THE POTENTIAL USE OF VERY HIGH RESOLUTION SATELLITE DATA FOR URBAN AREAS – FIRST EXPERIENCES WITH IKONOS DATA, THEIR CLASSIFICATION AND APPLICATION IN URBAN PLANNING AND ENVIRONMENTAL MONITORING

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ABSTRACT

The study sets out the benefits of the new IKONOS satellite image data for urban planning and for urban information tasks in general. Following a brief delineation of the reference modalities, the quality of the data is assessed and the problems for georeferencing are pointed up. Diverse fields of application of the data in urban planning and administration are then enumerated. Classification of IKONOS satellite data using, respectively, a pixel and a segment-based approach is described. To this end, classifiers arrived at using the ExpertClassifier (ERDAS) and eCognition (Definiens) classification programs are introduced and their respective recognize and classification qualities compared. ExpertClassifier draws on a pixel-based classification strategy which has performance limitations where high-resolution images are concerned but is ideal in implementation terms. In the case of eCognition, pixels of homogeneous areas are collected into segments. Besides the spectral signature, it is also possible to use form, size and neighbourhood and hierarchy relations as means of classifying segments. Such classification properties grow in importance as the image resolution increases.

1 INTRODUCTION

Urban spaces are the areas developing most dynamically. This is where the highest demands are made on basic geodata in terms of actuality and spatial resolution. Aerial and also, in future, very high resolution satellite imagery provide the wherewithal for keeping urban geodata inventories up to date and documenting them. Urban administrators, notably those in planning and environmental administration, are increasingly going over to using GIS. High-resolution, georeferenced imagery is playing an ever more central role as background information alongside digital geodatabases such as ATKIS, ALK and DGM. Up to now, though, the use of image data in GIS has dictated the expensive and error-prone transformation of series of aerial shots into orthophoto mosaics in a process involving, digitalisation, georeferencing and mosaicking. These stages are rendered redundant through the use of high-resolution satellite data.

As part of a project promoted by the German Research Community (Deutsche Forschungsgemeinschaft) on the benefit and application of new high-resolution satellite imagery in spatial planning (Me 1592/1-2), an IKONOS scene for a predominantly urban space (Dresden city area) was processed with a view to examining how it could assist in planning urban geodata inventories and keeping them up to date. As well as being investigated for their suitability for urban structure type mapping on a block-by-block basis, for up-dating inventories in land-use plans and for urban nature conservation tasks, the data were classified with the aid of, respectively, pixel and segment-based classification approaches and the classification results were compared.

2 IKONOS IMAGE DATA - BASIC INFORMATION, IMAGE QUALITY, GEOREFERENCING

2.1 INFORMATION ON IKONOS SATELLITE IMAGE DATA

We commence in what follows by providing key information on IKONOS satellite image data, a detailed description of which is to be found in MEINEL & REDER (2001). The data have been available since the beginning of 2000 and deliver a geometric resolution of 1 m in the panchromatic and 4 m in the four multispectral channels (VIS, NIR). Data are currently only being recorded to order, since these are only selectively available in archives due to the low swath width. Prices for Europe have risen from originally $18/sq. km to $35/sq. km for PAN and MS and $53/sq. km for 3 or 4-band image fusion products and are hence very high. It recently became possible to procure archive data. The minimum area here is 25 sq. km, with the following charges per sq. km: $18 for PAN, $18 for MS, $24 for PSM with 3 channels and $29 for PSM with 4 channels.

The minimum order value for a data recording is $3 000, the minimum area 11 km x 11 km. The frame border does not necessarily have to be cut at right angles, and irregular boundaries too are feasible. This may significantly reduce the cost of acquiring data for urban study areas that are frequently irregular in form (e.g. only shots of the city within the city boundaries). The most important ordering specifications relate to the 4 corners of the area of which a shot is required, a time slot within which the shot is to be taken, the bit width (8 or 11 bit) and the product type desired. At present, data are offered under the name of CARTERRA in the three product forms 1-P (1 m panchromatic), 4-MS (4 m multispectral) and 1-PSM (3-channel natural-colour or infrared product sharpened by the panchromatic image or else all four channels sharpened).

The repetitions rate of IKONOS with no sensor tilt is 140 days. A tilt of up to 26° cuts the repetitions rate to as little as 1.5 days, but the resolution are degraded as result. Using a predefined ellipsoid (WGS84) and a map projection (e.g. UTM), even the most basic CARTERRA Geo product is rectified. Data are then essentially fit for use in geoinformation systems (GIS ready). There are, however, problems with locational accuracy (see 2.2).

In the case of the IKONOS scene ordered, there was a 20-day period between the time-slot for the shot commencing and the shot being taken, with 5 days required for delivery. These timings are refreshingly short for all tasks except disaster monitoring. A clouding factor of up to 20 % (!) has to be tolerated with IKONOS orders, however. If lower cloud levels are required, a considerable surcharge on the already high product prices has to be paid. Clouding and the resultant shadow areas in the centre of the scene of Dresden due to a total information shortfall of 18 % (!) of the overall area. It has to be surmised, therefore, that recordings are made as soon as the standard conditions for cloud level and tilt range obtain.

2.2 RATING THE IMAGE QUALITY OF IKONOS

The quality of imagery is rated as very good (Fig. 1). In the panchromatic images, the contrast is such that the white lines of sports-field, parking-area and road markings are clearly discernible. At 11 bit, radiometric resolution is very high. Whilst the panchromatic image products are subjected to dynamic range adjustment (DRA) as standard, multispectral data are delivered unstretched. Roofs, facades, open ground and, in a few cases automobiles led in some instances to points of overmodulation (0.08 % of the area of the panchromatic image), though in no case to subsequent strip mismatches.

In the three channels of the visible spectrum of the MS-scene, only the first third, and in the close infrared approx. half of the bandwidth available was utilised. Virtually no points of overmodulation were discernible in the multispectral image. The angling of the sensor led in parts to problems when evaluating the imagery. In the case of the Dresden shot, for instance, which was taken at a tilt of 14° (76.8° nominal collection elevation), buildings can clearly be seen to lean over. This leads to problems for classification due to the reflection of facades and for mapping due to the obscuring of edges as a result of the oblique angle of the shot.

With multispectral and panchromatic image data having been recorded simultaneously and having identical corner co-ordinates, the two sets of imagery are locationally identical, allowing an image fusion to be computed immediately and with a highly focused image.

The CARTERRA Geo product is merely orbit-rectified. With no account being taken of relief-related distortions, Space Imaging promises a mean positioning error of < 50 m for 90 % of points (CE90) and 23.6 m for 66.6 % of points (RMSE). These values were exceeded considerably, however, with a mean positioning error of 108 m along the x-axis and 144 m along the y-axis. Orthorectification can only be avoided if the angle of sensor tilt is very small and the relief is relatively smooth. In most cases such a step will be necessary in order to use these costly image products with the appropriate quality. Given that Space Imaging does not publish any information on the sensor model and the orbit parameters, no exact orthorectification is possible and currently only approximate solutions are computable (KERSTEN et al. 2000, TOUTIN & CHENG 2000). If no models for orthorectification are available, it is necessary to purchase image data of the requisite level of precision. But product prices are then so high that they can no longer compete with prices for orthophotography at all.

2.3 IMAGE PREPROCESSING

The IKONOS image data (recording date 4 June 2000, 10.50 a.m. local time) had to be georectified prior to classification, since it was intended to incorporate further geodata into the classification. Serving as the reference for rectification was a digital orthophoto mosaic from 1999 with a 1m raster width and positional

accuracy of ≤ 0.5 m. It needs to be pointed out at this juncture that 1:10.000 scale topographic maps are unsuitable as a basis for rectification due to their locational inaccuracies. 37 pass points (GCPs) were generated on the panchromatic image data with even distribution. A polynomial quadratic transformation equation based on these pass points computed an RMS error of 0.53 m ($\Delta x = 0.33$ m, $\Delta y = 0.42$ m). Given the identical image location, the transformation equation could also be used for the rectification of the multispectral image data. These were resampled using nearest neighbours so as to retain the grey scale values for subsequent multispectral classification; in contrast to the panchromatic channel, which was adjusted using the Cubic Convolution procedure (Projection: Transverse Mercator) to avoid image artefacts (e.g. step effect). Owing to the comparatively flat terrain, few locational problems obtain in the image section, the maximum locational deviation in the study area being ≤ 3 m.

3 EMPLOYING IKONOS SATELLITE IMAGE DATA FOR URBAN TASKS

The data were submitted to various city departments with regard to the issue of their usefulness in specific contexts. Their geometric resolution is such that they are certainly on a par with aerial photography. The areas of application listed in Table 1 were arrived at:

Duty holder	Types of application
City Planning Office	Land-seal mapping, up-dating of Land Use Plan inventory, assessing building progress, green space planning
Environmental Protection Office	Biotope and land use-type mapping, green area and tree cadastre, urban structure type mapping
Economic Development Office	Locational planning, utilisation of industrial estates
Local Administrators	Planning documents for building ventures
Surveyor's Office	Up-dating of geodatabases
City Marketing Dept	

Tab. 1: Possible uses for IKONOS satellite image data

Given that the image fusion products have a geometrical resolution of 1 m, all image interpretation tasks down to a scale of 1:5.000 are in theory possible. Thus, for instance, urban biotope and land use-type mapping (scale 1:5.000) can be up-dated. It is also possible to up-date inventories in Land Use Plans (scale 1:10.000). The image data are additionally of assistance in drawing up and up-dating green-area and tree cadastres, though there are a plethora of issues concerning urban nature conservation that call for an even higher resolution and, above all, for elevation data of the sort provided by stereoscopically taken aerial shots. The infrared channel can be used to produce index mapping of vegetation (NDVI), which in turn is a prerequisite for semi-automated land-seal mapping routines. With the aid of pixel-based land-seal values, it is possible to calculate mean block land-seal values through intercalation with a digital block map. Urban structure type mapping is feasible without additional maps. The image data also provide valuable information for the assessment of building commissions and zoning maps. Wherever up to date topographical data are scarce the data can be used as a means of establishing evidence. They form an excellent basis for study maps to green space planning in cities.

4 CLASSIFICATION OF IKONOS SATELLITE DATA

4.1 DESCRIPTION OF THE STUDY AREA

For classification purposes the aim was to select a section of the IKONOS scene of Dresden that contains a large number of different ground-cover and land-use types. These conditions are met by a section of the western area of Dresden, which was clipped to a size of 2.4 km x 2.4 km (Fig. 1). The northern section contains sites with predominantly and commercial uses. A wide range of ground-cover and use types are to be found in the southern part. These are supplemented by lands that have only recently been modified or are still being developed (open ground). Amongst the features are newly-built roads that are not recorded in the digital block data for Dresden (as at 1999), for instance.

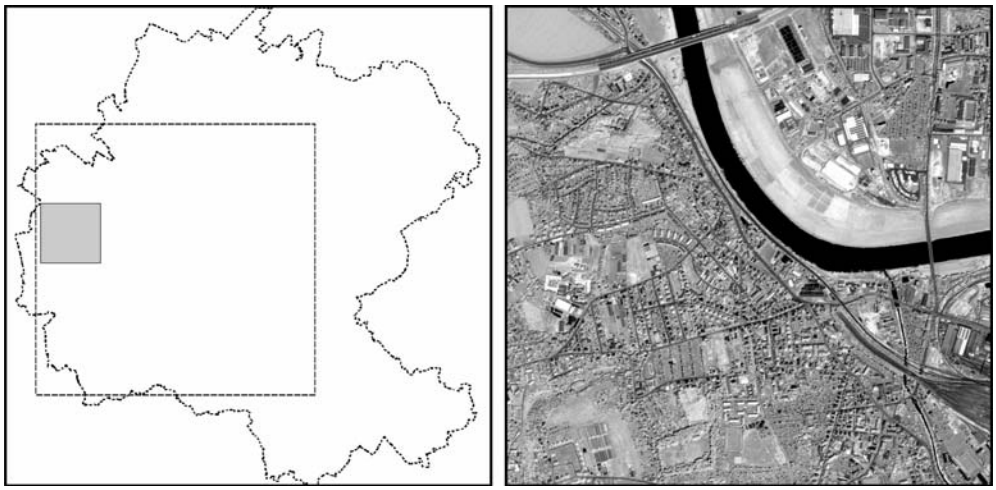

Figure 1. Location of the study area (shaded grey) in Dresden and within the overall IKONOS scene plus panchromatic image excerpt (© Space Imaging Europe SA).

The area should also be comparatively flat so as to keep locational errors to a minimum given that there is no means of orthorectification.

4.2 INPUT DATA AND CLASSIFICATION KEY USED

Despite IKONOS delivering even more enhanced geometric image resolution, it is not possible to extract all the desired ground-cover and utilisation classes with the requisite level of content-related and geometrical accuracy from remote sensing imagery alone. The inclusion of geodatabases that are increasingly becoming available area-wide is enabling classification results to be improved (multi-source data fusion) and has been applied for this reason in the context of the studies covered here. At the same time, only geodata were used that are available in standardised form and virtually nationwide for Germany.

For classification with ExpertClassifier, the four MS channels of the IKONOS sensor (4 m ground resolution), the NDVI vegetation index and the second principal component for classification were used. Further input data took the form of a modified texture layer computed on the basis of panchromatic image data and an unsupervised classification revised using statistical operations.

Complementary data used were a digital block map (digitalisation scale 1: 5 000) as well as an ATKIS data set. The block map facilitated the demarcation of street areas (block residual area) that cannot be sufficiently well classified on the basis of remote sensing data owing to tree-crown cover and a multitude of different road surface materials. An ATKIS-DLM25/1 was resorted to in the course of pixel-based classification to verify unclear hypotheses in respect of special utilisation classes (railway land, sewage settling sumps). When using the ATKIS data set it was ensured that only virtually immutable land uses (e.g. graveyards, track installations and river courses) were included in the classification. Bearing in mind when ATKIS data were last up-dated (1993 in the present case), other land might have changed its use or ground-cover characteristics in the meantime. An ATKIS-DGM25 served to avoid false classifications of bodies of water by incorporating the known level of the Elbe.

Basis for segmentation and classification with eCognition was an image product from the panchromatic channel and the four multispectral IKONOS channels that was computed by means of image fusion using the Principal Component procedure. Preliminary studies showed that, with this fusion image (1 m raster width), the boundaries of ground-cover classes can be identified more accurately than by using multispectral data (4 m raster width) or panchromatic image data (1 m raster width) only. The panchromatic channel of the IKONOS image was also used, being very helpful in demarcating very small objects such as trees and allotment huts at the finest segmentation level. A vegetation index calculated on the basis of IKONOS-MS scene (NDVI) served as a means of distinguishing between vegetation-covered and non vegetation-covered areas as well identifying various grades of vegetation cover (e.g. meadow/woodland) in the classification. The raster-based set of digital block data used to define streets and to structure areas into construction blocks at the coarse segmentation level again came in useful in this respect.

Since it is not possible with eCognition to operate with input data of differing raster size, all data had to be adapted to the smallest raster size. This entailed recalculating all data to a 1m-raster width and hence massively increasing the amount of input data.

The original aim for the comparison of classifications was to use the same classification key throughout. This had to be modified to an extent in the course of the project (Tab. 1), since in the case of classification by means of eCognition a more differentiated and to an extent use-centred class-formation was facilitated through the inclusion of neighbourhood relations and formal factors (e.g. sports fields, parking facilities, orchards).

4.3 PIXEL-BASED CLASSIFICATION WITH EXPERT-CLASSIFIER

4.3.1 BRIEF DESCRIPTION OF IMPLEMENTATION

For the first time with Version 8.4 of ExpertClassifier, ERDAS offers a rule-based, hierarchical classification approach. ExpertClassifier comprises Knowledge Engineer, which facilitates the production of knowledge-based decision trees with the aid of a graphic editor, and Knowledge Classifier for subsequent operational application of the classifier. A separate decision tree made up of logically interconnected hypotheses, rules, conditions and variables has to be developed for each class.

As well as the image data themselves, the set of rules can draw on elevation models, slope inclination, exposition and all types of synthetic channel (NDVI, ratios, texture etc.). Vector layers can likewise be incorporated together with their attribute values (though vector data are raster-processed internally). In addition, ExpertClassifier provides the means of including programs (SML- and C-programs) in the decision trees. In this way it is possible, for instance, to only assign areas of a specified size to a class or else to directly incorporate the most diverse statistical calculations, filtering processes, logic functions or combinations of these operations into the classification. Input layers need neither to have the same raster resolution nor to cover identical areas. Meaningful results are only to be expected where all input layers overlap, however. Uncorroborated pronouncements can be weighted in ExpertClassifier by according them a given Confidence Level.

For the purposes of evaluating a classification, the program provides a Pathway cursor with the aid of which the rules used for each classification point can be visualised (branch within the decision tree) and if need be interactively enhanced. As well as entire decision trees, individual components within them can likewise be activated and deactivated, resulting in rapid evaluation and on-going classification enhancement.
The set of rules produced with the aid of Knowledge Engineer can be applied to other scenes using Knowledge Classifier. To this end it is necessary to define the input scenes of the classification model as a query variable. At the same time, all programs and graphic models incorporated into the set of rules are adopted.

4.3.2 CLASSIFICATON WITH EXPERT-CLASSIFIER

Basis for the creation of the decision tree was knowledge of the spectral properties of the ground-cover types, roughness within lands, typical land sizes and altitudes. The variables adopted to confirm criteria were derived in part from prior knowledge and comparatively safe assumptions and in part by specifying suitable discrimination values by measuring the multispectral channels and synthetic data sets. Classification has been steadily improved with the evaluation tools available.

The rule for the class “Arable Land” was as example established that, at the time of the recording (4 June 2000), arable lands had vegetation cover, a comparatively homogeneous surface (little roughness) and a minimum size of 1.5 acres. These individual assumptions were formulated as hypotheses, established as rules and defined with the corresponding variables and conditions. The Roughness variable relates to the texture layer generated and modified on the basis of the panchromatic channel. The scale of vitality was derived from the NDVI. Classification was now effected by selecting pixels with an NDVI > 0.5 and a roughness < 1,900 (discrimination function), collating neighbouring pixels with these properties (segmentation using CLUMP), and finally selecting segments > 1.5 acres (SIEVE). These functions were implemented in Spatial Modeller and incorporated into the decision tree. The long-term stability of lands in the Railway Premises/Track Installations class is such that recourse could be had here to ATKIS. ExpertClassifier provides the means of evaluating vector attributes, in this case the ATKIS code for railway premises (3501). The spectral signature of these areas served as an additional decision-making criterion. Computing times for the area considered were so low that it was possible to rapidly evaluate and comprehensively enhance its classification.

4.4 SEGMENT-BASED CLASSIFICATION WITH ECOGNITION

4.4.1 OUTLINE OF THE METHODOLOGY INVOLVED

The Definiens AG company (formerly Delphi2) launched eCognition at the end of 2000, a software product that eschews pixel-based methods and classifies on a segment-basis instead. The software's concept draws on the Fractal Net Evolution technique whereby complex subject-matter is represented by means of semantic networks. Full expositions of the programming underlying the software are to be found in BAATZ & SCHÄPE (1999, 2000) and in the Online User Guide. Studies were conducted as part of beta testing with Version 1.0 (26 June 2000).

The eCognition software adopts a segment-driven approach, i.e. in the initial phase homogeneous areas are collected into image segments. In the second stage - the actual classification event - a knowledge-based decision tree is produced, it being possible to effect classification either by using Fuzzy Logic-based membership functions or by selecting test areas (Nearest Neighbour classifier). Combining a number of segmentation levels yields a semantic network of image segments. Thus it is possible to use not only the grey values but also relations to neighbouring lower or higher-order image segments as well as formal properties. Creating segments avoids the "salt and pepper" effect invariably associated with pixel-based approaches (BLASCHKE 2000a, BLASCHKE 2000b).

Unlike ERDAS Imagine, eCognition is purely an image analysis system, one that can only currently be run on PCs. Image processing operations upstream of classification have to be computed separately to eCognition using an image processing program (in this case ERDAS Imagine). The system only accepts raster data as input data.

4.4.2 SEGMENTATION WITH eCOGNITION

The eCognition approach involves segmenting raster data into homogeneous sites and hence abstracting raster cells into regions. This greatly reduces the number of image elements for classification and significantly reduces the volume of data. Segmentation is controlled primarily by means of the scale factor, which indirectly determines the size of segments. To achieve the best segmentation for a given image, it is essentially necessary to run tests until the appropriate segmentation parameters have been found.

As a means of identifying the influence of the scale factor on mean segment size, segmentation was effected for a sample area using a variety of scale factors. In the process, a quadratic correlation between scale factor and mean item size was established. One aspect of importance to a segmentation program is the reproducibility of segments, forming the basis for subsequent classification as they do. It was demonstrated that, given repeated segmentation, segments are reproduced identically if the image excerpt remains unchanged. Where the size of the excerpt was altered, however, identical segmentation parameters gave rise to different segment patterns. Segment boundaries are modified not only at the edge of the image - which would be understandable - but also within the image. Given that, owing to the long computing times involved with eCognition, initially excerpts of larger scenes are classified and the classification is then applied to the whole scene, this is a definite disadvantage.

Generally speaking, an image ought to be segmented using several scale factors so as to do justice to the hierarchical structuring of the picture content. The finest level of segmentation necessitates the greatest computing input, since one is then dealing with individual pixels. This is why Definiens states that segmentation from fine to coarse segments is advisable. Further segmentations (with a larger scale factor) use the existing segments and require less computing time to collect these into larger ones.

The input data set out under Subsection 4.2 were used for segmentation with the following conditioning factors: the panchromatic layer was only used at the fine-scale level. Though the NDVI layer was not employed for classification, it was for the subsequent evaluation of characteristics in the course of classification.

The area under consideration was segmented on three levels, to wit fine (scale factor: 10, mean segment size: 23 pixels), medium (50/487) and coarse (165/6,589). Very small items such as trees, allotment huts and roofing were demarcated at the fine-scale level, as indeed were inconsistencies within otherwise uniform ground-cover phenomena. Whole buildings are segmented at the medium-scale level, whilst at the coarse scale-level large entities such as bodies of water, fields and entire blocks of buildings are demarcated.

4.4.3 CLASSIFICATION WITH eCOGNITION

Image segments were classified contrary to their segmentation sequence at the three levels from coarse to fine on the basis of their mean grey values, formal characteristics, neighbourhood relations and relations with higher and lower-order segments. Membership functions were formulated in the coarse and medium utilisation classes. At the fine segment level results were refined with the aid of test areas assigned to a given class through visual interpretation. The criteria for distinguishing between classes were selected by interrogating individual elements (Image Object Information) or by means of a Feature View, with the aid of which each criterion can be represented as a surface graphic. Classes already allocated can be inherited up or down in the hierarchy of entities and levels. This process has gradually given rise to a comprehensive knowledge-based classification tree. Useful means of evaluating classification were the characteristics of segments (alternative assignments) as well as graphic representation of the probability of class membership (Best Classification Result). Additional manual class allocation is possible, though it was not made use of here.

4.5 COMPARISON OF CLASSIFICATION RESULTS AND THEIR IMPLEMENTATION

4.5.1 VISUAL COMPARISON OF CLASSIFICATIONS

Visual comparison of the two sets of classification results reveal marked differences (Fig. 2). Whereas eCognition yields very homogeneous areas due to segmentation beforehand, classification with ExpertClassifier results in well known small-element pixel classification pattern (“salt and pepper” effect).

Figure 2: Classification results for the whole area (left: ExpertClassifier, right: eCognition).

Fig. 3 compares images citing various classification sections. The top row shows how a newly built road was correctly classified with eCognition (by evaluating form and neighbourhood), whilst ExpertClassifier was only partially able to itemize it as a sealed open space. The middle row demonstrates that IKONOS data can as a rule be used to classify individual houses despite correct classification being impeded by the detailed representation of the multifarious roofing materials and diverse sunlighting scenarios. The bottom row shows how eCognition was able to correctly classify a river and two sports fields.

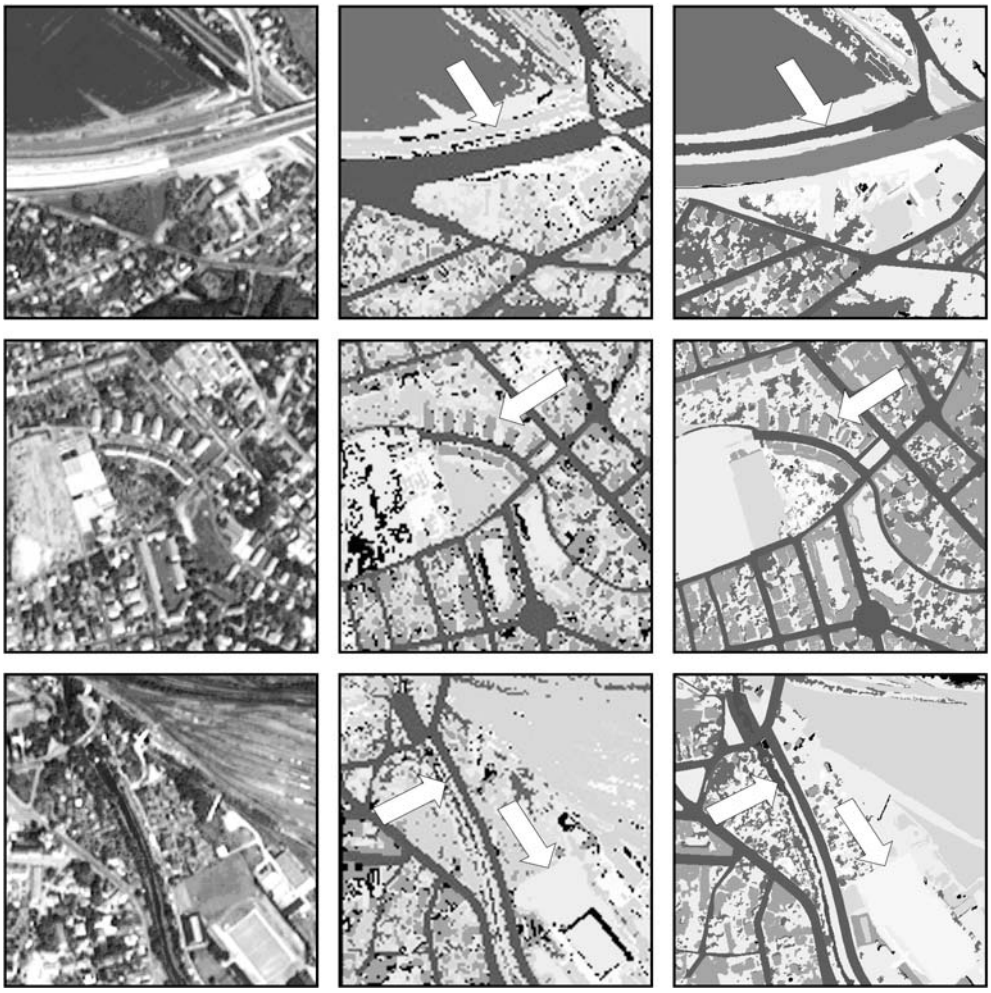

Figure 3. Sections from the test area (left: IKONOS image, centre: ExpertClassifier classification results, right: eCognition)

There were differences in the proportion of unclassified areas (shaded black in Fig. 2 and 3), which made up 0.42 % of the overall area in pixel-based classification as compared with just 0.07 % in its segment-based counterpart. In the latter case, unclassified segments of uncommon utilisation classes can also be manually allocated to the corresponding utilisation class, thus making exhaustive classification possible in principle. Pixel-based classification always leaves isolated disconnected pixels that cannot be clearly assigned to any class.

By incorporating neighbourhood relations and surface shape, eCognition permits more differentiated classification keys. It was, for example, able to identify sports fields through an analysis of form and size and some houses through their adjacency to roads. Overall it can be stated that large, homogeneous areas can be classified more securely and in less time with eCognition than can more heterogeneous areas.

4.5.2 COMPARISON OF CLASSIFICATION QUALITY

The Accuracy Assessment Tool in ERDAS Imagine was used to compute the quality of classification and identification. 20 test points were produced by a random generator for each class, regardless of their proportionate area. To avoid test points at utilisation boundaries (which cannot, after all, be clearly classified using visual interpretation either), test points were required to be located within homogeneous areas.

Visual determination of cover and use in respect of these test points was primarily on the basis of the IKONOS-data image fusion product. In doubtful cases an aerial shot from 1999 was used, and in some cases corroboration was by means of *in situ* inspection. The results of classification monitoring are shown in Table 2.

Class	ExpertClassifier		eCognition	
	Identification quality [%]	Classification quality [%]	Identification quality [%]	Classification quality [%]
Arable land	100.0	100.0	100.0	100.0
Pasture/meadow	78.3	90.0	80.9	85.0
Flood plain	94.7	90.0	-	-
Sports field	-	-	100.0	95.0
Woodland/tree	95.2	100.0	100.0	95.0
Deciduous woodland, scrubland	85.7	90.0	-	-
Orchard	-	-	100.0	95.0
Garden/allotments[1]	94.1	80.0	-	-
Body of water	100.0	100.0	100.0	100
Industrial/commercial estate[2]	-	-	62.5	75.0
Built environment	90.9	100.0	94.7	90.0
Railway premises	100.0	90.0	100.0	100.0
Motorway	-	-	100.0	100.0
Road surface[3]	-	-	-	-
Unsealed area with no vegetation	85.7	60.0	83.3	75.0
Sealed area	68.0	85.0	69.6	80.0
Parking facilities	-	-	83.3	75.0
Overall classification quality	89.6		89.6	

[1] The Garden/Allotments class was broken down into its ground-cover constituents for the purposes of classification with eCognition at the finest segmentation level tested here.
[2] Sealed industrial/commercial estates are classified as Sealed Areas under ExpertClassifier.
[3] Road surfaces were excluded from the quality assessment, since they were directly extrapolated from the residual block area rather than being classified.

Tab. 2: Comparative quality of identification and classification.

Both classifications produce the same overall classification quality of 89.6 %. It needs to be pointed out again at this juncture, however, that classification with ExpertClassifier was effected on a 4 m raster with 11 classes, whilst classification with eCognition was on a 1 m raster with 13 classes. Considerable discrepancies manifested themselves in the individual classes, moreover. These are at their clearest in the classes for unsealed areas with no vegetation, railway premises and built environment.

5 CONCLUSION AND OUTLOOK

The new satellite data with a panchromatic resolution of 1 m and a multispectral resolution of 4 m facilitate image fusion products at a scale of 1:5000. Thanks to their four multispectral channels, these can be computed both as natural-colour and infrared products. Given the necessary acceptance of up to 20 % clouding, the reference conditions can be regarded as being critical. At $35/sq. km, prices for image products in Europe are very high in addition. One problem at present relates to the rectification of image data. This makes great demands on the geometrical positioning accuracy of the reference data. Topographical survey maps to a scale of 1:10000 (TK10) are not generally accurate enough, orthophoto mosaics being more suitable. With shots being taken at an angle of up to 26°, furthermore, orthorectification is required in most instances.

The imagery produced is eminently suitable for diverse urban information and planning functions due to its very high geometric resolution. It can be used, for example, to up-date the land-use-plan inventory as well as biotope and use-type mapping. The data are also useful for assessing building applications and zoning maps. The absence of elevation details poses problems for some urban nature-conservation tasks, however, and the geometric resolution is still insufficient in places.

New very high-resolution satellite data necessitate new approaches to evaluation besides those based on pixels and grey values. As the geometric resolution of image data rises and a broader range of input data are employed for classification purposes, use must be made, alongside the spectral signature of raster cells, of the characteristics of larger, interconnecting areas. Forms, area sizes, neighbourhood and hierarchy relations are important characteristics of this kind for ground-cover and land-use phenomena. By extracting these new characteristics, classes can be formed in a more nuanced and sure manner. Alongside the classification of ground cover from remote sensing data that has figured most prominently hitherto, determining land use is now becoming increasingly important. This demand can be met to an extent through classification with eCognition. Furthermore, the segment-driven approach delivers a lower proportion of unclassified areas as well as a far more homogeneous product than conventional pixel-based classification, which always tends to entail a 'salt and pepper' effect.

Acknowledgement
The authors wish to thank Definiens AG, Munich, for providing the beta version of the eCognition software package.

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