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THE POSSIBILITIES TO SUPPORT ZB GIS® DATABASE UPDATE USING OBJECT-BASED IMAGE ANALYSIS IN ECOGNITION DEVELOPER SOFTWARE

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Abstract. The process of updating a spatial database is a necessary part of database management in order to keep the stored information of an acceptable quality. The first step of database update requires change detection. Many methods have been suggested to detect changes, mostly pixel-based. Recently, with the spread of very high resolution images and object-based image analysis, object-based methods were developed, too. This article presents object-based change detection method for update of the vector database ZB GIS®, that is a geometric base of the Slovak National infrastructure of spatial information, using orthophoto of the area of interest. The method stages include the following: segmentation of orthophoto using the geometry of database objects and further according to spectral and spatial information, classification according to ZB GIS®, defining reclassification rules between two classes. The proposed method was tested in two localities – Malženice (agricultural landscape) and Chopok-Jasná (mountainous landscape) reaching the overall accuracy of classification 87.12% and 84.55%, respectively. The main limitation of the method is that it can be applied only for polygonal objects.

Keywords: remote sensing, change detection, object-based image analysis, object-based classification, spatial database, database update.

Introduction

Spatial databases represent the base of national spatial infrastructures and provide an access to the information that is necessary for the effective management of both public and private matters. In Slovakia this function is being fulfilled by the National infrastructure of spatial information, whose geometric base is The Fundamental Database for Geographic Information System ZB GIS® created between 2002 and 2010. Data in this database is collected with respect to some quality requirements but the data quality naturally decreases with time and thus after some time it is necessary to perform database update. The same applies to any spatial database that has some quality requirements.

The process of updating a spatial database, with exception of the method of repeated data collection, consists of two steps. It is effective to update the data after detecting changes first. Changes can be identified by indirect indicators (e.g. granted planning/building permissions or certificates of final inspection) or by comparison of remote sensing images (Adamják 2008). Since ZB GIS® data is partly gained from remotely sensed data that is now easily and cheaply accessible it is efficient and rational to use it for change detection, too. However, it is obvious that this approach will have its limitations and will have to be combined with other methods, e.g. of indirect indicators and/or field data collection.

Analysis of remotely sensed data is usually performed at the pixel level. Recently, for approximately 10 years, the object-based approach, that attempts to approximate computational image analysis to human vision, has been starting to be preferred (Addink *et al.* 2012; Blaschke 2013). Number of research papers have evaluated object-based approach as more accurate than pixel-based methods, both for remotely sensed image classification (e.g. Myint *et al*. (2011) classifying urban types of land cover, Whiteside *et al*. (2011)

mapping savannahs in Australia, Duro *et al.* (2012) using three different classifiers) and change detection (Roostaei *et al.* 2012). Its advantage is that it takes into account not only spectral characteristics, but the object extraction also enables to use such characteristics as shape, size, texture or neighbourhood. It also eliminates the problem of pixel-based analysis of remote sensing images of high and very high resolution: so-called salt-and-pepper effect that creates fragmented classified image. Accuracy of object-based image classification can be improved using ancillary data (e.g. digital terrain model) for identification of objects that have different height than its surrounding, e.g. trees and buildings (Dehvari, Heck 2009; Whiteside *et al.* 2011).

There are more approaches to the use of object-based analysis in change detection. Chen *et al.* (2012) divide them into four groups: image-object, class-object, multitemporal-object and hybrid change detection. Sometimes, the latter, that combines pixel- and object-based approach, is not considered equal to the former methods but rather to be at the level of pixel-based and object-based approach. Hussein *et al.* (2013) therefore conclude three object-based change detection techniques: direct object change detection, classified objects change detection (post-classification approach) and multitemporal/multidate-object change detection, which is basically identical with the division of Chen *et al.* (2012) after excluding hybrid approach.

The literature on the use of object-based change detection techniques for update of spatial vector databases is somewhat limited. In most cases post-classification approach is applied, since spatial database can be considered as a classification of remotely sensed images. It was used by Carleer and Wolff (2008) and Hanson and Wolff (2010), too. Both teams suggested methods built upon two levels of segmentation; in the first level image is segmented using existing vector database, in the second one these segments are further segmented according to its spectral characteristics, with the first level classified identically with the database objects and the second level using nearest neighbour classifier (Carleer, Wolff 2008) and rule-based classification for selected classes (Hanson, Wolff 2010). Part of the methods using object-based classification to detect changes is focused on specific classes, mostly buildings (Poulain *et al.* 2009; Bouziani *et al.* 2010).

This study aims to propose and test a method for change detection of polygonal data in spatial vector database ZB GIS® using object-based image analysis and without the need to carry out classification of image segments derived from up-to-date aerial orthophoto that is a standard approach for vector database update using object-based methods. Moreover, the method will use the data already contained in the database, in both segmentation and change detection process so this additional available information will not be lost. The method can be applied to any vector spatial database and is easy to perform. Firstly, two levels of segmentation are carried out, the first one according to the input vector data and the second one based on vector and spectral data as well. Secondly, rules for classification of individual classes are developed and second-level-segments are reclassified accordingly. These reclassified segments represent the detected changes.

The processes of image segmentation and change detection are carried out in the eCognition Developer software, since it is the leading software in the field of segmentation and object-based classification of remotely-sensed images. It has many algorithms for segmentation and classification and offers the widest range of different object properties. Moreover, eCognition Developer software enables classification with user-defined membership functions and properties and also the creation of customized algorithms using variables, domains, conditions, loops, etc. In a comparison of software capable of segmentation by Stanková and Straka (2012), this one was considered to have the most possibilities.

1. Material and methods

1.1. Study area

Study areas were defined by the extent of orthophotos that have been used to detect changes. Two areas that differ by the character of landscape and land cover were objects of this study. The orthophoto of the area of Chopok-Jasná in northern Slovakia captures mountainous landscape partly changed by man for the purposes of winter tourism (ski resort). The area lies in the western part of the Low Tatras with coniferous woodland, grassland and rocks as dominant land cover.

The other orthophoto was taken over the village Malženice situated in the Danubian upland in the western part of Slovakia. This area is intensely used for agriculture, it is the type of agricultural landscape with the longest growing season and with high intensity of agricultural production (growing cereals is dominant, vine is also grown) (Miklós 2002).

1.2. Data

As input both vector and raster data was used. The vector data of spatial vector database ZB GIS® is to be updated and raster data of orthophotos is to be used for change detection of this data.

The vector data of ZB GIS® was provided by the Geodesy, Cartography and Cadastre Authority of Slovak republic in a format of ArcGIS geodatabase and then exported to ESRI shapefile that is accepted by the software eCognition Developer used for object-based analysis. However, only features with polygonal geometry type were worked with, since identification of point and linear features from raster data is limited and, moreover, object-based image analysis produces only polygonal elements. Classes analysed in two study areas can be found in Table 1. The class Areas around linear objects (FC042) represents solely roads in our case. Areas with no typical use (SA021) are areas around buildings, thus it can be grassland, concrete surface etc.

The digital orthophoto of the Malženice area was produced from digital aerial image taken on 1st September 2009 by UltraCamX. The image was taken at a height of approximately 1300 m with focal length of 100.5 mm and resolution of 0.1 m. It was processed into the orthophoto at the Department of Cartography, Geoinformatics and Remote Sensing of Comenius University in Bratislava (Kožuch 2011). The produced orthophoto covers the area of 2.6 km^2 with dimensions of 1.2 and 2.2 km and contains mostly extravilan of the village with agricultural use, although there is also a part of the settlement on the margin of the image.

Table 1. List of used ZB GIS® classes

FACC	Class name	Study area	
		Malženice	Chopok-Jasná
AK040	Sports/playing field		✓
AK050	Tennis court		✓
AL015	Building	✓	✓
AL019	Storehouse	✓	
AM080	Water tank		✓
AQ040	Bridge, viaduct		✓
AQ140	Car park		✓
BH080	Lake		✓
DA020	Barren land		✓
DB090	Mound, dike		✓
EA010	Arable land	✓	
EA040	Orchard, garden	✓	
EB010	Meadow	✓	
EB015	Grassland and shrubland	✓	✓
EC015	Woodland	✓	✓
FC042	Area around linear objects	✓	✓
OA020	Other objects	✓	✓
SA021	Area with no typical use	✓	✓

The orthophoto of the Chopok-Jasná area is a cut from a bigger orthophotomosaic of whole Slovakia produced by companies EUROSENSE and Geodis in 2005 of aerial images taken during three previous years (it is not known to us when was which part taken). The orthophoto has a resolution of 1 m and the cut has dimensions of 3.2 and 4.2 km and area of almost 13.5 km^2.

The ZB GIS® data in the area of Chopok-Jasná was collected in the earlier phases of the database building, in November 2005. In the Malženice case, the vast majority of the data was collected in May 2007. Obviously, the orthophoto of Chopok-Jasná was taken earlier than the ZB GIS® data was collected, however, considering that methodology of change detection is to be suggested and not actual update is to be carried out, this is considered as irrelevant.

1.3. Segmentation

The inputs of image segmentation are in this case not only rasters (orthophotos), but also vector polygonal features of ZB GIS®. These features cover Earth's surface continuously and with no overlap and after their merging into one shapefile layer they could be used as input in eCognition Developer segmentation to produce the first level of image segmentation based on the borders of the ZB GIS® features. The purpose of such process is to preserve borders of existing features because the goal of database update is not collecting new features from the beginning but rather editing the existing that are detected as changed, either in geometry or in attribute (class belonging).

The second level of segmentation is crucial for detection of changes in geometry of features and for detection of new features. In this step using multiresolution segmentation algorithm, the objects in the first level of segmentation were further segmented based on their spectral characteristics. The algorithm enables to set three parameters that influence size and shape of resulting segments. Scale defines the maximal heterogeneity of segment and thus influences its size. Too low value can result in undersegmentation of image and *vice versa*. The parameters of shape (trading off colour homogeneity against shape homogeneity) and compactness (trading off smoothness against compactness) control the shape of resulting segments.

Because settings of appropriate values of segmentation parameters depend not only on resolution but also on user's individual requirements, various settings of scale, shape and compactness parameters were tested. Since the segmentation results cannot be evaluated quantitatively in the used software they were assessed visually. Firstly, the most convenient setting of scale parameter was searched for whilst settings of the values of shape and compactness remained constant (values defaultly set in eCognition Developer were used, i.e. shape = 0.1; compactness = 0.5) (see Fig. 1). Finally, using this value of scale parameter, different settings of shape and compactness parameters were tested.

When evaluating the segmentation results it was taken into account up to which extent the algorithm is able to separate the parts of objects that in fact do not belong to the same class but are the parts of neighbouring object or represent a new object. Minimum areal mapping units of ZB GIS® classes defined in The Class Catalog of ZB GIS® (ÚGKK SR, TOPÚ 2008) were also considered. They vary between classes: the lowest value (12 m^2) is used for buildings, water tanks and shacks. This value was thus considered as a minimum updating unit. In the case of the image of the Chopok-Jasná area, however, considering its resolution (1 m) and also the fact that it is not area with intense construction and detected changes are expected to be forestation/deforestation mostly, larger segments were desired. Moreover, some buildings cannot be identified in the image even visually.

When setting the shape and compactness parameters the main requirement was to obtain not too fragmented objects that are as representative and accurate as possible. In the case of the Malženice orthophoto the visual analysis was focused mostly on delineation of buildings because for this class regular shape is of bigger importance than for other classes. In the Chopok-Jasná orthophoto the requirement of not too strong fragmentation was primarily inspected on segments of coniferous woods as this class is especially prone to such behaviour.

In the case of the Chopok-Jasná study area the segmentation was carried out over the whole image since repeated segmentation process with different parameter setting was allowed by its size and resolution in reasonable times. Although the Malženice orthophoto covers smaller area because of its finer resolution (0.1 m) the segmentation is much more time-consuming. Therefore a representative part of the area was selected, which served as a test area when searching for the most desirable values of segmentation parameters for the whole image. The test area contained built-up as well as open area, smaller as well as larger objects, including changed and new objects. The used values of input segmentation parameters for both orthophotos are found in Table 2.

Table 2. Used values of input segmentation parameters for both study areas

Study area	Scale	Shape	Compactness
Malženice	200	0.2	0.8
Chopok-Jasná	125	0.3	0.9

The segments in both levels (generated according to the ZB GIS® and by multiresolution segmentation) were classified according to the ZB GIS® data, which later enabled to use the existing information stored in the database (e.g. distance from existing buildings).

1.4. Change detection

The principle of the suggested method of change detection in vector spatial database is to find such characteristics of class objects extractable from orthophoto

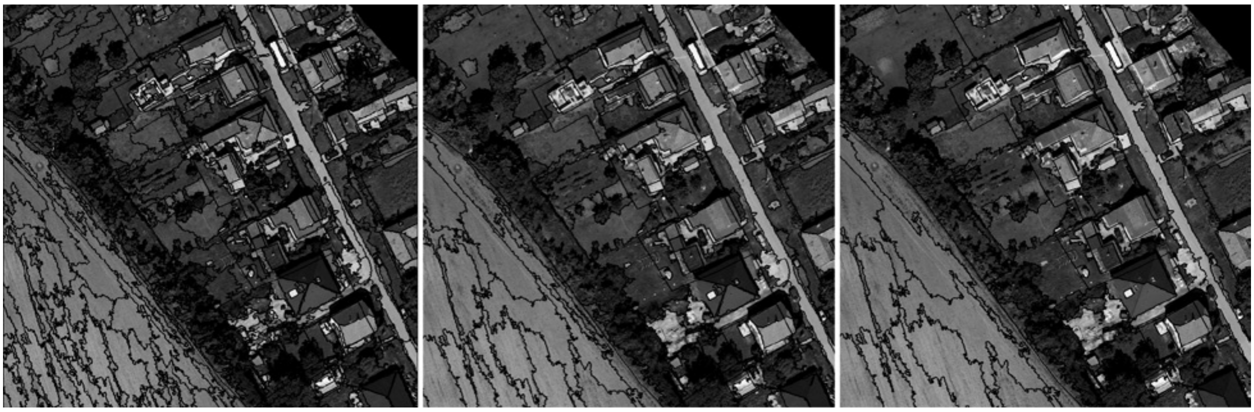

Fig. 1. Comparison of segments generated using different settings of scale parameter value (100, 200 a 300; shape = 0.1; compactness = 0.5): example of section of the Malženice study area

that are specific to individual classes and by which they can be distinguished from objects in other classes, to define reclassification rules and, based on them, to reclassify segments that are wrongly classified in the database. The advantage of object-based approach is in the wide range of characteristics that can be used; not only spectral but also such characteristics that are related to shape and texture of objects or to relation to neighbouring objects, super- and sub-objects. In addition, the classification of segments in the second level according to the original ZB GIS® data allowed us to compare object characteristics of respective two classes and use this information to identify misclassified, i.e. changed, segments and to determine the direction of the change (from – to) at the same time.

The process started with identification of pairs of ZB GIS® classes that represent change vectors of segments in the images. For these pairs, firstly, characteristics that human eye would use to distinguish these two classes were suggested (e.g. colour, shape, texture, relation to neighbouring objects). These characteristics were then searched for in eCognition Developer software along with their values defining the differentiation of the classes. If they were not sufficient to distinguish classes, then less visually apparent characteristics were tested (spectral-related). To test the characteristics and their values visualization options of the software were widely applied. The values of the characteristics were finally summarized into reclassification rules, based on which segments were reclassified between classes. Reclassified segments represented segments with detected change.

The accuracy of the resulting (re)classification was evaluated by an error matrix. The reference segments were chosen from two subsets – from segments with identified change and from segments with no identified change. From both subsets 10% of segments were randomly selected, with an exception of segments with no change in Malženice study area, where given their number, 5% of segments (332) were considered as sufficient. These randomly selected segments were visually interpreted and this value was regarded as reference. The segments that could not be clearly included into one of the classes were omitted from the reference sample.

2. Results

2.1. Segmentation

The results of segmentation are two levels of segments – the first level of ZB GIS® objects and the second level of smaller segments created from the first level by multiresolution segmentation algorithm. Due to the requirements for the size of segments in the second level (the level used for change detection) such objects were sometimes delineated that in fact do not represent land cover and classes defined in ZB GIS® – particularly vehicles. Shadows were also created as separate segments. These issues had to be taken into account later in the process.

Most of the objects were delineated correctly, even though there were cases of too fragmented segments despite the efforts to eliminate them (segments of coniferous woods in Chopok-Jasná study area). Segments of buildings were not generated ideally. Since one side of rooftops was shadowed (generally rooftops of Slovak houses are not flat) and thus had different spectral response, many buildings were segmented into two (or more) segments, which later limited the use of shape characteristic for this class. Shape of some small buildings was not extracted correctly, because they were spectrally similar to their surrounding. Some artifacts were delineated as individual segments, although not required, especially walls of houses that naturally occur in images because they are created by central projection. Being predominantly of white colour, they have very different spectral response from its surrounding and rooftops. In the Malženice orthophoto separate segments were created for pipelines and power lines. However, these are stored in the database as lineal features and due to the criterion for geometry type set in the beginning these classes were not taken into account for change detection and the segments were considered to belong to the same class as its neighbouring objects. Creating segments of these linear features could not been prevented due to the very fine resolution of the image.

2.2. Change detection – Malženice

In the Malženice study area several types of change were identified. Part of them represents changes that are a result of changing in time, the other part seems to be a result of generalization when collecting the ZB GIS® data. Overview of the changes over a section of the study area with the original ZB GIS® classification is found in Figure 2.

The largest part of changes is represented by the change of arable land (EA010) to vineyards (EA050) and from meadows (EB010) to arable land (EA010) – 55% and 31% of all changes, respectively; in the area was namely identified a whole new vineyard and all features of the class of meadow were identified to be in fact arable land. Changes in areas of all classes before and after change detection are in Table 3.

To identify the inclusion of segments into the classes besides the radiometric characteristics the shape characteristics and neighbourhood relations were often used, which was enabled by the object-based approach. These were characteristics such as segment length-to-width ratio and relative border when identifying vineyards (EA050), distance from existing buildings when identifying newly constructed buildings (AL015), neighbouring a building when identifying areas with no typical use (SA021) or length and border index when identifying areas around linear objects (FC042), i.e. roads. Even though it was possible to use more characteristics than only radiometric, misclassification still occurred to some extent, mostly regarding pairs of arable land (EA010) and grassland and shrubland (EB015) and of woodland (EC015) and grassland and shrubland (EB015). In the first case, despite the fact that the image was taken after harvest and arable land thus had relatively homogeneous radiometric characteristics over the whole area, there were parts where weed was already growin and these were identified as grassland. The result was not improved after using textural characteristics. Besides, confusion of driveways and buildings often occurred, since segments of these objects have similar radiometric and shape characteristics. Combinations of characteristics and their values used for segment reclassification are found in Table 4. These characteristics with the aim to distinguish individual classes were evaluated visually and considered the best. Classification with these parameters was used as an input into the accuracy assessment.

Fig. 2. Changes detected in a section of the study area of Malženice over the original ZB GIS® classification

According to the error matrix (Table 5) the overall classification accuracy after the change detection is 87.12%. The lowest values of partial accuracy were reached by classes of orchard, garden (EA040), grassland and shrubland (EB015) and other objects (OA020). The highest accuracy, producer's as well as user's, were recorded for class vineyard (EA050).

2.3. Change detection – Chopok-Jasná

In the study area of Chopok-Jasná three types of changes were identified: from woodland (EC015) to grassland and shrubland (EB015), from barren land (DA020) to grassland and shrubland (EB015) and from grassland and shrubland (EB015) to woodland (EC015). The location of changes can be seen in

Table 3. Areas of classes before and after change detection and respective change in the study area of Malženice

Class	Area [m²]			Area change [%]
	Before	After	Difference	
AL015 – building	19140.31	22643.75	3503.44	18.30
AL019 – storehouse	36.01	36.01	0.00	0.00
EA010 – arable land	2209047.97	2139250.74	–69797.23	–3.16
EA040 – orchard, garden	49435.39	48942.59	–492.80	–1.00
EB010 – meadow	102070.20	0.00	–102070.20	–100.00
EB015 – grassland and shrubland	72521.86	66624.16	–5897.70	–8.13
EC015 – woodland	37095.32	30424.79	–6670.53	–17.98
FC042 – area around linear objects	12982.65	15271.05	2288.40	17.63
OA020 – other objects	223.02	223.02	0.00	0.00
SA021 – area with no typical use	69438.70	65977.45	–3461.25	–4.98
EA050 – vineyard	0.00	182597.87	182597.87	–

Table 4. Matrix of characteristics values used for reclassification of segments in the study area of Malženice

former class / new class	AL015	AL019	EA010	EA040	EB010	EB015	EC015	FC042	OA020	SA021
AL015	–	N/A	ratio B ≥ 0.334 ratio G ≤ 0.34 distance to AL015 < 1000px	ratio G ≤ 0.345 ratio B ≥ 0.334 or ratio R ≥ 0.35	N/A	N/A	N/A	N/A	N/A	ratio G ≤ 0.348 ratio B ≥ 0.3339 or ratio R ≥ 0.362 rel. border to AL015 ≤ 0.3 compactness ≤ 2.7 length/width ≤ 2.5
AL019	N/A	–	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EA010	N/A	N/A	–	N/A	N/A	ratio G ≤ 0.37	N/A	N/A	N/A	N/A
EA040	N/A	N/A	N/A	–	N/A	N/A	N/A	N/A	N/A	N/A
EB010	N/A	N/A	N/A	N/A	–	N/A	N/A	N/A	N/A	N/A
EB015	N/A	N/A	ratio G ≥ 0.365; AF1 ≤ 165 No. of neighbours of EC015 = 0	N/A	N/A	–	N/A	N/A	N/A	N/A
EC015	N/A	N/A	ratio G ≥ 0.365; AF1 ≤ 165 No. of neighbours of EC015 ≥ 1	N/A	N/A	N/A	–	N/A	N/A	N/A
FC042	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	N/A	ratio G ≤ 0.348; ratio B ≥ 0.333 or ratio R ≥ 0.362 length ≥ 300px border index ≤ 3.55
OA020	ratio G > 0.348 ratio B < 0.334 width > 20px border index ≤ 1.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	N/A
SA021	N/A	N/A	No. of neighbours of AL015 ≥ 1 area < 40000px	N/A	N/A	N/A	N/A	N/A	N/A	–
EA050	N/A	N/A	1. σ of green layer ≥ 20 direction <150, 167) length/width > 10; 2. rel. border to EA050 > 0.35; 3. No. of neigh. of EA050 ≥ 3; 4. No. of neigh. of EA050 ≥ 3; 5. rel. border to EA050 = 1	N/A	N/A	N/A	N/A	N/A	N/A	N/A

AL015 – building, AL019 – storehouse, EA010 – arable land, EA040 – orchard, garden, EB010 – meadow, EB015 – grassland and shrubland, EC015 – woodland, FC042 – area around linear objects, OA020 – other objects, SA021 – area with no typical use, EA050 – vineyard, N/A – no change, ratio R/G/B – amount of R/G/B layer contributing to the total brightness, AF1 (Arithmetic Feature 1) – ratio of mean intensity of layer 2 and hue, σ – standard deviation.

Table 5. Error matrix of classification accuracy evaluation in the study area of Malženice

class	AL015	EA010	EA040	EA050	EB015	EC015	FC042	SA021	Total	UA
AL015	27		1					6	34	79.41%
EA010		202		10	13	2	1	5	233	86.70%
EA040	1		10		1			3	15	66.67%
EA050				118					118	100.00%
EB015		1		1	22			1	25	88.00%
EC015						5			5	100.00%
FC042							9	1	10	90.00%
SA021	7		8				1	33	49	67.35%
Total	35	203	19	129	36	7	11	49	489	
PA	77.14%	99.51%	52.63%	91.47%	61.11%	71.43%	81.82%	67.35%		87.12%

Figure 3, a detailed view of changes with the ZB GIS® classification before and after the change detection is found in Figure 4.

Overall there was recorded a decrease in the area of barren land (DA020) (17.42% of the original area) and woodland (EC015) (0.61%) and increase in the area of objects of grassland and shrubland class (EB015) (15.29%). Similarly to the study area of Malženice, it was problematic to distinguish segments of classes of woodland (EC015) and grassland and shrubland (EB015); errors were generated mostly in the cases of shrubby, mountain pine and young forest cover. Segments with these types of land cover have very similar values of radiometric characteristics and they are indistinguishable according to shape and texture characteristics, either. In the end, to differentiate them at least to a certain extent a combination of brightness value (generally lower for forests) and a ratio of mean intensity of layer 2 (green) to hue was used.

In the error matrix (Table 6) it is obvious that the lowest producer's accuracy was reached in the class of barren land (DA020) (just below 70%) and the lowest user's accuracy was reached in the class of grassland and shrubland (EB015). The accuracy values of all other classes were above 75%. The overall accuracy was calculated to be just above 84.5%.

Fig. 3. Identified changes in the study area of Chopok-Jasná over the orthophoto

3. Discussion

Based on the accuracy evaluation results it is apparent that there is a big difference in the quality of change detection of different classes, which relates to the different degree of separability in the feature space using both radiometric and object-based characteristics. However, the use of characteristics related to object-based approach was beneficial when distinguishing some classes – e.g. vineyard (EA050) from arable land (EA010), orchard, garden (EA040) from grassland and shrubland (EB015) or when identifying areas around linear objects (FC042) and areas with no typical use (SA021). The most problematic was to clearly differentiate segments of grassland and shrubland (EB015) from arable land (EA010) (the Malženice study area), or woodland (EC015) (the Chopok-Jasná study area). One of the reasons seems to be the fact that this class is very variable, i.e. it contains grassy as well as shrubby cover and these are relatively different in terms of their characteristics; this class thus intersects in the feature space with the confusing classes.

The overall accuracy was higher in the study area of Malženice where shape characteristics and neighbourhood relations were used to a larger extent. What contributed to the better result was also the finer resolution of the orthophoto (tenfold compared to the orthophoto of Chopok-Jasná); on the other hand this resulted in a considerably longer time of processing. However, the difference in the overall accuracy results (2.57%) does not suggest that large increase in resolution would significantly improve the accuracy of the resulting classification. Therefore it might prove to be useful in the future to consider resampling of an image with extra fine resolution to a coarser resolution.

In the study area of Malženice the overall accuracy of 87.12% was reached, compared to 84.55% in the Chopok-Jasná study area. Some authors reported lower accuracies when updating spatial database using object-based approach: Volker (2004) 76% and Hanson and Wolff (2010) 73% by a method of postclassification comparison and 74% by the same method

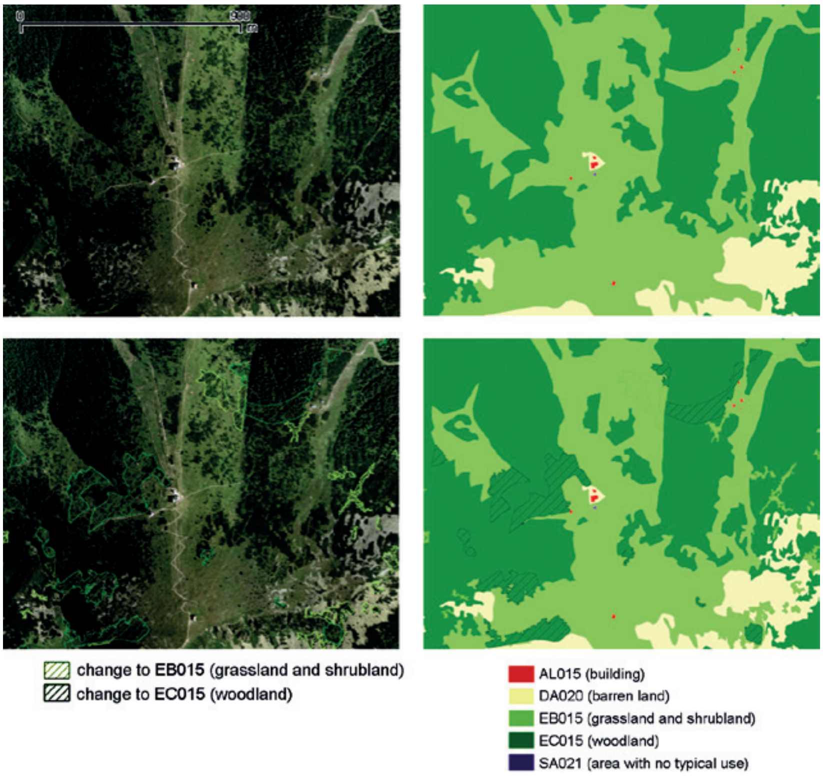

Fig. 4. Detail of the study area of Chopok-Jasná (left to right):
1) section of orthophoto, 2) original ZB GIS® classification,
3) identified changes over the orthophoto, 4) ZB GIS® classification after change detection

Table 6. Error matrix of classification accuracy evaluation in the study area of Chopok-Jasná

class	AL015	AQ140	BH080	DA020	EB015	EC015	FC042	OA020	SA021	Total	UA
AL015	13					1				14	92.86%
AQ140		2								2	100%
BH080			2							2	100%
DA020				29						29	100%
EB015				13	87	17	1			118	73.73%
EC015					6	62				68	91.18%
FC042							9			9	100%
OA020								1		1	100%
SA021									3	3	100%
Total	13	2	2	42	93	80	10	1	3	246	
PA	100%	100%	100%	69.05%	93.55%	77.50%	90.00%	100%	100%		84.55%

with a use of digital terrain model (DTM). Some of the developed methodologies of change detection in the spatial databases are focused on a specific class, often buildings, since buildings are objects relatively quickly changing and thus requiring frequent update. Bouziani *et al.* (2010) managed to correctly detect in two testing areas 92% and 94% of newly constructed buildings, respectively, which is significantly more than 77.14% in the Malženice case. It might be a result of using a larger number of characteristics – e.g. minimum distance between buildings and between building and road or building's orientation to roads. However, this also makes the methodology more complicated to carry out. In any case, it would worth testing it on the more classes (not buildings only) of the ZB GIS® database. Despite the high accuracy of buildings detection the authors encountered the same problem as we did – confusion of buildings and driveways.

The results could be improved using data on object height (DTM). This information would be helpful for identification of forests (distinguishing from shrubs) and buildings (distinguishing from driveways, often confused with). If infrared aerial images are available it is possible to use them to identify water bodies and vegetation cover more easily. However, it remains questionable if it would solve at least to a certain extent the problems encountered when identifying segments of the class grassland and shrubland. For example, in the work of Hanson and Wolff (2010) the use of DTM increased the accuracy of classification only by 1%.

The issue to discuss is also the methodology of accuracy evaluation. Considering that the orthophotos were gained with a considerable time lag after they were taken, it was not possible to obtain reference samples directly in the field. We realize the limitations of this method and it is obvious that the accuracy results cannot be considered absolutely correct, but relatively correct only, compared to the visual interpretation.

As far as the methodology of change detection for update of the ZB GIS® database is concerned, in further research it will be needed to be tested in more testing areas and in different landscapes, not in mountainous and agricultural only. The most questionable is the accuracy in urban landscape that is very complex in terms of the ZB GIS® features that contains.

Conclusions

Object-based image analysis benefits in comparison with pixel-based methods in the possibility to use besides spectral characteristics also characteristics related to shape, texture and neighbourhood of objects (segments). These types of characteristics were used when classifying segments into ZB GIS® classes (specifically building, area around linear objects, area with no typical use, vineyard) along with radiometric characteristics, that are still crucial when performing image segments classification. Despite the use of shape characteristics and neighbourhood relations overlapping of some classes in feature space keeps occurring. It regarded mostly the pairs of classes of grassland and shrubland and arable land and of grassland and shrubland and woodland.

The principle of the suggested method of object-based change detection as a support of the spatial vector database ZB GIS® update lies in the segment reclassification between two classes according to rules defined based on characteristics (radiometric, shape, neighbourhood) of the class objects. By this method the overall classification accuracies of 87.12% and 84.55% were reached in the study areas of Malženice representing agricultural landscape and Chopok-Jasná representing mountainous landscape, respectively. In the context of the resolution of the images of two study areas and time needed for processing it can be said that considerable increase of the image quality did not result in considerable increase of the classification quality.

The main limitation of the method is its applicability only on the objects with the polygonal geometry type. It was found out that in the image with very fine resolution from the area of Malženice (0.1 m) it is possible to identify even some objects with the linear geometry type, e.g. pipes and power lines. The use of the method to detect linear objects would however need more testing.

The method is strongly dependant on segmentation and thus proper setting of input parameters is very important. It is, similarly as defining the values of characteristics of classes, subjective to a certain extent. Therefore an experienced analyst is a requirement for the method to be properly applied.

However, the suggested method cannot be directly applied for the update of the database (that is why it is rather called a support of the update). Besides the fact that objects are not delineated perfectly in the segmentation step in terms of its shape, from the orthophoto it is not possible to get the information about the third coordinate, i.e. the height above sea level that is contained in the ZB GIS® database.

Despite the aforementioned limitations, the suggested method returns acceptable accuracy results (87.12% and 84.55%, respectively) and represents a shift towards the automation of the spatial database update. It is easy to perform and compared to other object-based method for vector database update does not require classification of image segments and also brings the use to the data contained in the vector database.

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