Object-Oriented Classification of Orthophotos to support update of Spatial Databases

F.P. Kressler, K. Steinnocher
ARC systems research
A-2444 Seibersdorf, Austria
florian.kressler;klaus.steinnocher@arcs.ac.at

M. Franzen
Federal Mapping Agency
A-1080 Vienna, Austria
michael.franzen@bev.gv.at

Abstract— **Interpretation of aerial images is normally carried out by visual interpretation as traditional classification routines are too limited in dealing with the complexity of very high resolution data. Segmentation based classifiers can overcome this limitation by dividing images into homogenous segments and using them as basis for further classification procedures. In this paper this approach is examined in view of its potential to support the update of existing land use data bases. A workflow was developed that allows the classification of high-resolution aerial images, the subsequent comparison with land use data and the assessment of identified changes. Special emphasis is put on the transferability of the procedure in terms of study area as well as image and land use data.**

Segmentation, Orthoimage, Classification, Human Settlement, Semi-automation, Change Detection, Databases

I. INTRODUCTION

Geospatial data such as cadastral maps are usually established and updated from aerial images by visual interpretation, a both time consuming and tedious task. With the advent of digital aerial images and improved analysis methodologies, semi-automated classification procedures can be an improvement both in terms of reliability as well as costs. Within the framework of EuroSDR (Spatial Data Research) the project ‘Change Detection’ was initiated to examine the update of geospatial data on the basis of digital remote sensing images, supported by semi-automated classification methodologies. Partners from Austria, Belgium, Denmark, Finland, Germany, Ireland, Switzerland and Turkey provided samples of their databases to allow an analysis whether the proposed procedure can fit the different data sets.

The automated or semi-automated analysis of high resolution images has been hampered by the high complexity of such images. Traditional pixel-based classifiers such as Maximum Likelihood very often lead to an undesired speckle effect [1] as they only look at one pixel at a time without considering its spatial context. Object based classifiers deal with this problem by segmenting an image into homogenous segments prior to any classification [2]. Classification is based on features calculated for each segment. These features not only draw on spectral values but may also be related to size, form, texture, neighborhood, previous classifications, and so forth. It can be seen that now much more complex classifications can be carried out, better suited to deal with very high resolution data. Although a number of object-based classification experiments have been performed (e.g. [3] and [4]), the number of applications using orthophotos is limited.

Aim of this study was to develop a classification procedure for very high resolution orthophotos to support the update of existing land use data bases. As land use classes are often defined by their function rather than properties that can be observed in an image, emphasis is put on showing where changes might have taken place, leaving confirmation of these changes, determination of correct boundaries and assignment of appropriate labels to the user. Development of the classification procedure was based on real-color orthophotos from Austria. In a next step the procedure was tested on data from Denmark, Germany and Switzerland. Although both images as well as land use data are quite different from those used for Austria, the procedure could be adapted very easily to suit the new data sets.

II. DATA SETS AND STUDY AREAS

For the development of the methodology 15 real color orthophotos from 2004, recorded over the towns of Weinitzen and Wenisbuch near Graz, Austria were used. Each orthophoto covers 1.25 x 1 km with a spatial resolution of 25 cm. The Digital Cadastral Map was used as reference data. This data set comprises 34 classes, 21 of which were present in the study area. In addition data sets from Switzerland, Germany and Denmark were examined (see Table 1). For Switzerland 3 real color orthophotos (spatial resolution 0.5 m) recorded in 1998 and reference data from 1993 were available, covering 3 x 3 km each. The reference data stems from the Digital Landscape Model of Switzerland. For Germany one real color orthophoto with a spatial resolution of 0.4 m, covering 2 x 2 km with reference data from the ATKIS (Amtliches Topographisch-Kartographisches Informationssystem) data base were provided and from Denmark two orthophotos (one real-color, one with infrared) with a spatial resolution of 0.5 m, covering 1 x 1 km and reference data were made available.

TABLE I. ORTHOPHTOS AVAILABLE FOR EACH COUNTRY

Country	Spectral *	Size (km) per image	Spatial (m)	Number of images
Austria	RGB	1.25 x 1	0.25	15
Denmark	RGB/IR	1 x 2	0.50	1
Germany	RGB	2 x 2	0.40	1
Switzerland	RGB	3 x 3	0.50	3

* RGB red, green, blur; IR near infrared

III. SEGMENTATION, CLASSIFICATION, COMPARISON

The workflow of the analysis can be divided into the three steps: segmentation, classification and comparison. It was developed using the software eCognition from Definiens. Segmentation involves grouping neighboring pixels into homogenous segments. The degree of homogeneity is governed by the parameters scale, color, shape, compactness and smoothness [5], allowing the procedure to be adjusted to fit different data sets and applications. Any segmentation based classification can only be as good as the underlying segmentation. Inaccuracies encountered here cannot be corrected at a later stage. In order to make the routine transferable from one data set to another a trade off has to be made between how many segmentation layers are created and how finely the parameters are tuned to arrive at the desired results. For the analysis the initial segmentation is carried out on 2 levels (see Table 2). Depending on the spatial, spectral and radiometric resolution different segmentation parameters were applied to each data set. Scale varies on level 1 between 35 and 45. Shape and color have been given equal weights of 0.5. The shape parameter is further defined by compactness and smoothness and here compactness is given with 0.9 considerable more weight than smoothness. Level 2 is created by merging existing segments of level 1 based on the absolute spectral difference. This value varies between 5 and 15, being very dependent on the radiometric quality of the data. This allows the merging of large homogenous objects, such as fields and grassland, while keeping other objects separate such as houses from the surrounding gardens. A third segmentation takes place after the initial classification. Here the borders of the segments are defined by the classification on level 2.

In eCognition classification can be carried out either by a nearest neighbor classifier or by fuzzy functions defined for selected features calculated for each segment. These features can relate to spectral values, shape, texture, hierarchical and spatial relations. Even though a rule based system is more time consuming to create it is given preference over the nearest neighbor approach as it allows more control over the classification process and can be more easily adapted to fit new data. During the classification each image segment is assigned to one (or no) class. With the assignment of a class to an image object, the relations to other classes formulated in the specific class description are transferred to the image objects. The result of the classification is a network of classified image objects with corresponding attributes. The following classes were defined for the Austrian data set: vegetation (further divided into forest and meadow), shadow, water, fields, bright objects, red roof, grey roofs and other urban objects. The features were selected in such a way so that they can be easily adjusted to fit new data sets.

TABLE II. SEGMENTATION PARAMETERS FOR LEVELS 1 AND 2

Country	Level 1			Level 2
	Scale	***Shape/ Colour***	***Compactness/ Smoothness***	***Spectral Difference***
Austria	35	0.5/0.5	0.9/0.1	10
Denmark	35	0.5/0.5	0.9/0.1	15
Germany	45	0.5/0.5	0.9/0.1	7
Switzerland	45	0.5/0.5	0.9/0.1	7

TABLE III. FEATURES USED FOR CLASSIFICATION ON LEVEL 2

Class	**Features used**
Vegetation	Ratio Green; Brightness
Forest	Brightness; Standard Deviation Green
Meadow	Not *Forest*
Shadow	Brightness
Field	Area; Brightness; Number of sub-objects; Ratio Red
Bright Object	Brightness
Red Roof	Ratio Red
Grey Object	Brightness; Mean
Other urban object	Not *Grey Object*

At the lowest level the class hierarchy could be limited to the classes vegetation, shadow, fields, urban and water. But preference was given to a more detailed classification, as it allows a subsequent refinement of the classification such as the correction of fields wrongly classified as red roofs. From this follows that the classification is performed in two stages, one where each segment is assigned to one of the classes, a second where the classification is refined and unwanted artifacts removed. For the second stage a new segmentation is performed on the basis of the initial classification, i.e. the borders of the segments on the new layer are defined by the classification boundaries for each class. Classification refinement is then carried out on the basis of neighborhood operations. The result is then the basis for the comparison with the reference data.

Table 3 gives an overview over the types of features used for each class. Depending on the type of land cover present in an image the class hierarchy has to be adjusted e.g. to account for water bodies. The parameters were chosen in such a fashion as to allow an easy adjustment to data from different sources. Depending on the radiometric correction performed on the data, no or hardly any adjustments have to be done to classify images from one data set. Most classes are defined by parameters derived from spectral values such as brightness, ratio and standard deviation. Only fields are also defined by other features such as area and number of sub-objects. Streets were not defined as a separate class but are assigned to whatever urban class the fall into depending on the type of surface used. In this strictly hierarchical classification non-urban features such as vegetation and fields are classified first and if the differentiation were only to emphasis urban/non urban objects the classification could be considered finished with the class *Not Fields*. However, in order to allow refinement of the classification, remove unwanted artifacts and allow a better comparison with the reference data, the urban classes are differentiated further.

Aim of the analysis is to highlight those areas where changes are likely to have taken place. Depending on the number of classes and the spatial aggregation level of the reference data the number of classes can be very different compared to those of the classification. For this reason comparison is carried out on the basis of plausibility as opposed to creating change/no change map. Depending on which class is present in the reference data and which in the classification, a segment is either assigned to the class *identical*, *plausible*, *questionable* or *new*. *Identical* are those class combination which indicate that the reference data and the classification show the same kind of class e.g. reed roof in the classification and building in the reference data. *Plausible* are those combinations that do not directly agree but very likely do not indicate change e.g. meadow in the classification and arable land the reference data. The term *questionable* refers to doubts whether, based on the classification, the reference data is correct. An example is grassland in the classification and road in the reference data. As grassland can usually be identified very well the reference data must be put into question. Loss of built up area falls into this class as well. *New* are all those combinations that are an indication of building activities such as grassland in the reference data and bright object in the classification.

IV. Results

In the following section the results for the Austrian study area will be presented. In addition first experimental results for the other data sets will be discussed. A subset from one orthophoto was selected to allow a more detailed analysis although the procedure was applied to all 15 orthophotos. As described in section III segmentation was performed on two levels. Fig. 1 shows the subset of the Austrian orthophotos with segmentation level 2 overlaid in magenta. The initial classification was performed on level 2 using fuzzy functions drawing on features calculated for each segment as defined for each class within the class hierarchy. As some segments can be wrongly assigned a new segmentation level, based only on the existing classification, was created. Using neighborhood functions unwanted artifacts such as shadows in forest as well as incorrectly assigned segments in bare fields were corrected. The corrected classification for the subset is shown in Fig. 2. Segments assigned to either *red roof* (red), *bright objects* (magenta), *forest* or large trees (dark green), *grey objects (*cyan), *meadow* (light green), *other urban objects* (yellow), *fields* (orange) or *shadow* (black). When the classification is compared to the original image it can be seen that all urban features have been assigned to an urban class. Depending on the type of roof, houses are either classified as individual objects or blend in with the surrounding area: As the main emphasis is on the differentiation of urban and non-urban objects this does not represent a disadvantage.

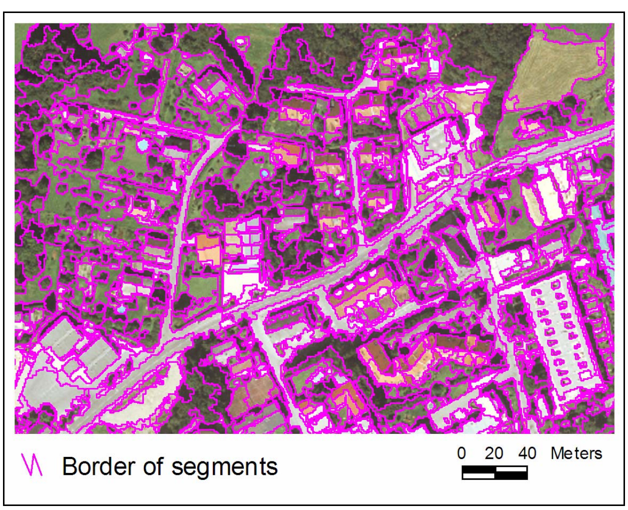

Figure 1. Segmentation Level 2

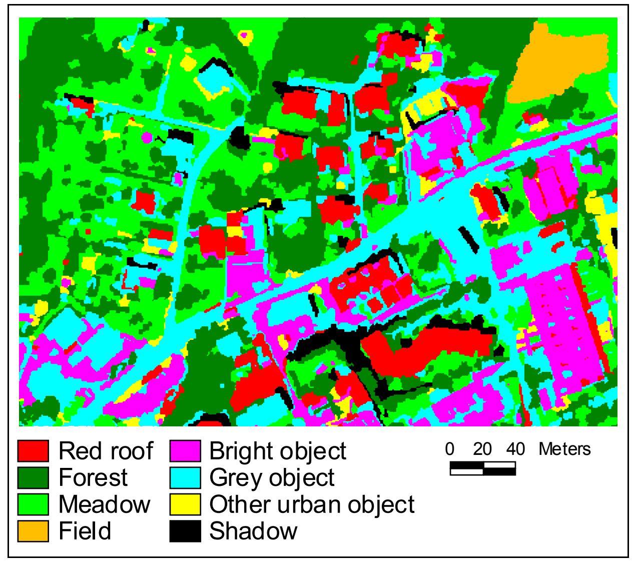

Figure 2. Corrected classification of subset

The next step is the comparison with the reference data to highlight where changes have taken place. Fig. 3 shows a subset of the cadastral map. Buildings (red) are depicted as individual houses, unsealed building plots (yellow) are most dominant with very few sealed building plots (magenta). Roads are shown in black, bare land in cyan, agricultural areas in orange, meadows in light green and forests in dark green. A visual comparison with the orthophoto shows that some building activities have taken place. To show the location and nature of these changes an evaluation matrix was applied to the classification and the reference data. The result is a change map comprising four classes: *identical* (green), *plausible* (yellow), *questionable* (blue) and *new* (red) (see Fig. 4). A visual comparison shows that all changes were correctly highlighted. The methodology tends to overestimate change, which is often due to the fact that the assignment of an area to a class in the reference data is not only based on land cover but also on historical or legal reasons.

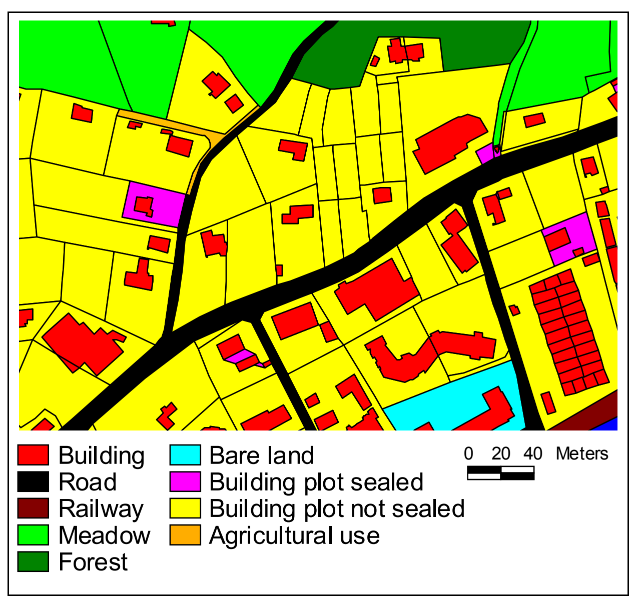

Figure 3. Subset of cadastral map

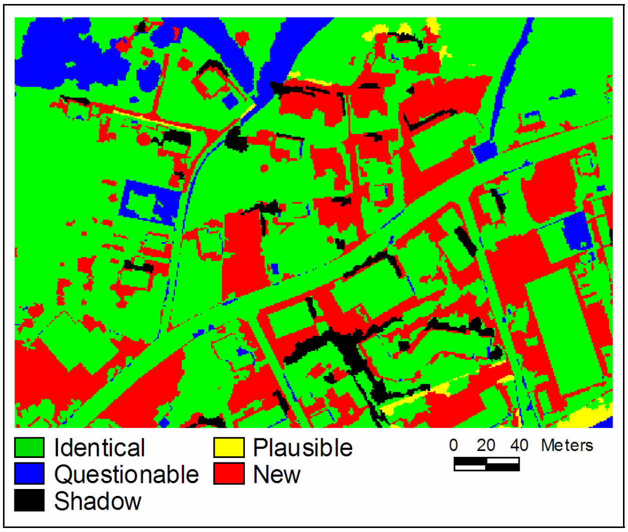

Figure 4. Evaluation of classification and reference data

The fact that certain areas are assigned to building plot sealed and others to building plot not sealed cannot be derived from the images alone. Discrepancies are highlighted both by the classes *new* (e.g. sealed areas on unsealed building plots) and *questionable* (e.g. meadow on sealed building plots). Other questionable segments appear were areas that are supposed to be covered by meadow are covered by forest. Information as shown in Fig. 4 can be the basis for updating the cadastral map both by updating the data base due to actual changes on the ground as well as by correcting inconsistencies.

The procedure described above was not only applied to all 15 orthophotos of the Austrian data set but experiments were also carried out on data provided by institutions from Denmark, Germany and Switzerland. These data were selected as they contain either real color or infrared orthophotos, which is a prerequisite for the procedure. The class hierarchy and evaluation matrix were adjusted to fit the land cover and classes present in the reference data. First results show that when using either infrared or real color images, even though an infrared band makes it easier to avoid some misclassifications, having a high radiometric resolution is most important. In most cases the same features could for the classification as originally defined and only some parameters had to be adjusted. The strict hierarchical approach makes it easy to adjust them and arrive at a satisfactory result. Differences in spatial resolution (ranging from 0.25 to 0.5 m) were no issue and no consistent changes had to be made to the segmentation parameters, being very much governed by the radiometric quality. Reference data had in general far fewer classes and thus a higher aggregation level than that of the Austrian cadastral map, but as the comparison is based on plausibility this presented no disadvantage.

V. Conclusion and Outlook

The use of high-resolution aerial images for the update of land use data bases is usually limited to visual analysis. Automated or semi-automated classification routines are often hampered by the complexity of the data. In this paper a workflow is described that, on the basis of an object-based classifier, allows the analysis of very high resolution orthophotos with the aim to show where changes have taken place. These changes are then evaluated on the basis of plausibility and the update of reference data can concentrate on those areas where building activities or other discrepancies have been highlighted. The classification routine was designed to ensure that very few changes have to be made when moving from one data set to another, either land use data or orthoimagery. This is even true when using data from different sensor types such as real color and infrared imagery. In order to examine the transferability from one data set to another, first experiments were carried out on data sets from four European countries, confirming the adaptability of the procedure. Based on the available results, the potential of using an object based classification procedure to support the update land use data bases can be considered very high, especially as it can be easily adapted to suit different kinds of orthoimagery as well as land use data bases. Further work will be carried out to test the procedure in a real-working environment and have its usability evaluated by the different institutions involved in this project.

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