SEGMENTATION BASED CLASSIFICATION OF AERIAL IMAGES AND ITS POTENTIAL TO SUPPORT THE UPDATE OF EXISTING LAND USE DATA BASES

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ABSTRACT:

The interpretation of aerial images is normally carried out by means of visual interpretation as traditional classification routines are too limited in dealing with the complexity of very high resolution data. Segmentation based classifers 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.

KURZFASSUNG:

Luftbilder werden in der Regel visuell ausgewertet da traditionelle Klassifikationsverfahren nicht geeignet sind, mit der hohen Komplexität hochauflösender Daten umzugehen. Segmentbasierte Verfahren umgehen dieses Problem, indem sie vor einer Klassifikation ein Bild in homogene Segmente unterteilen, die dann als Basis für die Klassifikation dienen. Hier wird dieses Verfahren in Hinblick auf seine Eignung, die Aktualisierung bestehender Landnutzungsdaten zu unterstützen, betrachtet. Ein Verfahren wurde entwickelt, dass die Klassifikation hochauflösender Luftbilder, einen Vergleich mit bestehenden Landnutzungsdaten und eine Bewertung der gefunden Veränderungen erlaubt. Besonderen Wert wurde auf die Übertragbarkeit des Verfahrens auf andere Untersuchungsgebiete, Bild- und Landnutzungsdaten gelegt.

1. 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 (Willhauck, 2000) 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 (Baatz and Schäpe, 2000). Subsequent 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, neighbourhood, 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 applications have been carried out (e.g. Meinel et al., 2001 and Herold et al., 2002), the number of applications using high resolution othophotos only has been very limited. Aim of the study is 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 ortho imagery 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.

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2. DATA SETS AND STUDY AREAS

For the development of the methodology 15 real colour orthophotos from 2004, recorded over the towns of Weinitzen and Wenisbuch near Graz in Austria were used. Each orthophoto covers 1.25 x 1 km with a spatial resolution of 25 x 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 in this study (see Table 1).

Country	Spectral*	Size (km)	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, blue; IR near infrared

Table 1, Orthophotos available for each country

For Switzerland three real colour orthophotos recorded in 1998 and reference data from 1993 were available. The spatial resolution of the orthophotos is 0.5 m and cover 3 x 3 km each. The reference data stems from the Digital Landscape Model of Switzerland. For Germany one real colour orthophoto with a spatial resolution of 0.4 x 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-colour, one with infrared) with a spatial resolution of 0.5 x 0.5, covering 1 x 1 km and reference data were made available. The data sets are all different in terms of sensor system used, spatial resolution, reference data and type of area covered.

3. 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.

3.1 Segmentation

Segmentation involves grouping neighbouring pixels into homogenous segments. The degree of homogeneity is governed by the parameters scale, colour, shape, compactness and smoothness (Benz et al., 2004), 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 colour 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.

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 2, Segmentation parameters for levels 1 and 2

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. Level 3 is used to improve the classification and remove unwanted artefacts

3.2 Classification

In eCognition classification can be carried out either by a nearest neighbour classifier, using selected segments as training samples to define the different classes, 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 neighbour approach as it allows more control over the classification process and can be more easily adapted to fit new data. A class hierarchy (see Figure 1) formulates the knowledge base for classifying image objects and contains all classes in a hierarchically structured form.

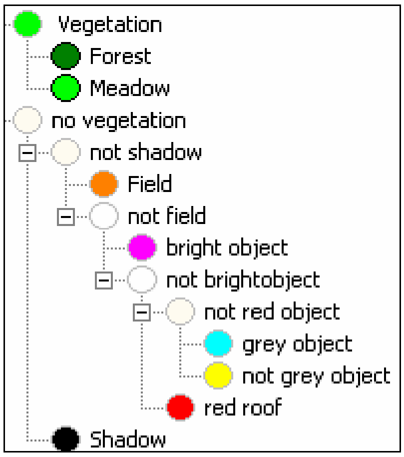

Figure 1, Example of class hierarchy

After the classification each image object is assigned to a certain (or no) class and thus connected with the class hierarchy. 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 and clearly defined relations to each other as well a to the classes in the class hierarchy. For the classification the number of classes is dependent on the scene.

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 that they can be easily adjusted to fit new data sets. Streets are not an individual class but are classified as one or more of the urban classes. 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 artefacts 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 neighbourhood operations. The result is then the basis for the comparison with the reference data.

Table 3 gives an overview over the types of features for 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.

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*

Table 3, Features used for classification on level 2

Most classes are defined by parameters derived form 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 (see also Figure 1) 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 artefacts and allow a better comparison with the reference data, the urban classes are differentiated further.

3.3 Comparison

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 change 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 would also fall into this class.

Reference Data \ Classification	Forest	Meadow	Field	Red roof	Bright object	Grey object	Other urban object
Field	questionable	identical	identical	new	new	new	new
Railway	plausible	plausible	plausible	identical	identical	identical	identical
Building plot sealed	questionable	questionable	questionable	identical	identical	identical	identical
Building plot not sealed	identical	identical	identical	new	new	new	new
Bare land	identical	identical	identical	new	new	new	new
Recreational area	plausible	identical	identical	plausible	plausible	plausible	plausible
Market garden	identical	identical	identical	plausible	plausible	plausible	plausible
Building	questionable	questionable	questionable	identical	identical	identical	identical
Water	questionable	questionable	questionable	questionable	questionable	questionable	questionable
Water stagnant	questionable	questionable	questionable	questionable	questionable	questionable	questionable
Extensively used meadow	questionable	identical	identical	new	new	new	new
Yard	plausible	plausible	plausible	identical	identical	identical	identical
Agricultural use	plausible	identical	identical	new	new	new	new
Wasteland	identical	identical	identical	new	new	new	new
Other	plausible	plausible	plausible	plausible	plausible	plausible	plausible
Street	questionable	questionable	questionable	identical	identical	identical	identical
Orchard	identical	plausible	plausible	new	new	new	new
Forest	identical	plausible	plausible	new	new	new	new
Pasture	questionable	identical	identical	new	new	new	new
Vineyards	questionable	plausible	identical	new	new	new	new
Meadow	questionable	identical	identical	new	new	new	new

■ identical ■ plausible ■ questionable ■ new

Table 4, Comparison of reference data and classification as used for Austrian data set

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.. Table 4 shows the evaluation matrix as applied to the data from Austria. The rows represent the classes of the cadastral map present in the study area, the columns those of the classification. Green are those class combinations that are considered *identical*, yellow those that are *plausible*, blue are *questionable* and red those that are considered *new*. It can be seen that all classified classes referring to urban structured are evaluated in the same manner.

4. RESULTS

In the following sections results for the Austrian study area will be presented. In addition first experimental results for the other data sets will be discussed.

Figure 2, Subset of orthophoto from Austria

A subset (see Figure 2) from one orthophoto was selected to allow a more detailed analysis although the procedure was applied to all 15 orthophotos.

4.1 Segmentation

As described in section 3.1 a segmentation was performed on two levels. Figure 3 shows a subset of the Austrian orthophotos with segmentation level 1 overlaid in magenta. While the different land cover types are well separated, larger objects such as roads and fields are divided into numerous segment. In order to merge these together while keeping objects such as house separate, a second segmentation is performed based on colour difference alone.

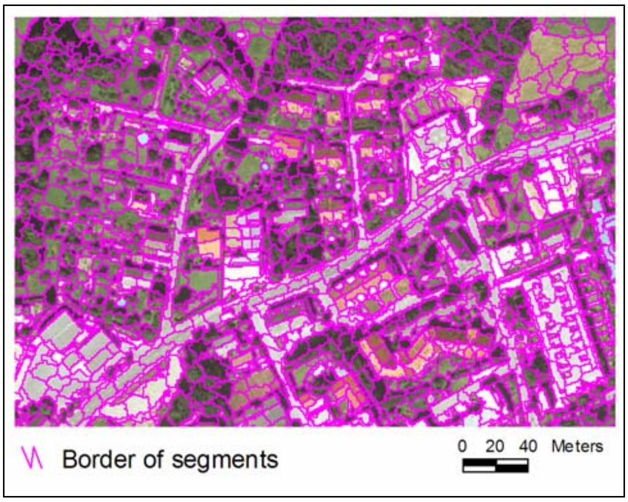

Figure 3, Segmentation Level 1

Figure 4 shows the results of segmentation level 2. It can be seen that while roads, fields and larger houses have been merged into larger segments, segments with high contrast to the surrounding have not been affected by this procedure.

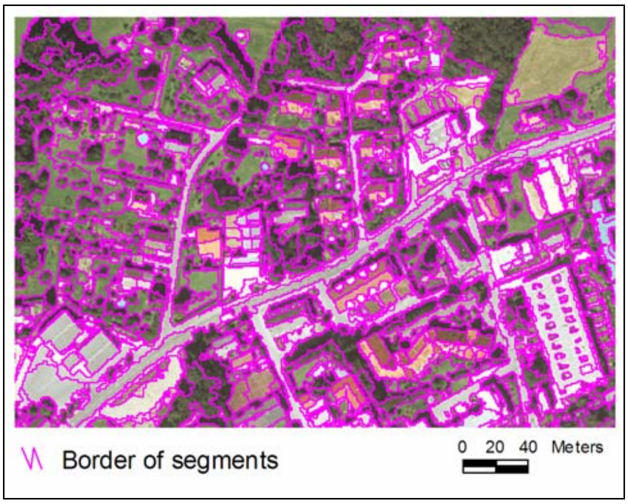

Figure 4, Segmentation Level 2

Classification is carried out on level 2, although some references are also taken from level 1.

4.2 Classification

The classification on level 2 (see Figure 5) was carried out by using fuzzy functions drawing on features calculated for each segment as defined for each class within the class hierarchy. Segments assigned to the class *red roof* are shown in red, *bright objects* in magenta, *forest* or large trees in dark green, *grey objects* in cyan, *meadow* in light green, *other urban object* in yellow, *fields* in orange and *shadow* in black. It can be seen in that all sealed areas have been correctly identified, although some misclassifications remain in agricultural areas. In order to correct these misclassifications as well as shadows in forests, a new level is created by a segmentation based only on the existing classification.

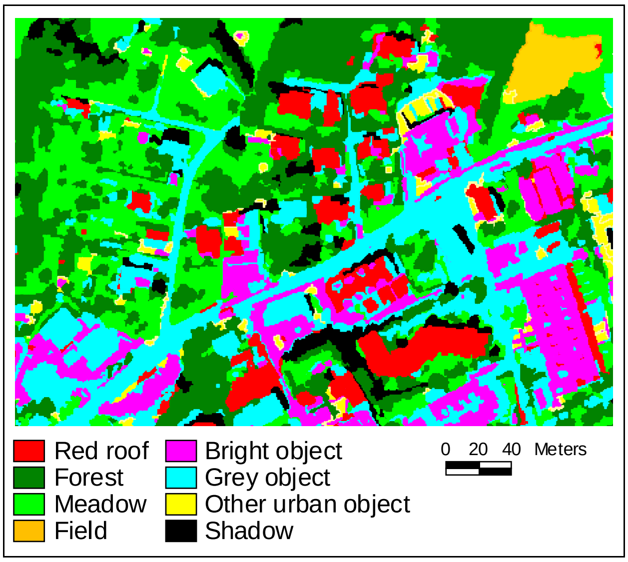

Figure 5, Classification on level 2 of subset

On this new level unwanted artefacts are corrected using neighbourhood functions, e.g. a segment classified as red roof but bordering mostly to fields is very likely a field and thus classified. In addition shadows in forested areas are corrected. The corrected classification for the subset is shown in Figure 6.

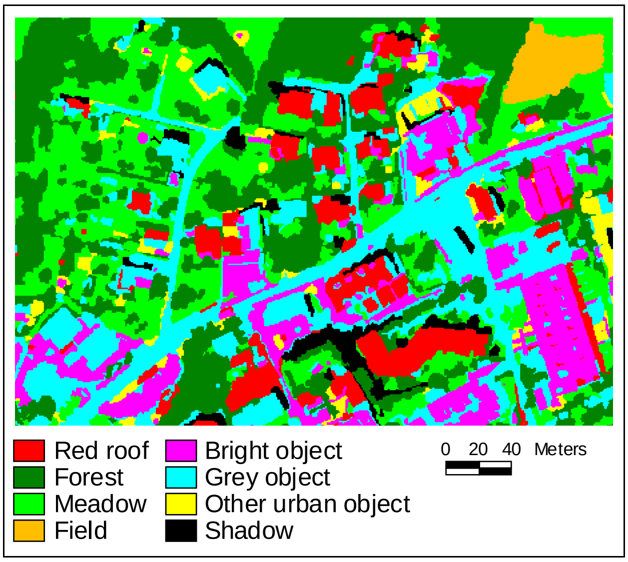

Figure 6, Corrected classification of subset

When the classification is compared to the original image it can be seen that all urban features have been assigned to one of the urban classes. 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 any disadvantage.

4.3 Comparison

The next step is the comparison with the reference data to highlight where changes have taken place. Figure 7 shows a subset of the cadastral map. Buildings (red) are depicted as individual houses, not sealed building plots (yellow) are most dominant with very few sealed building plots (magenta). Roads are shown in black, bare land in cyan, areas reserved for agricultural use in orange, meadow in light green and forest in dark green.

A visual comparison with the orthophoto (see Figure 2) already shows that quite a few building activities have taken place. In order show the location and nature of these changes and evaluation matrix (see Table 4) was applied to the classification and the reference data. The result is a change map comprising four classes (see Figure 8). Depending on the class combination segments are either assigned to the classes *identical* (green), *plausible* (yellow), *questionable* (blue) or *new* (red). Shadows (black) are present in the final result as no further information exists for those segments.

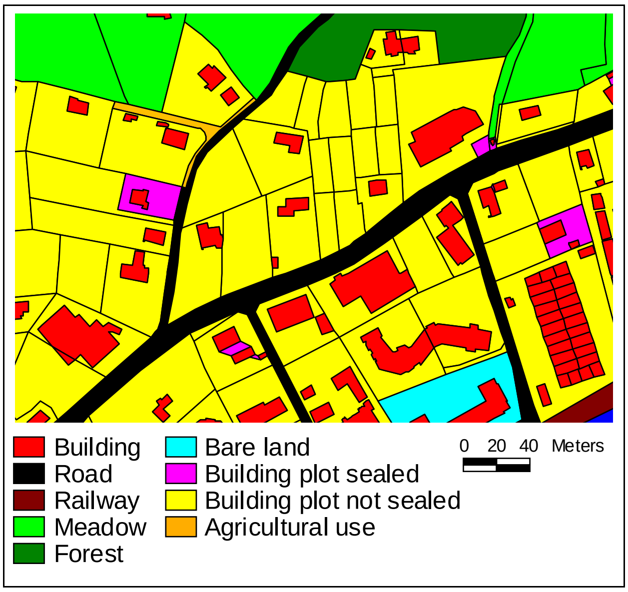

Figure 7, Subset of cadastral map

Based on a visual comparison between the orthophoto, the cadastral map and the evaluation all changes were correctly highlighted. It can also be seen that the methodology tends to overestimate change. This is very often due to the fact the assignment of an area to one class or another in the reference data is not only based on actual land cover but also on historical or legal reasons.

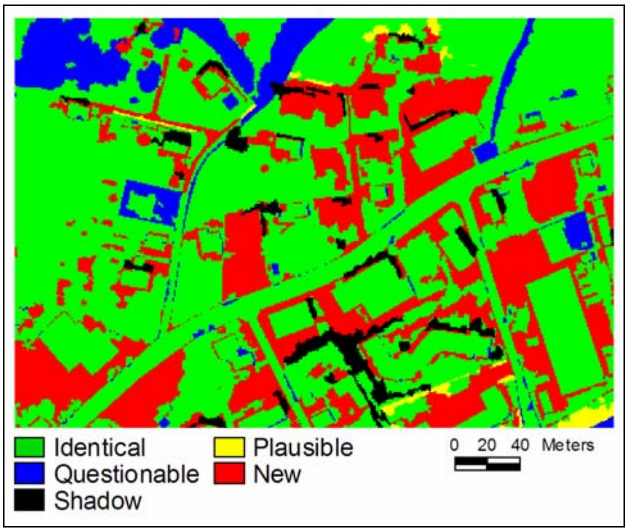

Figure 8, Evaluation of classification and reference data

The fact that certain areas are assigned to building plot sealed and others to building plot not sealed cannot be derived from the orthoimagery alone. Discrepancies are highlighted both by the class new (e.g. sealed areas on unsealed building plots) and the class 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 Figure 8 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.

4.4 Other Datasets

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 colour or infrared orthophotos, which is a prerequisite for the procedure. Class hierarchy was adjusted were necessary, i.e. it was extended to cover water bodies as well. In addition the evaluation matrix had to be adjusted to fit the classes of the different types of reference data. The first results of the analysis show that when using either infrared or real colour images, even though an infrared band makes it easier to avoid some misclassifications, having a high radiometric resolution is eve more important. The basic classes can be identified in all images and one a class hierarchy has been set up, the features defining each class can be used and only some parameters have to be adjusted. The strict hierarchical approach makes it easy to adjust these parameters and arrive at a satisfactory result. Differences in spatial resolution (ranging from 0.25 to 0.5 m) were no real issue and no consistent changes had to be made to the segmentation parameters, being very much governed by the radiometric quality of the data. 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 plausibility this presented no issue, even when in one data set (from Denmark) only houses were present.

5. 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. Object-based classifiers are better suited to deal with this complexity and offer a chance to support the update process. In this paper a workflow is described that, on the basis of a object-based classifier, allows the analysis of very high resolution orhtoimagery. Aim is to highlight those areas where inconsistencies with the existing land use data occur. These differences are evaluated on the basis of plausibility depending on the classes present in the classification and the reference data. The update of reference data can concentrate on those areas where building activities or other discrepancies have been highlighted.

The classification routine was designed in such a way, that very few changes have to be made to the classification hierarchy when moving from one data set to another. This is also true when using data from different sensor types such as real colour and infrared imagery. Depending on the quality of radiometric correction, no or only very little adjustments have to made to the parameters governing the classification. In order to examine the transferability from one data set to another, first experiments were carried out confirming that the procedure can be adapted to fit both different orthoimagery as well as reference data. 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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