Geoinformation Issues
Vol. 2, No 1 (2), 19-26/2010
DOI: https://doi.org/10.34867/gi.2010.2

Application of object-oriented method for classification of VHR satellite images using rule-based approach and texture measures

Stanislaw Lewinski
Institute of Geodesy and Cartography, 27 Modzelewskiego St., PL 02-679 Warsaw, Poland
Tel.: +48 22 3291976, Fax: +48 22 3291950, E-mail: stanislaw.lewinski@igik.edu.pl

Zbigniew Bochenek
Institute of Geodesy and Cartography, 27 Modzelewskiego St., PL 02-679 Warsaw, Poland
Tel.: +48 22 3291977, Fax: +48 22 3291950, E-mail: zbigniew.bochenek@igik.edu.pl

Konrad Turlej
Institute of Geodesy and Cartography, 27 Modzelewskiego St., PL 02-679 Warsaw, Poland
Tel.: +48 22 3291991, Fax: +48 22 3291950, E-mail: konrad.turlej@igik.edu.pl

Abstract. New approach for classification of high-resolution satellite images is presented in the article. That approach has been developed at the Institute of Geodesy and Cartography, Warsaw, within the Geoland 2 project – SATChMo Core Mapping Service. Classification algorithm, aimed at recognition of generic land cover categories, has been elaborated using the object-oriented approach. Its functionality was tested on the basis of KOMPSAT-2 satellite images, recorded in four multispectral bands (4 m ground resolution) and in panchromatic mode (1 m ground resolution). The structure of the algorithm resembles decision tree and consists of a sequence of processes. The main assumption of the presented approach is to divide image contents into objects characterized by high and low texture measures. The texture measures are generated on the basis of a panchromatic image transformed by Sigma filters. Objects belonging to the so-called high texture are classified at first steps. In the following steps the classification of the remaining objects takes place. Applying parametric criteria of recognition at the first group of objects four generic land cover classes are classified: forests, sparse woody vegetation, urban / artificial areas and bare ground. Non-classified areas are automatically assigned to the second group of objects, which contains water and agricultural land. In the course of classification process a few segmentations are performed, which are dedicated to particular land cover categories. Classified objects, smaller than 0.25 ha are removed in the process of generalization.

Keywords: object-oriented classification, land cover, KOMPSAT 2

Received: 4 October 2010 /Accepted: 5 January 2011

1. Introduction

The main objective is to assist an operational service for land cover mapping using the most recent findings from scientific research. Since launching in 2000 first commercial eCognition software for object-oriented data analysis numerous research and application activities were undertaken, in order to apply the approach for elaborating semi-automatic method for land cover classification based on satellite images. The works were concentrated on two main aspects of object-oriented approach: multi-resolution segmentation to adjust objects to terrain elements in an optimum way, and on classification methods, exploiting comprehensively spectral, spatial and textural features of image objects, as well as their mutual relationships. The authors of the works applied in their studies multi-resolution satellite data (Whiteside, 2005) as well as very high-resolution images (QuickBird, Ikonos) which gave possibilities to analyse more effectively texture and shape features (Kressler et al., 2005; Wei et al., 2005; de Kok and Wezyk, 2008; de Kok et al., 2008).

The most common classification approach was based on applying training areas for particular land cover classes and Standard Nearest Neighbour Classifier to assign objects to land cover categories (Hajek, 2005; Yuan and Bauer, 2006; Elmqvist et al., 2008). However, owing to the development of Definiens eCognition software alternative approaches to classification process are now being studied. They are based on the use of parametric values of spectral / texture type and hierarchical classification workflow, based on decision tree method (Lucas et al., 2007; Lewinski and Bochenek, 2008; Su et al., 2008). The presented work is located in this category of research / application works. It emerges from the needs formulated within current international projects conducted in FP7 Programme, e.g. Geoland 2 Project. One of the main objectives of this project is to prepare operational service for land cover mapping and monitoring of land cover changes in Europe, based on HR and VHR satellite images. Development of efficient, reliable semi-automatic method for producing land cover maps is one of Geoland 2 major tasks and the Institute of Geodesy and Cartography, Warsaw, participates actively in fulfilling this task. The presented method is the result of an extensive research, which was carried out recently within Geoland 2 SATChMo Core Mapping Service.

2. Satellite data and study areas

Very high-resolution images acquired by KOMPSAT 2 - Korean Multi-Purpose Satellite were used in this study. Main characteristics of KOMPSAT 2 images are as follows: four spectral bands - blue, green, red and infrared plus panchromatic image, with 4 m resolution in multispectral mode and 1 m resolution in panchromatic mode, 15 × 15 km scene size. The images were collected by the European Space Agency for the Geoland 2 Project in August – September 2009 and pre-processed at ESA facilities prior to their delivery for further research works.

Four images were utilized in sequence for developing and testing a new approach for land cover classification. Basic test area was located in central-western Poland, in Wielkopolska region. The area encompasses all main land cover classes; agricultural land is predominant in this region, mixed with forests, small cities, rural settlements and grassland patches. While the method has been developed, it was next tested and tuned, using three other test areas, located in Germany, United Kingdom (mid-latitude zone) and Spain (Mediterranean zone).

3. Methodical approach

3.1. General assumptions

The general idea in this work was to prepare a semi-automatic method of land cover classification, which could be used for operational mapping throughout the whole Europe of nine main land cover categories related to CORINE LC level 1 and level 2 nomenclature:
- urban / artificial;
- bare non-cultivated ground;
- agricultural areas;
- forest / woodland / trees;
- sparse woody vegetation;
- grassland;
- other vegetation (moorland, etc.);
- water;
- snow and ice.

The basic assumption in developing classification approach in this work was to apply a decision tree method instead of sample-based method, and to determine appropriate object features for sequential discrimination of particular land cover categories. The whole process of classification was divided into four main stages:
- stage 1: division of study area into two object's groups, the first – characterized by high texture and the second – by low texture measures;
- stage 2: classification of high texture group, including urban / artificial class, forests / woodland / trees, sparse woody vegetation and bare non-cultivated ground;
- stage 3: classification of low-texture group, comprising agricultural areas, grasslands, snow and ice (if existing) and water;
- stage 4: re-classification of existing classes in order to refine the classification output.

The assumption applied in this work was to use both multispectral data and panchromatic images. The idea to use panchromatic imagery was justified by very detailed information on terrain features due to 1 m ground resolution, which enabled to differentiate terrain objects by texture measures with high accuracy.

Classification workflow applied in this work is presented in Figure 1.

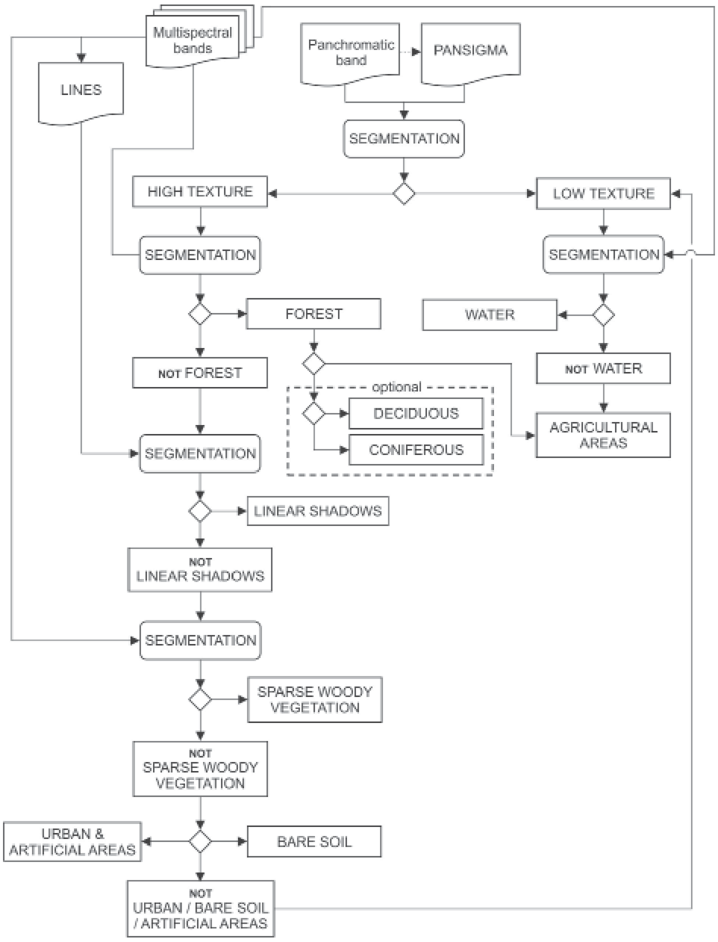

Fig. 1. Classification workflow elaborated within the eCognition (ver. 8) environment

3.2. Hierarchical classification of land cover categories

At the initial phase of classification process an original panchromatic image of the study area was transformed through filtering process. The aim of this step was to acquire the resultant image, which could be easily divided into high- and low texture areas. Two Sigma filters were used for this purpose, which emphasize inner and outer object boundaries, respectively. The sum of two filtered images formed the resultant PAN SIGMA image, which was used at the next stages of analysis for deriving texture information.

The panchromatic image after filtration, in conjunction with the original one, was used for making first segmentation, i.e. division of the study area into homogeneous objects. Scale parameter in this segmentation was assumed to be quite high in order to keep the resultant objects as large as possible.

While panchromatic image supported with filtered one was segmented, PAN SIGMA image was divided into high- and low texture areas by applying statistical measure called quantile, following solution proposed by de Kok and Wezyk (2008). This measure allows to split the analysed population (range of PAN SIGMA values in this case) into two sub-populations which, e.g. can represent two groups of land cover, characterized by different textures. The crucial point is to determine quantile value, which could make such a division with high thematic accuracy. This can be done by iterative process through analysis of division into high and low texture, while applying various thresholds (quantile values) within test area. In theory such a quantile value should be fixed for various satellite scenes, but in practice it can change depending on the character and differentiation of land cover. As a result of this step two groups of objects were created: high texture group, including urban / artificial class, forests / woodland / trees, sparse woody vegetation and bare non-cultivated ground, as well as low texture group, comprising agricultural areas, grasslands and water. High texture is assumed to be a fixed property of urban / forest (spectral discontinuity) as well as spectral low variability

Geoinformation Issues
Vol. 2, No 1 (2), 19-26/2010

(spectral continuity) can be assumed a characteristic property of agriculture / water and large grass fields.

In parallel to the discrimination of high and low texture areas the extraction of lines, represented mainly by linear shadows, has been performed. That step was done on the basis of the infrared channel analysing orientation of linear features within IR image. The resultant layer with lines has been used at the later stages of classification, to refine final classification image.

Once the high texture image has been created, it was segmented again, using multispectral channels (green, red, infrared) and a lower scale factor, in order to obtain smaller objects. After this segmentation the division of high texture area into forests / woodland trees class and non-woodland area was done. As a criterion of this division the value of spectral feature called RatioR has been applied. This customized feature is defined by a formula (de Kok and Wezyk, 2008)

$$RatioR = R / (R + G + B + IR + PAN)$$

where R, G, B, IR, PAN denote reflectance values in respective spectral channels.

Threshold value of RatioR feature was determined, similarly to the previous step, by quantile. In addition, second spectral feature has been applied – Normalized Difference Vegetation Index (NDVI). This index is represented by the formula

$$NDVI = (IR - R) / (IR + R)$$

The use of thresholds for both features – RatioR and NDVI – enabled to delineate within high texture area objects representing forest / woodland / trees class. In the presented classification workflow this class can be optionally sub-divided into 2 forest categories: coniferous, and deciduous forests. In case of such division, a sampling approach is utilized: samples for coniferous and deciduous forests are collected and Standard Nearest Neighbour method is used for classification within forest object class.

The stage of delineating forests / woodland trees category is equipped with additional procedures, allowing to extract from this class areas which despite of high texture belong to agricultural category. Two types of extraction can be done: agricultural fields characterized by high texture and openings located within forest areas. For the first type of extraction threshold values in IR reflectance and texture homogeneity IR measure are utilized, while for the second one – brightness threshold values and homogeneity PAN measure are applied.

Once the classification of forest / woodland / trees category had been completed, the analysis of the remaining area within high texture category was started. At the first step of the analysis segmentation of this area was done with low scale factor, using line layer, prepared in previous step of the work. Next, classification of shadows was performed by applying a threshold value in line layer. At the final step of this stage new segmentation of the remaining high texture area has been performed with low scale factor, using three spectral bands (red, green, infrared).

That area was in turn classified, in order to distinguish next land cover category – sparse woody vegetation. Two feature attributes are used for this purpose: NDVI and RatioR, with priority put to NDVI threshold and complementary utilization of RatioR threshold. The remaining high texture area was at the next step classified with the aim to discriminate two land cover categories: urban / artificial class and non-cultivated bare ground. In case of urban / artificial class two features were used for the discrimination:
- customized feature – standard deviation in red channel / square root of area;
- texture homogeneity measure in PAN image.

In case of non-cultivated bare ground a threshold for brightness index was applied in conjunction with texture homogeneity measure in panchromatic band. The classification workflow enables here to change the sequence of distinguishing both land cover categories, depending on classification results.

When the classification of all land cover categories belonging to high texture group had been completed, the third main stage of the work was started – the classification of low texture area. Three basic land cover classes exist in this group – water, grasslands and agricultural areas. In the presented approach water category was distinguished first from this group. At the initial phase additional segmentation of low texture areas has been performed, with possibility to refine it using second segmentation, employing spectral differences between objects in IR band. After completion of segmentation procedure water was classified applying the threshold in IR reflectance. Two stage approach can be used in this phase, which allows for more precise delineation of small water bodies and rivers.

Once water class was distinguished within low texture area it was assumed that the rest of this area represents agricultural areas and grasslands. No distinction was finally made between those two land cover categories, due to unfavourable dates of acquisition of satellite images (late summer / early autumn). In order to discriminate these classes with high accuracy a multi-temporal approach would be more appropriate.

At the fourth stage of the classification workflow the re-classification of some classes was done. It concerned especially the class of linear shadows which in this step is assigned to main land cover categories, depending on condition of its adjacency. Moreover, some areas representing bare non-cultivated ground were shifted to urban / artificial class, when adjoining this class to a high degree. While completing all four stages of classification, generalization process has been conducted, with the assumption of preserving objects which fulfil a condition of Minimum Mapping Unit – 0.25 ha. Final classification image for the Polish study area is presented in Figure 2. It was a subject to the accuracy assessment procedure, in order to evaluate real performance of classification algorithm which is described in this section.

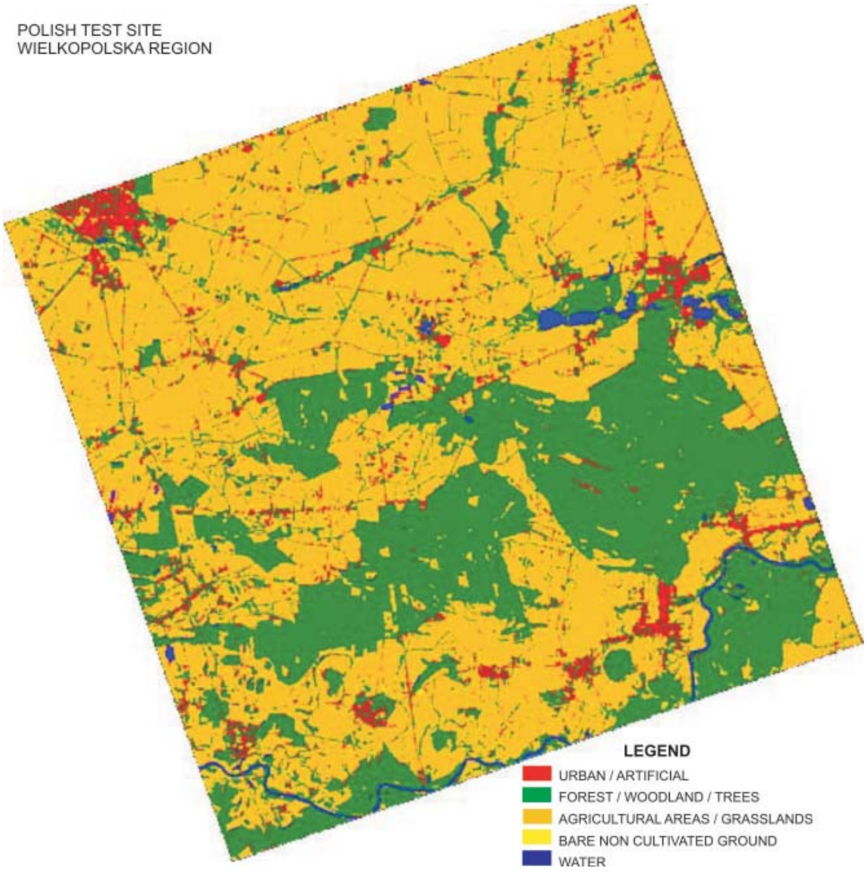

Fig. 2. Classification image of Polish test site – Wielkopolska region

4. Discussion of the results

Accuracy assessment procedure has been conducted within PCI Geomatica environment. 500 control points were randomly distributed within study area, proportionally to the area of each land cover class. For each point with its surroundings land cover was interpreted visually and next compared with classification image. The results of accuracy assessment in the form of error matrix, including producer's and user's accuracy, are presented in Table 1.

Table 1. Accuracy assessment of classification of Kompsat 2 image

Classified data	Reference data / control points					
	forests/ woodland	urban/ artificial	bare ground	water	agriculture/ grassland	total
forests	**176**	6	0	0	12	**194**
urban	4	**24**	2	3	6	**39**
bare ground	1	2	**8**	0	11	**22**
water	0	0	0	**23**	2	**25**
agriculture / grassland	3	0	1	0	**216**	**220**
total	**184**	**32**	**11**	**26**	**247**	**500**
accuracy [%]						
producer's	95.7	75.0	72.7	88.5	87.4	
user's	90.7	61.5	36.4	92.0	98.2	
overall accuracy **89.4%**						

Overall accuracy of classification reached 89.4%, so the achieved result fulfils the requirements for generic land use maps prepared within GMES Land Services (85%). The obtained accuracy is supported by a high Kappa coefficient.

The best results were achieved for three land cover categories: forests, water and agricultural areas / grasslands. Both assessments – from point of view of producer's and user's accuracy – proved high level of accuracy. In each category results of accuracy assessment exceed the pre-determined level of 85%. However, one should note, that agricultural areas / grassland class is a broad land cover category, so when separating it into two independent classes the accuracy level can be slightly lower.

Urban / artificial class and bare non-cultivated ground reveal moderate, although acceptable producer's accuracies. Precision of discrimination of urban / artificial class mainly depends on its detailed assigning to high-texture group. Bare non-cultivated ground can be mixed up with agricultural bare soil, when having low texture characteristics, at the same time decreasing its level of recognition, especially from user's point of view. So further works on finding features, which could aid in improving recognition of this class, are needed.

5. Conclusions

The presented work demonstrates object-oriented classification method which applies a rule-based approach, utilizing threshold values for spectral / textural / contextual features in a decision tree workflow, instead of more commonly used sampling approach and Nearest Neighbour classifier. The advantage of the proposed method is its simplicity – each land category is described by one or two features which allows the operator to adjust the features quite easily in order to achieve acceptable result of class delineation. Moreover, the whole process of classification can easily be modified by adding a new feature or class when needed.

Application of multi-resolution segmentation at different stages of classification process is another characteristic element of the proposed method. It enables to adjust size and shape of objects to particular land cover classes more precisely than in a one-step segmentation approach. Innovation of the proposed approach is also application of textural image created through filtration of VHR panchromatic image for separating land cover categories characterized by high or low texture at the initial stage of classification. Some works in this field were already conducted (de Kok et al, 2008), but using the sum of two images created through Sigma filters seems to be a new solution.

The presented approach was verified through its application for three other test sites, located in Germany, United Kingdom (mid-latitude zone) and Spain (Mediterranean zone). The classification results, especially for German and British sites, indicate, that the proposed method can effectively be applied for land cover mapping in a temperature zone of Europe, with minor adjustment of features used for class discrimination. In case of the Mediterranean zone, characterized by specific types of vegetation and agriculture, the proposed approach requires some modifications, but its general idea is fully applicable. Further research on improving the proposed method is still needed in order to increase accuracy of urban / artificial class and bare non-cultivated ground, as well to prepare the efficient solution for grassland delineation, based on multi-temporal approach. When completed, the operational method for generic land cover mapping can effectively be applied on European scale within GMES Land Services.

Acknowledgements

The presented work has been done within FP7 Geoland 2 project, financed by the European Commission and supported by the Ministry of Science and Higher Education. The method was tested using KOMPSAT-2 satellite images collected by ESA (European Space Agency) for Geoland 2 project – Application SATChMo Core Mapping Service.

References

de Kok R., Wezyk P., (2008): *Principles of full autonomy in image interpretation. The basic architectural design for a sequential process with image objects*, In: Object-Based Image Analysis, Th. Blaschke, S. Lang, G.J. Hay (Eds), Series: Lecture Notes in Geoinformation and Cartography, Springer Berlin Heidelberg, ISSN: 1863–2246, pp. 697–710.

de Kok R., Wezyk P., Weidenbach M., (2008): *The role of edge objects in full autonomous image interpretation*, Proceedings of GEOBIA 2008 – Pixels, Objects, Intelligence, GEOgraphic Object Based Image Analysis for the 21st Century, Calgary, Alberta, Canada.
http://www.isprs.org/proceedings/XXXVIII/4-C1/Sessions/Session1/6717_DeKok_Proc_pap.pdf

Elmqvist B., Ardo J., Olsson L., (2008): *Land use studies in drylands: an evaluation of object-oriented classification of very high resolution panchromatic imagery*, International Journal of Remote Sensing, Vol. 29, No 24, pp. 7129–7140.

Hajek F., (2005): *Object-oriented classification of remote sensing data for the identification of tree species composition*, Proceedings of ForestSat 2005 Conference, 31 May – 3 June 2005, Boras, Sweden.
http://www.ecognition.com/sites/default/files/229_forestsat2005_20__20filip_20hajek.pdf

Kressler F.P., Steinnocher K., Kim Y.S., (2005): *Enhanced Semi-Automatic Image Classification of High-Resolution Data*, Proceedings of the IGARSS 2005 Symposium, Seoul, Korea, 25–29 July 2005. http://www.ecognition.com/sites/default/files/240_igarsskressler2.pdf

Lewinski St., Bochenek Z., (2008): *Rule-based classification of SPOT imagery using object-oriented approach for detailed land cover mapping*, Proceedings of 28th EARSeL Symposium „Remote sensing for a changing Europe", Istanbul, Turkey, 2–5 June 2008, pp. 197–204.

Lucas R., Rowlands A., Brown A., Keyworth S., Bunting P., (2007): *Rule-based classification of multi-temporal satellite imagery for habitat and agricultural land cover mapping*, ISPRS Journal of Photogrammetry and Remote Sensing, Vol. 62, Issue 3, August 2007, pp. 165–185.

Su W., Li J., Chen Y., Liu Z., Zhang J., Low T.M., Suppiah I., Hashim S.A.M., (2008): *Textural and local statistic for the object-oriented classification of urban areas using high-resolution imagery*, International Journal of Remote Sensing, Vol. 29, No 1, pp. 3105–3117.

Wei W., Chen X., Ma A., (2005): *Object-oriented Information Extraction and Application in High-resolution Remote Sensing Image*, Proceedings of the IGARSS 2005 Symposium, Seoul, Korea, 25–29 July 2005, pp. 3803–3806.

Whiteside T., (2005): *A multi-scale object-oriented approach to the classification of multi-sensor imagery for mapping land cover in the top end*, Proceedings of NARGIS 2005 – Application in Tropical Spatial Science. 4–7 July 2005, Charles Darwin University, Darwin, NT, Australia. http://www.ecognition.com/sites/default/files/272_18.1_20whiteside__20tim.pdf

Yuan F., Bauer M.E., (2006): *Mapping impervious surface area using high resolution imagery: A comparison of object-based and per pixel classification*, Proceedings of ASPRS 2006 Annual Conference, Reno, Nevada; 1–5 May 2006. http://www.ecognition.com/sites/default/files/184_asprs2006_0178.pdf

Zastosowanie metody obiektowej klasyfikacji wysokorozdzielczych zdjęć satelitarnych z wykorzystaniem podejścia parametrycznego i informacji o teksturze

Stanisław Lewiński
Instytut Geodezji i Kartografii, ul. Modzelewskiego 27, PL 02-679 Warszawa
Tel.: +48 22 3291976, Fax: +48 22 3291950, E-mail: stanislaw.lewinski@igik.edu.pl

Zbigniew Bochenek
Instytut Geodezji i Kartografii, ul. Modzelewskiego 27, PL 02-679 Warszawa
Tel.: +48 22 3291977, Fax: +48 22 3291950, E-mail: zbigniew.bochenek@igik.edu.pl

Konrad Turlej
Instytut Geodezji i Kartografii, ul. Modzelewskiego 27, PL 02-679 Warszawa
Tel.: +48 22 3291991, E Fax: +48 22 3291950, -mail: konrad.turlej@igik.edu.pl

Streszczenie. W artykule przedstawiona jest metoda klasyfikacji wysokorozdzielczych zdjęć satelitarnych. Została ona opracowana w Instytucie Geodezji i Kartografii w ramach europejskiego projektu Geoland 2 – serwisu SATChMo.

Algorytm klasyfikacyjny, którego celem jest rozpoznanie podstawowych klas pokrycia terenu, został opracowany z zastosowaniem podejścia obiektowego. Jego działanie zostało sprawdzone na podstawie zdjęć KOMPSAT-2 rejestrujących obrazy w czterech kanałach wielospektralnych (4 m) oraz w kanale panchromatycznym (1 m).

Struktura algorytmu zbliżona jest do drzewa decyzyjnego i składa się z szeregu kolejno wykonywanych procesów. Podstawowe założenie przyjętego sposobu postępowania stanowi podział treści zdjęcia na obiekty charakteryzujące się niskimi i wysokimi wartościami tekstury. Jest on wykonywany na podstawie przetworzonego filtrami Sigma kanału panchromatycznego. Najpierw klasyfikowane są obiekty z grupy tzw. wysokiej tekstury a następnie pozostałe. Stosując parametryczne kryteria rozpoznania, w pierwszej grupie obiektów klasyfikowane są lasy, roślinność rozproszona, zabudowa oraz tereny pozbawione pokrywy roślinnej. Obiekty niesklasyfikowane są automatycznie dołączane do drugiej grupy obiektów, w ramach której rozpoznawane są wody oraz tereny rolnicze. W toku procesu klasyfikacji jest wykonywany szereg segmentacji dedykowanych poszczególnym klasom. Obiekty mniejsze od 0.25 ha są poddawane generalizacji.

Słowa kluczowe: klasyfikacja obiektowa, pokrycie terenu, KOMPSAT 2