Enhanced Semi-Automatic Image Classification of High-Resolution Data

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Abstract— With the launch of KOMPSAT-2 at the end of 2005 the availability of high resolution data should be greatly improved. The use of download facilities in Europe will allow increased coverage without interfering with the original mission of KOMPSAT-2. With platforms currently under development by the European Space Agency such as the Service Support Environment (SSE) and eoPortal larger audiences can be reached with different technical know-how. As these platforms go beyond mere data distribution but allow the implementation of applications this opens new possibilities but also poses new demands on application development. In this paper an object oriented classifier is used to derive basic land cover classes from high-resolution satellite image. The result is then integrated with vector data to identify different land user categories.

I. INTRODUCTION

KOMPSAT-2, to be launched at the end of 2005 with a spatial resolution of 1 m in the panchromatic and 4 m in the multispectral bands will have characteristics comparable to IKONOS-2. The use of download and dissemination facilities in Europe will allow a wide coverage and the development of applications aimed at a wider audience. New platforms such as the Service Support Environment (SSE)[1] developed by the European Space Agency (ESA) offer the possibility of making data and applications available to a wider audience with different levels of expertise.

Classification of high-resolution satellite images using standard per-pixel approaches is made difficult by the high complexity of the data, often leading to an undesired salt and pepper effect. One way to deal with this problem is to reduce the image complexity by dividing an image into homogenous segments prior to classification. This has the added advantage that segments can not only be classified on basis of spectral information but on a host of other features such as neighborhood, size, texture and so forth. In this paper the use of a segmentation based classifier for identifying basic land cover classes and subsequently land use classes from high resolution images is examined. Special emphasis is put on limiting the features used for land cover classification to make the procedure transferable to different data sets. In order to derive land use from the previous classification the results are integrated with vector data. The polygons defined by these data sets describe areas for which, based on the land cover composition, different land uses classes are derived. In order to examine the stability of the land use classification, the rules were applied to one coarse and one highly detailed vector data set. While segmentation based classification of high resolution satellite data has been examined in a number of papers, e.g. [1] and [2], per-parcel classification has been more limited [3].

II. DATA AND STUDY AREA

The study area lies in the North of the city of Vienna, Austria covering 4.9 x 4.9 km (see Fig. 1), for which one satellite image and two vector data sets were available. The satellite image was recorded by IKONOS-2 on 1st, June 2000 (see Fig. 1). The image shows a wide variety of land uses ranging form large scale industrial/commercial complexes to small individual houses with gardens. In addition large water bodies, fields and residential complexes are present. Clouds and their shadows obscure parts of the image.

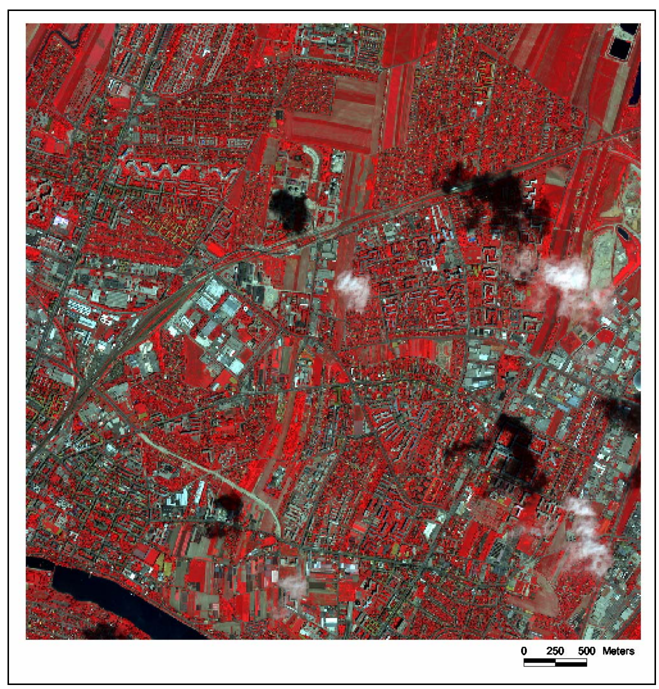

Figure 1. 432-false color composite of IKONOS scene

[1] http://services.eoportal.org/

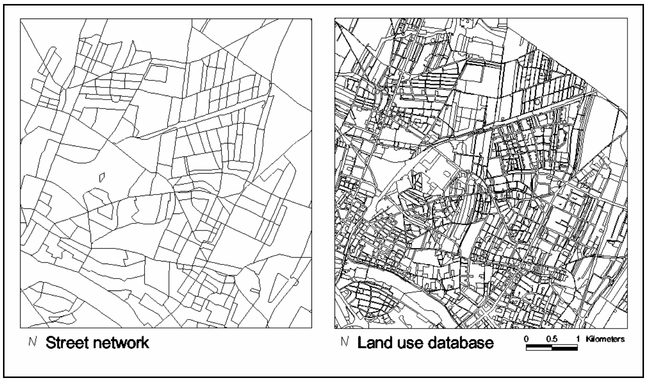

Figure 2. Vector data sets

KONOS records reflected light in four spectral bands, 0.45-0.52 µm (blue), 0.52-0.60 µm (green), 0.63-0.69 (red) and 0.76-0.90 (near-infrared) with a spatial resolution of 4 m and radiometric resolution of 11 bit. Except for the radiometric resolution these properties are similar to those of KOMPSAT-2. One vector data set is derived from a street network covering major roads, the other from a land use data base from the City of Vienna (see Fig. 2). While the street map is rather coarse, the land use data base is highly detailed, each polygon being defined by a unique land use. As both data sets were established independent of the satellite data and of each other, some minor discrepancies do exist.

III. SEGMENTATION AND CLASSIFICATION

The first step of the analysis is the identification of image objects. This is done by using the multiresolution segmentation approach as implemented in the software package eCognition [4]. Based on a number of parameters (scale, color, shape, smoothness and compactness) the image is divided into homogenous segments. The parameters govern size, shape and spectral variation within each segment. Starting with single pixel objects, they are merged into bigger ones using an iterative procedure. Each image objects "knows" its neighboring objects, making it possible to define relations between these objects. New segmentation levels can be created by merging or separating existing segments based on the above parameters. In addition segments can be merged using only spectral information allowing the delineation of large homogenous areas such as water bodies while keeping smaller objects such as houses with large spectral differences to their surroundings separate. The resulting segmentation layers are the basis of the subsequent classification.

For the classification a class hierarchy was created. In this hierarchy each class is defined by fuzzy functions drawing on features calculated for each segment. The available features range from spectral information, size, shape, neighborhood, texture to classifications on other levels and information from additional data set. Six basic land cover classes were defined, covering *urban*, *bright urban*, *forest*, *grassland*, *water* and *bare field*. *Cloud* and *shadow* were defined as well and all segments that could not be allocated to one of the above classes are assigned to *unclassified*. Table 1 gives an overview of the features used to define each class.

TABLE I. FEATURES USED FOR CLASSIFICATION

Class	Features used
Water	Ratio near infrared Standard deviation blue
Shadow	Brightness
Vegetation	Ratio near infrared
Forest	Standad deviation near infrared
Grassland	Not forest
Sealed	Not Vegetation Ratio near infrared Ratio red Standard deviation near infrared
Bright urban	Brightness
Bare field	Not cloud Not shadow Not urban Not vegetation Not water Not urban Brightness
Cloud	Brightness
Unclassified	Non of the above

Except for the classes *water* and *sealed* all classes could be described by using only one feature. In addition neighborhood operations were performed to correct some classification uncertainties, e.g. by assigning an *unclassified* segment bordering mostly to *urban* segments to the class *urban*.

While the result can be easily interpreted by a human operator to differentiate different types of land use classes such as residential, residential with garden, industrial, and so forth, this information is still only implicit in the classification. In order to make a move from land cover to land use the classification is integrated with vector data. The borders of the polygons form parcels for which different land uses can be derived based on the land cover composition. For the present example eight land use classes were defined based on the prevalence of different land cover types within a polygon. Table II gives an on overview of the definitions used for the classification which are all based on the relative area of the different land cover classes, thus ensuring the transferability to different vector layers. In addition to the eight land use classes, the class *not enough information* was introduced referring to all those polygons that due to clouds, shadows or unclassified segments cannot be assigned to a specific land use.

TABLE II. CLASSIFICATION OF LAND USE

Class	Features used
Not enough information	Relative area of *cloud*, *shadow* and *unclassified*
Not urban	Relative area of *urban* and *bright urban*
Mainly forest	Relative area of *forest*
Mainly open	Relative area of *grass* and *bare field*
Mainly water	Relative area of *water*
Sealed urban	Relatvie area of *urban* and *bright urban*
High industrial/commercial	Relative area of *bright urban*
Medium industrial/commercial	Relative area of *bright urban*
High residential	Not medium industrial/commerical or high industrial/commerical
Low density urban	Relative area of *grassland* and *bare field*
Residential with garden	Not low density garden

All remaining segments are assigned either to the classes *not urban* (based on relative area of the sealed land cover classes *urban* and *bright urban*), *low density urban* (based on the relative area of *grassland* and *bare fields*) and *sealed urban* (based on the relative area of *urban* and *bright urban*). All segments not yet assigned fall into the class residential with garden. *Sealed urban* is again divided into the three classes *high density industrial/commercial*, *medium density industrial/commercial* and *high density residential* based on the relative area of *bright urban*. *Non-urban* areas are assigned either to the class *forest*, *water* or *open* depending on the respective relative area. *Bare fields* and *grassland* have not been identified as separate land use but combined in the class *open,* as their differentiation depends very much on the season of image acquisition. The rules defined above were applied to both vector data sets. The results show the distribution of the defined land use types over the study area and represent a qualitative improvement to the original classification by explicitly showing information on land use so far only implied in the land cover distribution.

IV. Results

Image segmentation was performed on two levels. On level one the parameter scale was set to 10, color to 0.5, shape to 0.5 (which is separated into compactness of 0.9 and smoothness of 0.1). Preference is given to receiving more compact segments, as they are more applicable to urban objects. On the second level only spectral information was used, merging all neighboring segments with an absolute mean spectral difference of 40 into larger segments. This merges segments, which belong to large homogenous areas such as grassland but have been separated because of the restrictions of the parameters on level 1, while keeping segments separate which are spectrally distinct from their neighboring segments. To perform the classification the rules established in the class hierarchy were applied to the second segmentation level.

Fig. 3 shows the results of the initial land cover classification. Six land cover classes in addition to *clouds* and *shadows* were identified. All segments that could not be assigned to one of these classes fall into the class *unclassified*. The distribution of *urban* (red) and *bright urban* (magenta) together with *forest* (dark green) already indicate different land use patterns. *Grassland* (light green) and *bare fields* (orange) show where arable areas are located although some grassland also occurs in areas dominated by urban land use. Segments classified as urban areas next to bare fields in the South of the image are due to greenhouses. Shadows (black) could be identified very well and clouds as long as they were thick enough. Areas obscured by thin clouds were assigned to unclassified as were some building sites and mineral extraction sites in the Northeast.

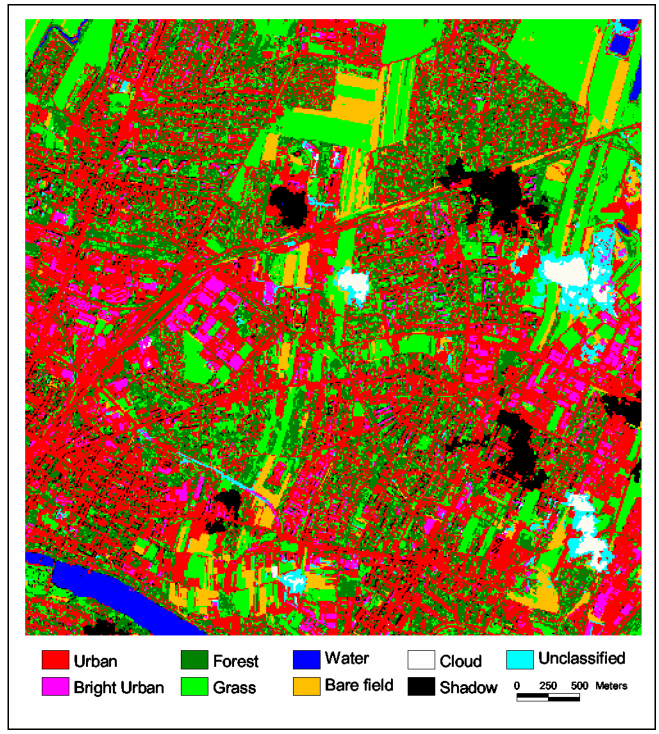

Figure 3. Land cover classificaiton on level 2

The next step is the integration of the land cover classification with the vector data sets. Based on the rules defined in Table II each polygon represented by the vector data sets was assigned to one of eight land use classes. Fig. 4 shows the results for the coarser street network. For a small number of polygons (black) not enough information was available due to shadows, clouds or unclassified segments. No polygon was assigned to the land use class of forest (dark green) as no large wooded areas are present in the study area. A large water body (blue) in the South was identified as were the large *open* (green) areas in the North and Northeast. The class *very low residential/open* (orange) very often coincides with arable areas with more complex agricultural land use such as market gardens. Four types of urban land use were identified. Depending on the proportion of *bright urban* land cover polygons were either assigned to *high residential/commercial* (magenta), *medium industrial/commercial* (yellow) or *high residential* (red). The remaining polygons are those with a significant proportion of urban as well as vegetation land cover and thus assigned to *residential with garden.* When the results are compared with the original image it can be seen that although some discrepancies exists, major land use patterns could be identified very well. The same is true for the classification based on the polygons of the more detailed land use data base (see Fig. 5). Using the same parameters as for the coarse land use classification the same major patterns could be identified, although the distribution of some of the land use classes changes. More areas were assigned to high *industrial/commercial* and fewer to *very low residential/open*. The assignment to *residential with garden* is very similar and some shifts take place between the assignment of *medium industrial/commercial* and *high residential*

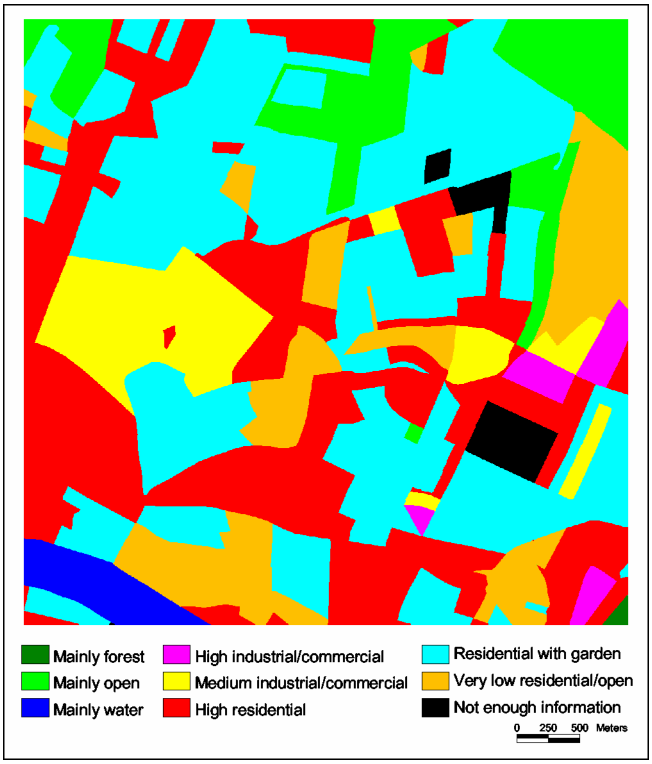

Figure 4. Land use classification based on street network polygons

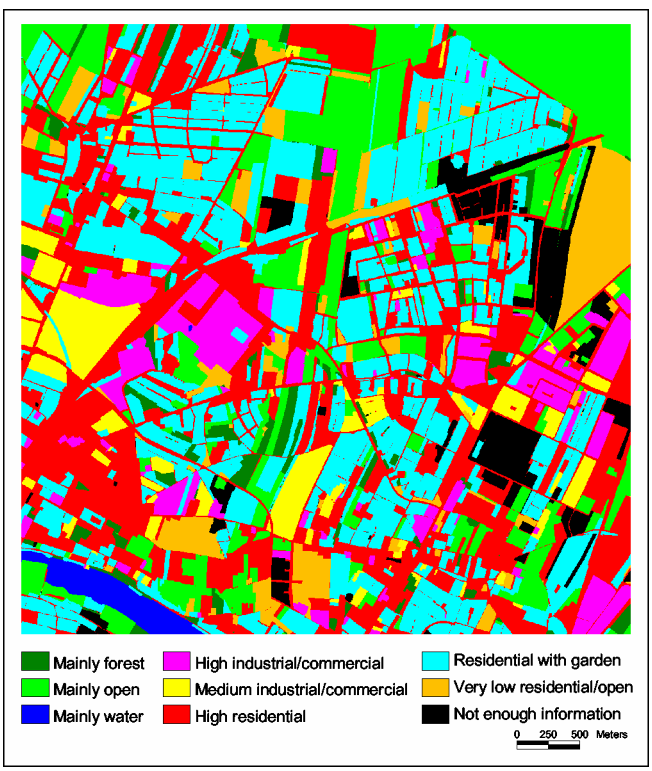

Figure 5. Land use classification based on land use data base polygons

V. CONCLUSION AND OUTLOOK

With the launch of KOMPSAT-2 at the end of 2005 and the expected increased availability of very high resolution satellite data, new applications for the routine use can be examined. In this paper a segmentation based classifier is used to identify basic land use classes from multispectral IKONOS data, which is similar to that provided in the future by KOMPSAT-2. Preference is given to a segmentation based classifier as statistical classifiers often lead to an undesired salt-and-pepper effect. In addition, the hierarchical classification, based on fuzzy functions, allows more control over the classification procedure and careful selection of the features used for the classification should allow an easy adaptation to new data sets. A sample application shows the integration of the land use classification with vector data to derive different types of land use based on the distribution of land cover within each polygon. Although the scale of the vector data sets are very different, ranging from very coarse to highly detailed, the major distribution of land use could be identified very well when compared to the satellite image. This is a first step towards interpreting land cover classification and reaching a higher information level. Next steps include testing the transferability of the classification procedure to high-resolution data sets from other cities and examine the stability of the chosen classification features and the necessary adaptation of the chosen parameters. The stability of the land use classification must be tested on similar vector data from different cities, ideally leading to comparable land use classification derived in a highly automated fashion.

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