs, irregular blobs* and *parallel lines* are utilised.

Discrimination between deciduous and coniferous forest
Natural objects like forest often have a characteristic radiometry. Atmospheric and topographic influences as well as conditions of illumination within an image show distinct variations. In rolling hills areas can be overexposed or covered by shadows. Moreover, variable illumination is caused by the direction of sun, the amount of cloud cover, etc. These are the main reasons why the prediction of radiometric values is not possible.
In (Cho, 2002) and (DeKok, 2002) it was shown that the differentiation between forest types based on radiometric features is efficiently possible if the respective parameters are obtained from training data. In the approach proposed in this paper the differentiation between deciduous and coniferous forest relies on the separability of NDVI values.

Figure 3 shows an example for an NDVI image. The scene shows both types of forest, the area covered by coniferous forest is bordered by continuous lines, mixed forest stands are marked by dashed lines. The NDVI values related to the coniferous forest are obviously smaller than for the deciduous forest.

Figure 3: NVDI image of deciduous and coniferous forest. Coniferous forest is bordered by continuous lines, mixed forest stands by dashed lines.

Discrimination between grassland and cropland
A means to differentiate grassland and cropland is the exploitation of structures caused by the cultivation, which is conducted more frequently in crop fields, compared to grassland. The machines normally cause a regular line pattern which is observable in the image. Those lines are mostly parallel to each other and parallel or orthogonal to the field borders.
An example for parallel lines in crop fields in contrast to grassland is shown in Figure 4. In this image grassland is marked with blue lines.

Figure 4: RGB image of grassland/cropland

Verification of garden
A garden area can consist of a large variety of objects: houses, single trees, hedges, beds, homogenous grass area etc. Due to this large variety it is not possible to define a mandatory arrangement of objects, nor to not allow a specific object type. Therefore, in this proposed approach, it is prescribed that at least one of the defined features needs to be observable, i.e. single blobs or parallel line features. Moreover, the number of houses inside one garden-area needs to be restricted. An example of garden is shown in Figure 5.

Figure 5: RGB image of garden

Verification of plantation and wine-growing fields
The exploitation of structural features is also a key means to verify plantations and wine-growing fields. Both object classes are characterised by intensive cultivation. In a (fruit) plantation the trees are arranged in a way leaving enough space in-between in order to be able to crop and maintain them automatically. Therefore, in IKONOS imagery the trees are observable as single blobs, arranged in a regular pattern (refer to Figure 6, showing a plantation). Similarly, the wine-growing grapevines are observable as parallel lines in IKONOS images. Due to the resolution of the images, single vines can not be identified, refer to Figure 7.

Figure 6: RGB image of a plantation

Figure 7: RGB image of a wine-growing area

Assessment catalogue

The extended object assignment is shown in Figure 2. The radiometric classes derived from the segmentation of the NDVI images are assigned to the various forest types in the ATKIS DLMBasis. The structural features are mainly used for the verification of special cultures and for cropland.

In the following two subsections the concepts for the implementation of the feature segmentation and classification algorithms are shortly introduced.

3.2 Segmentation of NDVI image

The assessment scheme above relies on the segmentation of the NDVI image into two classes. Whether this separation is feasible depends on many factors, as laid out above. Therefore, no a priori threshold or segmentation scheme can be defined.

Here, a supervised training is applied. In the given scene, sample areas of deciduous and coniferous forest are selected. The mean NDVI value, including a standard deviation for both classes is computed from these regions. If both mean values are significantly different from each other, they can be used for the segmentation. In case, both classes are not separable, the radiometric features based on the NDVI can not be used for the objects in the respective scene, i.e. the correctness of the ATKIS data with respect to the two forest types can not be assessed. Another possibility consists in the segmentation of the NDVI image using structural information. Whether such a method leads to reliable results is subject to further investigations.

3.3 Point and line structure detection

One core extension of the approach as described in section 3.1 consists in the detection of structural features, i.e. in the segmentation of a given (IKONOS) image patch into regions showing homogenous structure. The structural features considered are *regular blobs, irregular blobs* and *parallel lines.*

Detection of blobs

The detection of blobs in the context of this paper is identical to the detection of single, free-standing trees: these are assumed to be regions with a high contrast to the surrounding. In first experiments, those blobs have been detected as follows: The Laplace-of-Gaussian operator (LOG) was applied, leading to an image where the sum of partial second derivatives is assigned to each pixel. Due to the high contrast between the trees and the surroundings, the trees appear as light circular regions in the LOG-image, refer to top left and top right image in Figure 8. To obtain individual regions for each tree, a segmentation of the LOG-image has been conducted (bottom left image).

Detection of structures between blobs

The detected blobs, i.e. the single trees, are mainly used for the verification of plantations. In this case the blobs must be arranged regularly, to enable an easy automatic cultivation.

A basic property of regular blobs is that they are arranged in parallel lines. The idea to find those arrangements is to iteratively fit parallel lines into the set of detected blobs. To robustly identify outliers, a RANSAC algorithm is applied to estimate the parameters for the parallel lines. Through the insertion of a convergence criterion the cases where no parallel structures are existing can be identified, i.e. the blobs are then classified as being irregular.

In the right bottom image of Figure 8 the fitting of parallel lines into the blobs is shown.

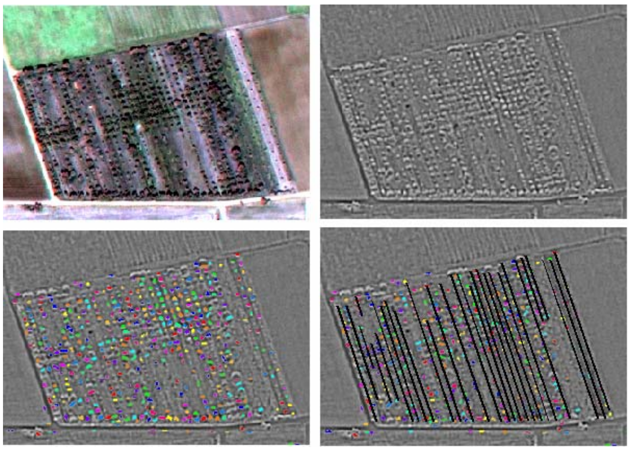

Figure 8: Detection of blobs and of regular structures: top left: RGB image showing a plantation, top right: LOG-image, bottom left: blobs filtered from LOG (coloured regions), bottom right: linear arrangements of blobs

Detection of parallel lines

The segmentation of a given image patch into regions showing parallel linear features is done in a two step-approach. First, lines are detected with an appropriate line extraction operator, for example as presented in (Steger, 1998). These lines are then transformed into hough space. A clustering in this space identifies those lines having a identical orientation. The advantage of this procedure is that it is insensitive against noise and gaps in line extraction have no major impact on the clustering. If no reasonable clustering in hough space is possible it is assumed that no parallel lines are observable in the given image patch.

4. EXAMPLES

The concepts for the extension of the WiPKA-approach regarding the verification of additional object classes are introduced above. The feasibility of these concepts is shortly demonstrated by two examples.

Verification of deciduous forest

Figure 9 shows a scene of an IKONOS image covered mainly by deciduous forest (blue borders). In ATKIS this object is also registered as a deciduous forest.

After the supervised texture classification this object is identified as forest. An examination of the NDVI values results in the object being labelled as deciduous forest. Since no contradiction to the mandatory assignment is detected, the respective ATKIS objects are accepted.

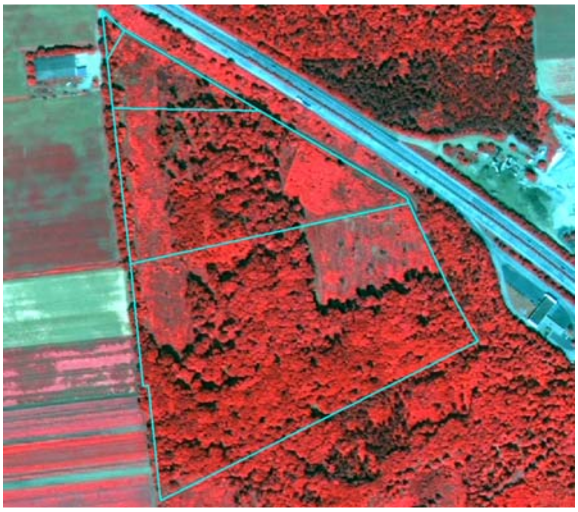

Figure 9: Correct registration of deciduous forest

Verification of grassland

In Figure 10 ATKIS grassland objects are bordered by blue lines. After the supervised texture classification the object in the image centre is detected as crop-/grassland. However, the extraction of parallel linear structures allows to falsify the ATKIS object grassland. Besides, the respective low NDVI values give hint regarding the absence of vegetation, i.e. also support the rejection decision.

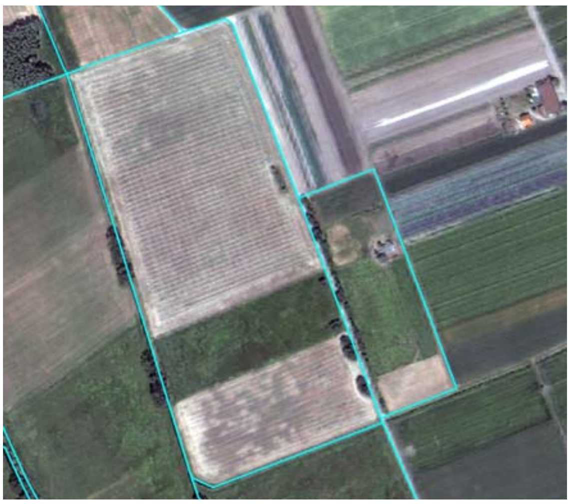

Figure 10: Incorrect registration of grassland in ATKIS (RGB)

5. CONCLUSIONS AND OUTLOOK

In this paper the existing project WiPKA is introduced and its approach to the verification of a given topographic dataset is presented. The envisaged extensions regarding the verification of additional object classes are presented. The main attention is directed to the verification of deciduous and coniferous forests, to the verification of cropland and grassland, and to the differentiation between several special cultures, such as garden, plantation and wine-growing areas. In the current approach the evidence for the verification is derived from a supervised texture classification and from building detection operators. In this paper the consideration of radiometric and structural features is proposed to be able to verify the additional object classes. The assignment between the given objects from the topographic database and the image segments being classified according to the defined features is derived, enabling the formulation of a verification scheme, called assessment catalogue.

The concepts for the new feature detection operators are outlined and first results are shown. The implementation and validation of these concepts is subject to ongoing research.

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