A COMPARISON BETWEEN THE ISODATA AND THE ECOGNITION CLASSIFICATION METHODS ON BASIS OF FIELD DATA

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ABSTRACT

Image analysis algorithms carry out the precise filtering of the information registered on imageries and the sorting out of the surface objects. They provide the capability to automatically recognize similarities and discriminate among different surface objects. The detail and success of discrimination that can be achieved by the use of these classification algorithms constitutes one of the limiting factors for the effective usage of remote sensing products.

In the frame of the presented work two different classification concepts are compared, the pixel based and the object oriented classification method. Both start with a segmentation of the image and are followed by a classification. As representative of the former one was selected the ISODATA clustering method and for the latter one the new innovative image analysis method of DELPHI 2 eCognition.

The level of the success of the two methods is evaluated by the use of ground truth data. The better precision and the improvement factor in pattern recognition that can be accomplished with the object based classification method are demonstrated. Ecognition's capability to finer assess already identified-classified surfaces is presented. Moreover, the advantages of the object oriented classification method are discussed and analyzed.

The focus of this work is on agricultural matters and particularly on precision farming applications. A way is presented of how the eCognition method could give thrust to remote sensing application for precision farming purposes.

1   INTRODUCTION

Natural landscapes, agricultural areas, as well as man-made constructions are dominated by textures and colors that reflect the diversity of the factors influencing the final sight of the surface objects (Musick et al., 1990). Homogeneity in the formations and colors is rather the exception than the rule.

During the last decades the identification of land use / land cover types was in the focus of remote sensing supported investigations. Maps showing the distribution of the classified units and the statistics of these classifications were important results of these evaluations. The geometric resolution of the operational systems (Landsat TM, Spot HRV, IRS) limited this investigations on the regional scale (1:50.000). New sensor generations with an improved geometric, spectral and radiometric performance like the airborne imaging spectrometer instruments (AVIRIS, MAIS, DAIS, CASI, etc.) or the spaceborne IKONOS system allow a mapping scale of 1 : 10.000 and better. The performance of this sensor generation allows the concentration of the scientific interest on status assessment of already identified surfaces. This is a key capability required for site specific applications, just like precision farming ones.

Precision farming comprises a management system, which is expected to improve not only the economical but also the ecological balance of agricultural management (Manakos et al., 2000). The strategy of precision farming management is to take into consideration growth differences on subplots. At each of these subplots should be applied only that amount of fertilizer, herbicides, pesticides, fungicides or water, which can be resorbed by the plants (fertilizer, water) or which is needed to control the pest attacks (pesticides, herbicides, fungicides). In precision farming it is, therefore, of decisive importance to detect and incorporate into a decision making management system areas in the fields, where growth differences occur, which is the distribution of them and what is the reason of their occurrence (Janssen, 1994; Manakos et al., 2000). As a consequence, it constitutes a main concern to monitor the unevennesses inside a plot and to classify them in interpretable groups, while respecting human instituted administrative boundaries.

Most classification algorithms are based on the digital number of the pixel itself and/or texture attributes in a certain defined vicinity around a pixel (Landgrebe et al., 1976). Limitations arise through this way of thinking. Typical objects in an image are not characterized by one color, but by a characteristic texture of colors, as well (Steinnocher, 1999). At the same time the same color can be part of the texture of different classes of objects. Furthermore, it is very difficult to integrate context information in pixel-oriented approaches. Topology and spatial relationship features are also missing.

In order to overcome these limitations new image analysis methods adopt an object oriented way of data assessment. DELPHI 2 eCognition method (Baatz et al, 1999& 2000) promotes the new perspective (Schneider et al., 1999 & 2000). The difference in identifying and grouping surface characteristics in meaningful classes between the object and the pixel oriented (ISODATA clustering) method (Tou & Gonzalez., 1974) is presented. The classification methods as tools for providing a missing updated land cover thematic map are tested against each other. Moreover, the new capabilities for status assessment of the object oriented classification method are exhibited.

The similarity between segmentation and classification was pointed out by different authors (Schneider & Steinweder, 1999; Flack, 1995). For the better understanding of the evaluation chain in this paper **segmentation** means the aggregation process, which based on image statistics and thresholds defined by the operator, produces homogeneous clusters or objects. **Classification** is used for the processing step, which labels the clusters or objects on base of spectral or spatial characteristics and results in user (or application) defined "meaningful" objects.

2   MATERIALS AND METHODS

2.1   Testsite

The testsite lies in the area of the research farm „Duernast" of the Agricultural Faculty of the Technical University of Munich in Freising /Weihenstephan between 11°41'55,4" and 11°43'2,86"E longitude and 48°23'53,38" and 48°24'16,34"N latitude. The main part of the test and surrounding area belongs to tertiary aged hills, formed from clastic sediments of the upper molassic series. Common soils in this area are sandy loams and loam with soil productivity from 34 to 67 on a scale from 0 (for an unproductive soil) to 100 (excellent productive soil).

2.2   Software

For image analysis purposes, as well as for the application of the ISODATA classification method, Xpace, v.6.3.0 from PCI was used. DELPHI 2 eCognition software supported the application of the DELPHI 2 eCognition classification method. The comparison of the ISODATA and the DELPHI 2 eCognition results with the land cover thematic map was carried out using ArcInfo v.7.1.2 from ESRI, as long with ArcView v.3.2 with the module of Spatial Analyst. Moreover, statistical analysis and diagram presentation of the data was performed by the use of conventional market software (Ms Excel).

2.3   Data set

A Daedalus Airborne Thematic Mapper (ATM) digital scanner imagery was at our disposal. It was registered on the 19th of July 1999. The footprint in this case was about 1,5 * 1,5m² at an altitude of 600m above ground level. The digitised field of view was 85,92° and the swath wide was about 716 pixels (DLR, 1989). The spectral registration took place simultaneously at twelve spectral ranges.

Field data concerning the land cover were gathered at the flight date and registered on a cadastral map of the area. These data were used for the class assignment and the classification results comparison.

2.4   Image processing

Firstly, the part of the city of Freising, buildings, roofs, streets, cars were masked in the selected area of interest. The area of interest consisted mainly of cultivated plots and forest. No rectification was carried out in order to avoid the resampling of the imagery and retain the original pixel positions and digital values. The masked imagery was processed with the ISODATA and the DELPHI 2 eCognition classification methods.

ISODATA classification method. The ISODATA clustering algorithm (Tou & Gonzalez., 1974; ERDAS, 1997) compares the radiometric value of each pixel with predefined number of cluster attractors, aggregates pixels in clusters and shifts the cluster mean values in a way that the majority of the former aggregated pixels belongs to a cluster. The user interacts with the procedure at the beginning indicating the number of the predefined clusters to be created and the iterations to be carried out and at the end, where he decides which cluster represents which surface land cover object and merges or rejects the classes with non-realistic representatives.

In this case the formation of 10 classes was desired according to the existing land cover ones. A maximum number of 20 iterations was used and the movement of the threshold was set to 0.01. Signatures for each cluster were created and

the corresponding statistics were kept. Minimum sample threshold and standard deviation, as well as cluster aggregation parameters were used in order to fine tune the classification.

DELPHI 2 eCognition classification method. At first, the DELPHI 2 eCognition software segmentates the imagery. Average size in pixel total number of the objects, and the homogeneity and shape homogeneity parameters of the objects to be formed can be coarsely tuned. This results to a condensing of information and a knowledge-free extraction of image objects. The formation of the objects is carried out in a way that an overall homogeneous resolution is kept. Finer and coarser segmentation levels can be created. Each of them respects the existence of it's coarser level. The segmentation algorithm does not only relay on the single pixel value, but also on pixel spatial continuity (texture, topology). The formatted objects have now not only the value and statistic information of the pixels that they consist. They carry also texture, form (spatial features) and topology information in a common attribute table (Baatz et al., 2000; Schneider et al., 2000). The user interacts with the procedure and based on statistics, texture, form and mutual relations among objects defines training areas. The classification of an object can then follow the "hard" nearest neighborhood method or the "soft" method using fuzzy membership functions (Schowengerdt, 1997).

At least two classification ways could be followed.
1. Usually spectral feature criteria are selected over the finer object level (de KOK, 1999). The results are inherited to the coarser ones and spatial feature criteria are used to fine tune the former classification result at the coarser object level. Fusion of the classified objects unites the spectral and spatial information of neighboring same classified objects and a polygon topology leading to a land cover thematic map is created. Furthermore, new segmentations can be added to the procedure and the classification can be extended to the discrimination of subclasses reflecting non homogeneous spots inside a class. For the latter process new spectral criteria layers can be integrated, such as vegetation indices image layers.
2. In case of a thorough knowledge of the land cover of the area of interest the average object size resulting from the segmentation could be tuned in a way that an object almost describes a polygon member of a land cover class (e.g. a plot). These objects are then manually assigned to a land cover class. Carrying out a further finer segmentation, finer objects respecting the borders of the coarser ones are created. These finer objets describe more detailed the transition line from one class to the other. Moreover, using hierarchy rules the former manual classification is directly transferred to the finer segmented level. Taking into account the statistic and form information of the finer objects, the latter ones that lie in the boundary area between two classes could be manually reassigned to the appropriate land cover class. The procedure is time effective and provides a most recent thematic map of the area.

In the first case the rule tree of the spectral and spatial criteria can be used to classify a wider area. In the second case the rule tree must be established in order to extrapolate the classification to a wider area.

This work has followed the classification flow diagram of the first case. The DELPHI 2 eCognition classification process begun with the segmentation of the available twelve channels in small objects. The statistic of each object and the selection of representative training objects for each class dictated the selection of the appropriate spectral criteria (ATM channels, channel standard deviations) for the imagery classification. The second classification step was to segmentate the imagery in a coarser object level. Hierarchy and spatial rules were adopted. They acknowledged the existence of the previous classification result and related the spatial location of the small objects with this of the coarser ones. Form and topology statistics were used in this step. Fine tuning was accomplished by using fuzzy membership functions in the spatial rule institution. Finally, the derived classified objects were fused according to their class belonging.

The two classification results (ISODATA & eCognition) were then compared with the existing land cover thematic map (ground truth data) (fig. 1A & 1B).

Method extrapolation for precision farming purposes (status assessment). The possession of a thematic map of the administrative boundaries of the plots, either as a classification result or as an existing one, comprises the initiation point for the status assessment phase. By the use of the DELPHI 2 eCognition object oriented method exists the opportunity to use vegetation indices and channel ratios to delineate spots inside a plot showing differences in their canopy vitality status. These vegetation indices and/or ratios could be inserted in the assessment process at the beginning of the classification procedure, before the segmentation one, as image layers. The inserted layers can be weighted between one and zero. Regardless of the assigned weight in the segmentation procedure the information that all image layers possess is kept and condensed in each object's attribute table.

In this work hierarchy rules accompanied with NDVI (Normalized Differentiation Vegetation Index) fuzzy scaling criteria are used in a fine object level to "subclassify" the field in it's non homogeneous sites (fig. 2). Three NDVI

qualitative subclasses for each land cover class are created, namely ndvi 1, ndvi 2 and ndvi 3 for low, average and high canopy vitality, respectively (over a NDVI scale from 0-255) (Manakos, 1999).

The ISODATA cluster database structure do not possess such a flexible data manipulating and storage concept that could automatically deal with the challenge of further status assessment. In this occasion, namely, dealing with the precision farming requirements.

3   RESULTS

Both segmentation methods manage to condense the information of the image layers into pixel aggregations. The difference in handling image data (pixel versus object oriented method) reflects in the resulted features and information that accompany each meaningful pixel aggregation, as well as in the potential for further data assessment.

3.1   ISODATA classification results

The formatted clusters comprise the statistic information of the pixels that they consist. The clusters were assigned to numbers and an effort was carried out to manually substitute the numbers with land cover classes. Field unevennesses and wide standard deviation of the spectral mean inside a field did not allow the assignment of a cluster to a land cover class in most cases, but to more than one (fig. 1A). Mixed classes appeared. The field of a vegetation type is not always recognised to belong entirely or mostly to a cluster. Clear boundaries are difficult to be delineated. The procedure stopped here, the ability to work inside an automatically recognised field in order to focus on and classify unevennesses was not available.
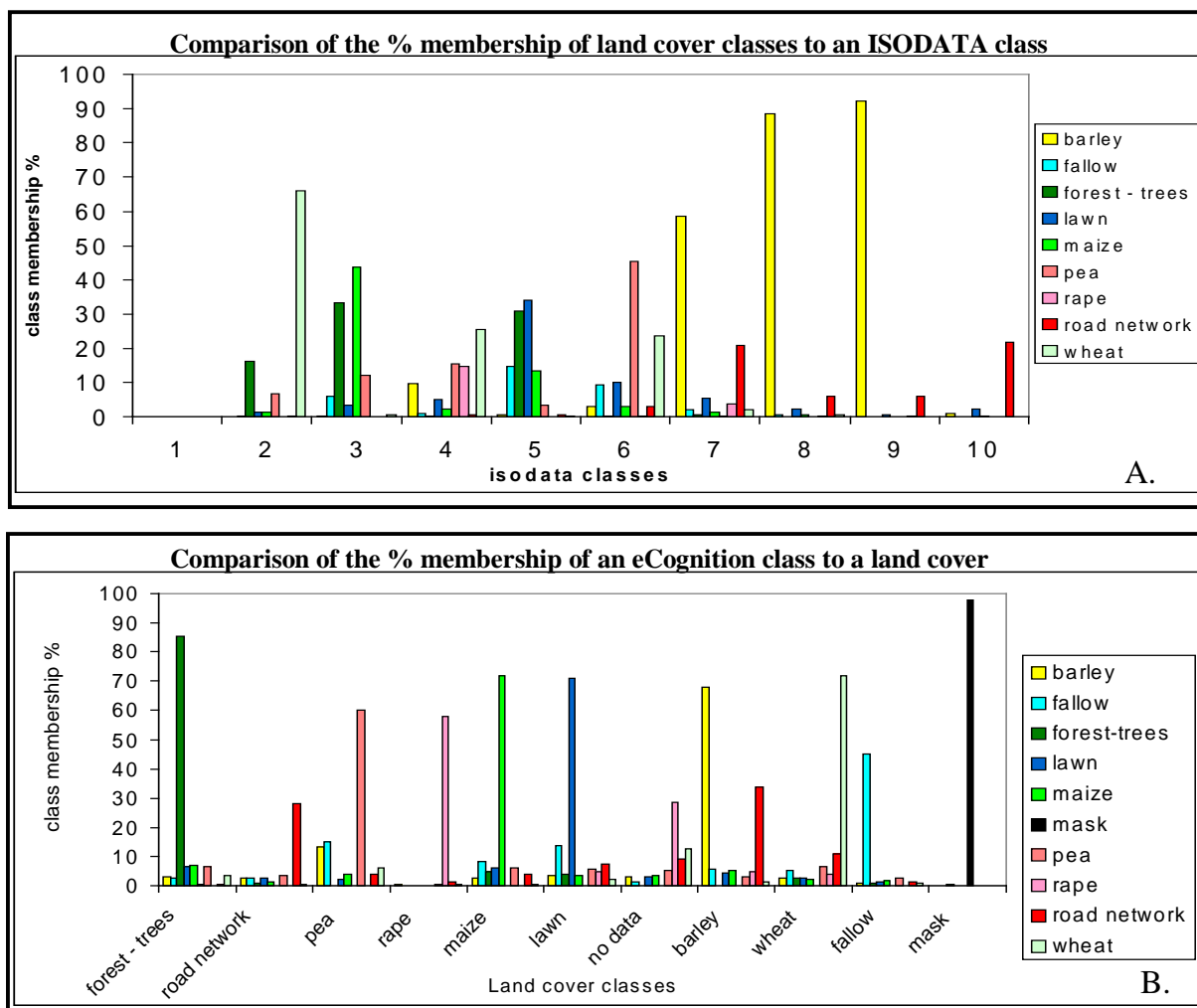

Figure 1. Success of the ISODATA and the DELPHI 2 eCognition classification methods to distinguish the land cover classes.

The percentages of class assignment were kept low and the mixed classes problem dominated the result. For example 66% of the pixels aggregated in cluster 2 belong to the wheat land cover class. At the same time around 25% of the pixel assigned to clusters 4 and 6 belong also to the wheat land cover class. The classes forest - trees, lawn, fallow, pea and road network, followed the same schema, namely pixel distribution in two or three clusters, where at the same time in each of these clusters other land cover classes were fluctuating at almost same or competent percentages. So, it could not be said that two specific clusters describe, if fusioned, a unique land cover class. On the contrary, barley seems to be described from the 7th, the 8th and the 9th clusters. A fusion of these clusters could lead to good results for barley, although that there is a 21% membership of the road network land cover class in cluster 7. Generally, it could be said that the ISODATA results did not allow land cover class discrimination either because a class belonging was distributed among more than one clusters or because one cluster described well more than one classes.

3.2   DELPHI 2 eCognition classification results

The DELPHI 2 eCognition classification method succeeded in most cases to achieve a high percentage of right land cover class assignment. Linear features, as road network delineation, suffered under a lower classification success (mixed class occasion). The road network class in particular was often confused with the classes of wheat, fallow, barley or lawn. Comparing with the ground truth data DELPHI 2 eCognition succeeded to assign with a percentage of almost equal or greater than 70% the forest-trees, maize, lawn, barley and wheat classes (fig. 1B). Pea and rape classes were almost at 60% successful assigned to the real land cover class. Fallow class was often misinterpreted as pea or lawn and in less occasions as maize, barley or wheat. In case of the area where ground truth data were missing (no data land cover class) rape or wheat seem to be the best candidates for the assignment. Interesting is the fact that the mask was classified up to 98% as mask and not 100% as expected. This should be resulted from the use of fuzzy membership functions in the classification procedure.

The resulted land cover classes contained the spatial features and topology information for the objects that they consisted of. These enriched the spectral features in the accompanying attribute table.

3.3   Extrapolation results for precision farming purposes

Using the DELPHI 2 eCognition capabilities, the land cover thematic map and the NDVI image layer provided the spectral and spatial rule sequence to classify non homogeneous sites inside a plot according to the vegetative status, while respecting the land cover class boundaries. The application of the spectral and spatial rule sequence took place in a part of the area under investigation as presented in fig. 2.
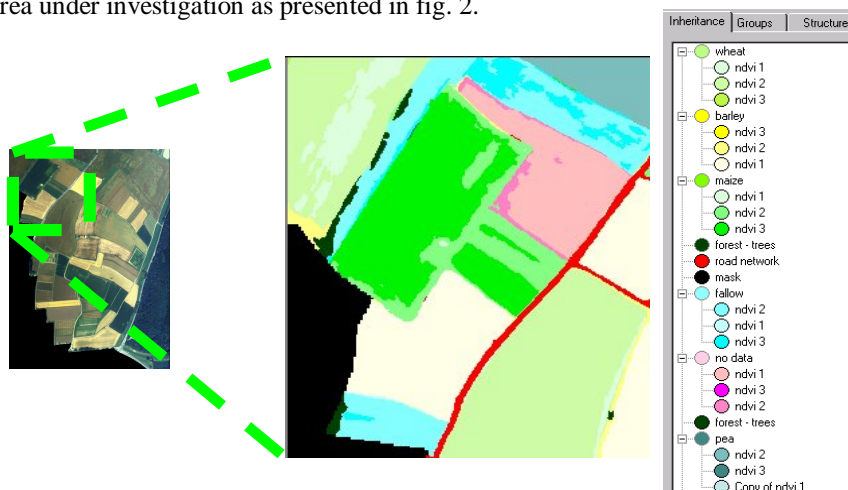

Figure 2. Classification of the non homogeneous spots in the fields according to canopy vitality status criteria.

At the date of image registration barley fields were either recently harvested or ready to be harvested. This reflects at the classification to the lower canopy vitality indicator (ndvi 1). Wheat was at the ripening phase and starting to become yellowish, which is indicated by the maximum classification to ndvi 2 and the delineation of subareas belonging to ndvi 1. Maize was growing (beginning of flowering growth stage) and that is why most of the field was classified in the higher vitality scale (ndvi 3). Growth problems were delineated and assigned to ndvi 2 and ndvi 1. Fallow fields showed also growth differences as far as the vegetative status is concerned, which was expected.

4   CONCLUDING REMARKS

In this paper two different classifications methods, ISODATA and eCognition, were tested in the frame of land cover detection and discrimination. Main focus was on agriculture and especially on the requirements of precision farming, namely, identification of land cover classes, delineation of land cover class boundaries and status assessment inside a plot. DELPHI 2 eCognition object oriented classification method showed better results than the ISODATA pixel based one, as far as the discrimination of land cover classes and boundary depiction is concerned.

Concerning the challenge of status assessment inside a land cover class, eCognition classification method demonstrated the better potential and adaptability. Canopy vitality status classes are generated inside each plot. By the use of the resulted class borders or of existing land cover boundaries it was managed to go further in spotting the non homogeneous sites inside a plot. The available land cover boundaries were integrated in the classification procedure. Then the imagery was assessed finer respecting these boundaries. NDVI was used providing a canopy vitality criterion. This case necessitates a flexible data manipulating and storage concept. The latter has to do with the base concept of the classification method and the unfoldment of this concept in this method. Not only precision farming could benefit from this process, but crop damage monitoring and yield estimation processes as well.

The spectral and spatial information extracted from the classification and status assessment analysis can be automatically transfered or incorporated into a decision making system (Buck, 1999), which could be especially designed for precision farming purposes (Auernhammer et al., 1999; Linseisen et al., 2000). This capability originates from the fact that the DELPHI 2 eCognition results have to do with the existence of meaningful objects that contain information about their geographic location and orientation.

Another attractive perspective of DELPHI 2 eCognition is that the available features and tools, which enabled the construction of the spectral and spatial rule classification flow diagram about the land cover classes, support also the automatical extrapolation and application of these rules to a wider area.

As far as the unsupervised ISODATA classification method is concerned, it's overall performance could be perhaps improved with more fine tuning of the input parameters. However, the heterogeneity factor inducted by the characteristic texture of colors of a land cover class is still neglected by the pixel based classification methods. This fact comprises an a priori disadvantage in the pixel based classification procedures. Moreover, the lack of topology features and the format of the data storage constitute obstacles for an automatical detailed status assessment.

To sum up, both classification methods managed to condense the image information into meaningful pixel aggregations.
- ISODATA clustering reached it's limits, as plot unevennesses and wide standard deviation of the spectral mean inside a plot did not allow successful assignments of clusters to land cover classes. Apart from this fact the condensing of the information into clusters and the format of data storage could not allow an automatical further data assessment or interaction with decision making rules.
- DELPHI 2 eCognition demonstrated a greater adaptability dealing with this challenge. Spectral and spatial features, topology information, compatible data storage format and object based managing of the data, accompanied with multilevel segmentation, context classification capability, ability of using hierarchy rules and fuzzy logic rule generation comprised meaningful tools that achieved a more successful land cover class detection. Furthermore, they enabled further status assessment in finer object domains while respecting class borders or administrative boundaries. Moreover, these characteristics allow an automatical incorporation of the spectral and spatial object based information into a decision making system.

A new perspective is arisen for applications dealing with land exploitation and nature preservation. The object based managing of the information simplifies interaction procedures with other information layers or databases. Particularly, in agriculture the internationally rising interest for site specific handling (precision farming) could be coped with the use and development of such a tool.

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