Integrating Imagery and ATKIS-data to Extract Field Boundaries and Wind Erosion Obstacles

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1. Introduction and motivation

The integration of different data sources is an important task to obtain overall solutions in many areas, for example geo-scientific analysis, updating and visualization. The specific task, being carried out at the Institute of Photogrammetry and GeoInformation (IPI) together with the Niedersächsisches Landesamt für Bodenordnung (NLfB) and the Bundesamt für Kartographie und Geodäsie (BKG), is the integration of vector data with imagery to enhance the Digital Soil Science Map of Lower Saxony (Germany) with automatically derived field boundaries and wind erosion obstacles (hedges, tree rows), c.f. (Sester et al. 2003). This data is needed for various problems: (1) One application area is the derivation of potential wind erosion risk fields, which can be generated with additional information about the prevailing wind direction and soil parameters, (2) another area is the agricultural sector, where information about field geometry is important for tasks concerning precision farming.
Several investigations have been carried out regarding the automatic extraction of man-made objects such as buildings or roads, see (Mayer 1999) for an overview, and regarding the extraction of trees, see (Hill and Leckie 1999) for an overview. In contrary, the extraction of field boundaries from high resolution imagery is still not in an advanced phase: (Löcherbach 1998) presented an approach to refine topologically correct field boundaries, but not the acquisition of new ones, and (Torre and Radeva 2000) give a semi-automatic approach to extract field boundaries from aerial images with a combination of region growing techniques and snakes.
Generally, the extraction of objects with the help of image analysis methods starts with an integrated modelling of the objects of interest and the surrounding scene. Furthermore, exploiting the context relations between different objects leads to more overall and holistic descriptions, see for example (Baumgartner et al. 1997). The use of GIS-data as prior knowledge supporting object extraction leads usually to better results (Baltsavias 2002). These aspects concerning the modelling of the extraction of field boundaries and wind erosion obstacles will be described in the next section in detail, before the strategy of the extraction of field boundaries and wind erosion obstacles will be explained. Furthermore, results will be given to demonstrate the potential of the proposed solution.

2. Modelling the integration of vector data and aerial imagery

Modelling the integration of vector data with imagery in one semantic model is an essential prerequisite for successful object extraction, as described in detail for example in (Butenuth and Heipke 2003). We differentiate in the semantic model an *object layer*, consisting of a geometric and a material part, a GIS part and a Real World part, and an *image layer* (c.f. Figure 1). The relations between the different layers ("concrete of") of one object are referenced in the image layer to CIR-images, which are generated in summer, when the vegetation is in an advanced period of growth. The use of prior knowledge plays a particularly important role, which is represented in the semantic model by an additional GIS-layer, in this case the vector data of ATKIS DLMBasis (c.f. Figure 1): (1) Information about field boundaries and wind erosion obstacles are only of interest in the open landscape; thus, settlements, forests and water bodies are masked out in the imagery for further investigations. (2) The road network, rivers and railways can be used as borderlines to select regions of interest to simplify the scene. The subsequent processing focuses on the field boundaries *within* the selected regions of interest, which have to be extracted; the *external* ones are consequently already fixed (e.g. a road is a field boundary). This fact is incorporated into the semantic model and the mentioned objects are introduced with a direct relation from the GIS-layer to the Real World. (3) The objects hedge and tree row are modelled in the ATKIS-data of the GIS-layer, but only, when they are longer than 200 m and lie along roads or are formative for the landscape. Accordingly, only part of the wind erosion obstacle is contained in the ATKIS-objects and the relation from the GIS-layer to the Real World is limited.

The combined modelling of the objects of interest leads in addition to relationships inside the layers: One object can be part of another one or be parallel and nearby, and together they form a network in the real world. For example, wind erosion obstacles are not located in the middle of a field, because of disadvantageous cultivation conditions, but solely on the field boundaries. Accordingly, the geometries of these different objects are in part identical or at least parallel with a short distance in between.

The object *field* is divided in *field area* and *field boundary* in order to allows for different modelling: On the one hand the *field area* is a 2D vegetation region, which is described in the image as a homogeneous region with a high NDVI (Normalised Difference Vegetation Index) value, and on the other hand the *field boundary* is a 2D elongated vegetation boundary, which is described in the image as a straight line or edge. Both descriptions lead to the desired result from different sides.

The object *wind erosion obstacle* is divided in *hedge* and *tree row* due to different available information from the GIS-layer. Afterwards, both objects are merged, because the "concrete of" relations are identical in modelling. In addition, the wind erosion obstacles are not only described by their direct appearance in geometry and material, but also with the fact, that due to their height (3D object) there is a 2D elongated shadow region next to and in a known direction (e.g. northern direction at noon). Therefore, the "concrete of" relation not only exists of an elongated, coloured region with a high NDVI value, but additional of an elongated dark region with a low NDVI value alongside the real object of interest in a known direction.

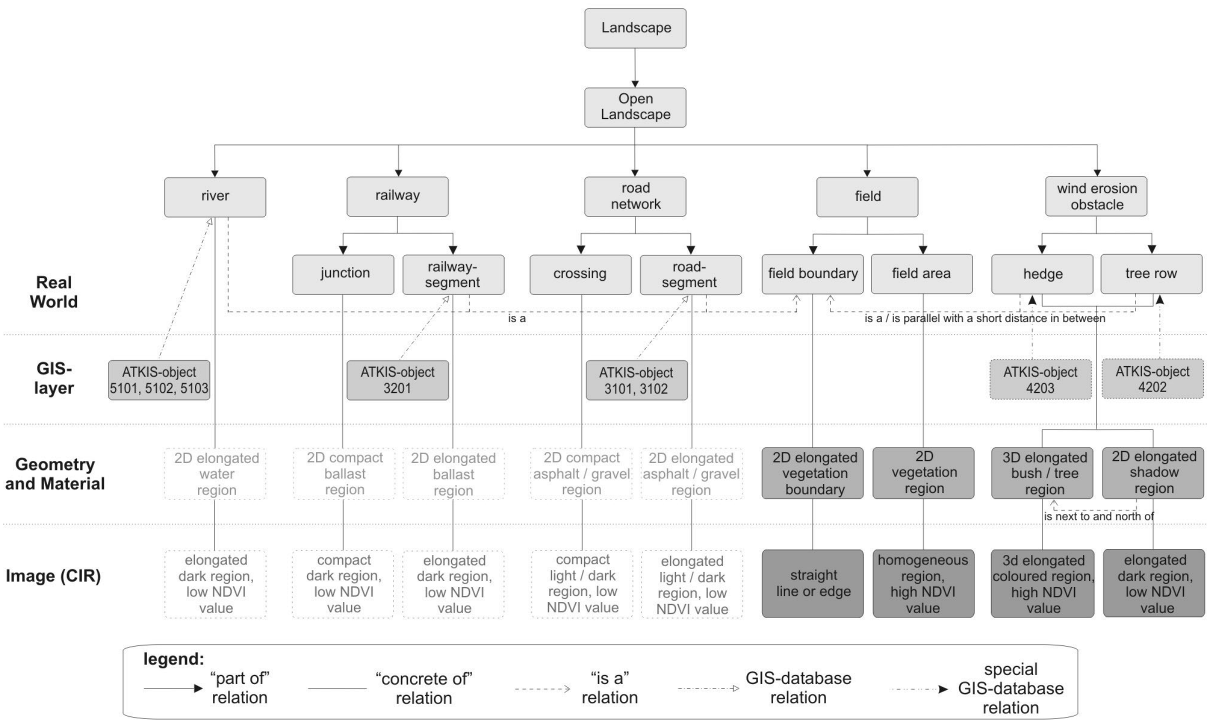

Figure 1: *Semantic Model*

3. Strategy to extract field boundaries and wind erosion obstacles from aerial imagery

The strategy to extract field boundaries and wind erosion obstacles is based on the modelled characteristics: Regions of interest are selected to take into account the constraints as described in the semantic model. The strategy divides the approach first into two different algorithms to accomplish the extraction of the different objects separately. At a later date we will return to a combined solution due to the mentioned geometrical and thematic similarities of the objects of interest. A common evaluation of the intermediate results will enable an enhanced and refined extraction process.

The strategy for the extraction of field boundaries includes the exploitation of different characteristics of fields and their surrounding boundaries to derive a preferably optimum result concerning correctness. The homogeneity of the vegetation within each field enables a segmentation of field areas, processed in a coarse scale to ignore small disturbing structures. The absolute values of the gradient are computed on the base of a Gaussian filtered version of the NDVI-image. The topography of the resulting grey values is used as input for a watershed segmentation (Beucher 1982). The deduced segments are marked with their corresponding mean grey value of the NDVI-image. Potential field areas are derived by grouping the resulting segments with respect to neighbourhood and a low grey value difference, additionally considering a minimum size. The segmentation result is only an intermediate one, because the case of identical vegetation in neighbouring fields – and therefore a missing boundary – is until now ignored. A line extraction is carried out in the original resolution image to derive missing field boundaries. The extracted line segments are processed to straight lines in consideration of a minimum length due to the characteristics of the field boundaries, remaining lines are rejected. A further step is the selection of lines, which are not located next to already derived boundaries of segments. In addition, lines are linked by their calculated intercept points of the lines, if the corresponding end points have a distance smaller than a threshold, and furthermore the lines are extended to the boundaries of the segments, if the distance lies again below a threshold. Finally, gaps between intercept points are closed, if the distance is not too large.

The strategy of the extraction of wind erosion obstacles contains the modelled prior knowledge to generate search areas deduced from the ATKIS-data. Extracted information about a high NDVI-value and a higher value of the Digital Surface Model (DSM) than the surrounding area give evidence of wind erosion obstacles within the defined search areas. Objects of interest, which are not located near to GIS-objects have to be extracted without prior information about the location. In addition to the extraction of high NDVI-values and higher DSM-values, characteristics as straightness, a minimum length and width have to be taken into account to derive wind erosion obstacles.

4. Results and conclusions

In Figure 2 on the left side a selected region of interest is shown, the boundaries of the region have been derived from GIS-data. In Figure 2 on the right side the results of the segmentation and the grouped field boundaries are depicted. The derived results of the proposed approach are promising, because not only well visible field boundaries, but also most of the ones which are hard to distinguish, could be successfully extracted. In the future, the use of colour and/or texture may stabilize the segmentation step. Additionally, the use of an integrated network of snakes for all field areas of the region of interest could improve the topological correctness of the results. The solution concerning the extraction of field boundaries has to be evaluated with a larger data set to better assess the proposed strategy. Work on the extraction of wind erosion obstacles is currently in progress, first results will be available soon.

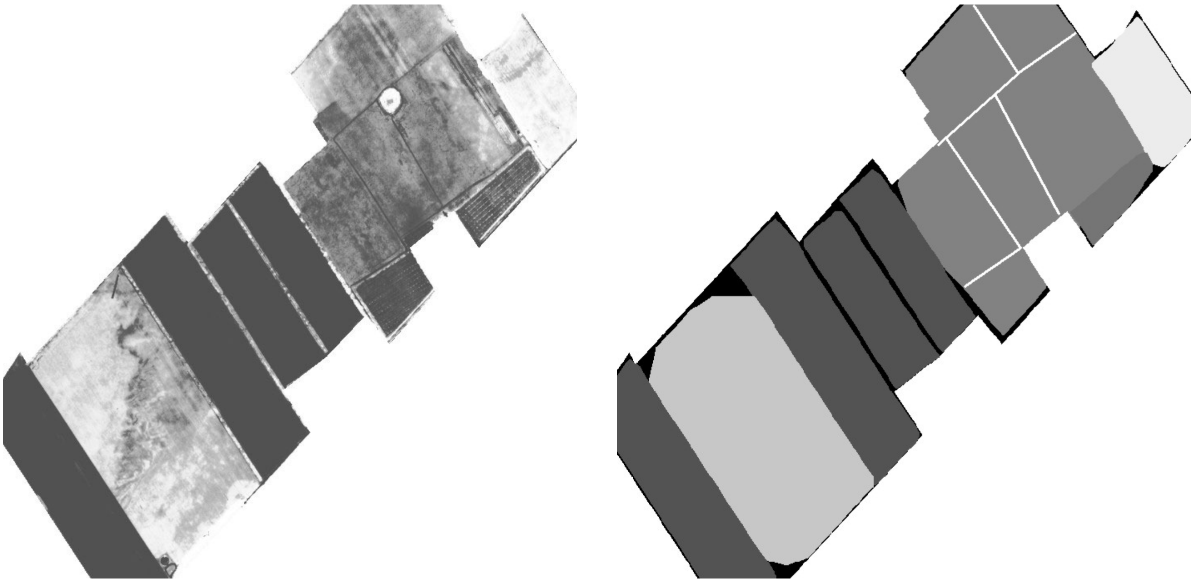

Figure 2: *Left: NDVI-image, depicted is one selected region of interest. Right: Segmented field areas, additionally shown are lines, extracted and grouped to field boundaries (white lines)*

5. References

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