Archives of Photogrammetry, Cartography and Remote Sensing,
special issue: Monograph „Measurement Technologies in Surveying", pp. 109-117
ISBN 978-83-61576-26-7

STUDIES ON PANSHARPENING AND OBJECT-BASED CLASSIFICATION OF WORLDVIEW-2 MULTISPECTRAL IMAGE

BADANIA NAD WYOSTRZENIEM I KLASYFIKACJĄ OBIEKTOWĄ WIELOSPEKTRALNEGO OBRAZU WORLDVIEW-2

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KEY WORDS: WorldView-2; multispectral pansharpening; object-based classification

SUMMARY: The new information contained in four additional spectral bands of high-resolution images from the satellite sensor WorldView-2 should provide a visible improvement in the quality of analysis of large-scale phenomena occurring at the ground. Selected part of the image of Poznan was analyzed in order to verify these possibilities in relation to the urban environment. It includes riverside green area and a number of adjacent buildings. Attention has been focused on two components of object-oriented analysis – sharpening the image and its classification. In terms of pansharpening the aim was to obtain a clear picture of terrain objects in details, what should lead to the correct division of the image into homogenous segments and the subsequent fine classification. It was intended to ensure the possibility of separating small field objects within the set of classes. The task was carried out using various computer programs that enable the development and analysis of raster data (IDRISI Andes, ESRI ArcGIS 9.3, eCognition Developer 8) and some own computational modules.
The main scientific objective of this study was to determine how much information from new spectral image layers after their pansharpening affects the quality of object-based classification of land cover in green and building areas of the city. As a basis for improving the quality of the classification was above mentioned ability of using additional data from new spectral bands of WorldView-2 image.
To assess the quality of the classification we used test that examines only the uncertain areas of the picture, that is these which lie on differently classified types of land cover. The outcome of assessment confirmed the thesis of the positive albeit small impact of additional spectral channels on the result of object-based classification. But also pansharpening itself only slightly improves the quality of classified image.

1. INTRODUCTION

Classification of very high resolution satellite (VHRS) images can provide many significant conclusions about phenomena occurring on the surface of the earth. It is especially important for areas where most human activities are developed, what can course significant changes of natural resources. There are significant changes in natural resources and ecosystems within and surrounding such places (Powell et al., 2007). They can be the main subject of analyses of remote sensing sources.

The high-resolution, multispectral sensor WorldView-2 makes a new standard of acquisition and recording RS data by registering in the new four spectral channels, while

providing 0.5-meter geometric resolution of the panchromatic band (Whitepaper, 2009, p.1; Wyczalek et al., 2010). Information from the new channels is useful primarily in studies of coastal waters, vegetation and atmospheric corrections (Whitepaper, 2009, p.2). Additional spectral channels should also help to raise the accuracy of classification of the terrain objects. However, it is hard to detect descriptions of some significant achievements, apart from a few mentions on the increase in the overall rate of accuracy of classification, especially an object-based one – OBIA (Carvalho, 2012).

OBIA – the technique which helps to analyse images (and/or other datasets) based on hierarchically organized segments (objects) – has been developed since the beginning of the 21th century (Blaschke, 2010). Image objects are built from radiometrically homogenous pixels which are clustered taking into account their shapes and continuities. Segmentation, as well as classification, can be conducted in a hierarchical manner at several scale levels. It allows common analytical operations on multiple layers of information – not only a number of spectral channels, but also a variety of thematic databases.

2. THE SUBJECT OF RESEARCH

2.1. Study area

The subject of analysis is small part of recreational areas over Warta River in Poznan (Fig. 1). The site is planted with trees, with sport facilities located in open places and residential development and workshops in the peripheries. It illustrates typical for post-industrial societies process of converting natural areas into parks with some recreational functions, and with development just outside their boundaries.

The test field covers an area of 320×240 meters. Tall objects, i.e. buildings and trees, are visible slightly to the side, from the southeast, due to the inclination of the sensor during registration. Non visible parts and the nearby area are heavily shaded. This phenomenon should be reflected in the classification procedure.

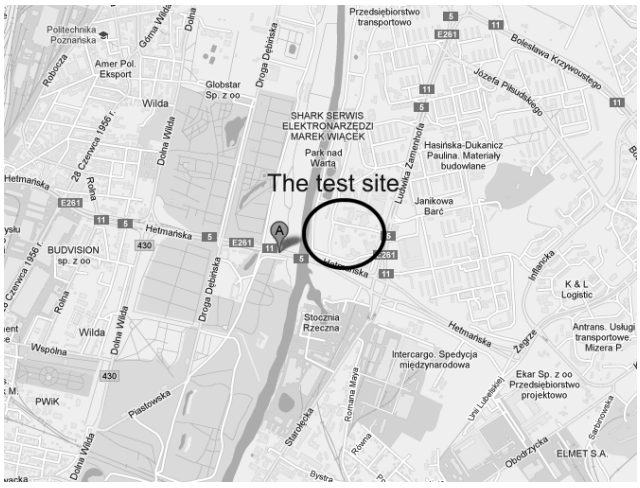

Fig. 1. The map of study area consisting of a green area over the Warta River and built sites in the neighbourhood (Google Map, 2012)

2.2. The image

The analyses had been done on the image data set containing panchromatic band and 8 spectral channels registered by the WorldView-2 satellite on 5 May 2010 at 10:02 hour of local time. During scanning the camera was rotated backwards at the angle of 12° along the orbit, and 7.5° in perpendicular direction. The sun rays illuminated the scene from the angle of 53°. There was very good visibility during the recording, but the area was obscured by separate clouds. The acquired raw data had been converted onto 2A OrthoReady standard. Panchromatic band has final spatial resolution 0.5 m, and the spectral layers are processed into spatial resolution 2×2 m. Spectral responses had been stored in 11-bit format, but in practice DN values are within the range of about 500-800 units, depending on the wavelength. Image producer gave very good opinion of its interpretational ability, i.e. 3.6 degree in a 9-stage scale of NIIRS.

The part covering the above described area had been extracted from the composition of all image channels. In the image it can be recognized roadways, sidewalks, playgrounds as well as cars, separate trees, areas covered with grass, bushes and exposed soil surfaces. To compose high-resolution colour image it was necessary to process spectral bands (MS) to the resolution of panchromatic (Pan) band with one of the pansharpening methods.

3. PROPOSED METHOD OF PANSHARPENING

The choice of pansharpening or image fusion method to increase geometric resolution of all spectral channels depends on the aim, which in this case is the classification of objects. In this context, methods that can fuse only three or four of the eight of WorldView-2 channels to the panchromatic space (e.g. IHS) should fall out of consideration. The proper ones must also take into account that the Pan channel covers different parts of colour space than the considered set (more than 3) of spectral channels.

The methods used to sharpen the multispectral image data assume by default that the panchromatic layer covers all spectral bands. Namely, Principal Components Transformation (PCT) replace the first principal component (PC1) calculated for the whole image by the values of pixels from the Pan layer and then – perform inverse transformation. Hyperspherical Color Space (HCS) Pan Sharpening (Padwick et al. 2010) developed for WorldView-2 imagery also assumes comparability of the total range of spectral bands with the range of panchromatic one. Meanwhile, the range of electromagnetic wavelengths of panchromatic component is narrower (White Paper, 2009). In particular, the wavelengths corresponding to the channels C and NIR2 fall entirely outside the scope of panchromatic. In this study we developed modified variant of HCS transformation which in greater degree matches panchromatic image to the set of spectral channels. The applied model describes weighted Instensity (I_W) using relation:

$$I_W = \sqrt{w_1\chi_1^2 + w_2\chi_2^2 + \cdots + w_8\chi_8^2} \text{ instead of: } I = \sqrt{\chi_1^2 + \chi_2^2 + \cdots + \chi_8^2}$$

where the weights (w_i) for the different channels are proportional to their participation in the range of panchromatic band. For this reason, the method have been called here the Weighted Hyperspherical Color Space (HCS/W) transformation.

Figure 2 shows RGB composition of results of both mentioned methods, e.g. PCT (c) and HCS/W (d) compared to the base image: Panchromatic (b) and MS (b).

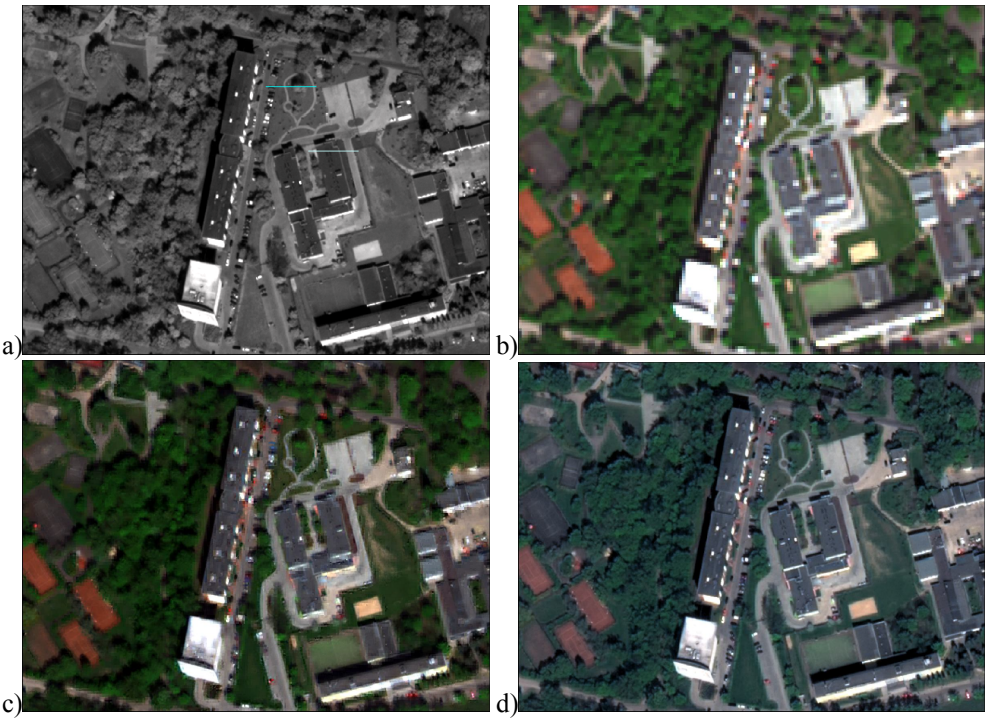

Fig. 2. The panchromatic (a) and spectral (b) layers of WorldView-2 image, the result of Principal Components (c) and Weighted Hyperspherical Color Space (d) transformations of test area, Poznan, Poland (composition of bands 2-3-5, geometrically degraded for presentation)

4. OBIA

Among the commonly used methods of image classification the object-based analyses (OBIA) are praised mainly because of the generalization of complexes of pixels (image objects) represented certain types of coverage (Blaschke, 2010). Such images appear to be more readable, and this makes easier further assessment of the nature of land cover. Basically the object-oriented classification approach is preceded by an image segmentation, which can take a multilevel hierarchical structure. Segmentation leads to separation in the image compact groups of pixels with similar radiometric and (partly) geometric features.

In described work object-based analysis was performed on all layers of WorldView-2 image using the program eCognition Developer 8, in three versions:

- original Pan (Fig. 2a) and MS channels (Fig. 2b),
- spectral channels sharpened using PCT (Fig. 2c),
- spectral channels sharpened using HCS/W transformation (Fig. 2d).

Although the recommended options include thematic layers, the work was performed only on the image data plus NDVI layer in order to avoid the influence of other factors in the process and results of classification.

4.1. Segmentation and classification of the test image

The modern approach to the object-based analysis mixes segmentation with separation of land cover classes. Such approach has been used in this work. The procedure of segmentation was the result of a number of trials combined with the assessment of obtained results. Finally, at first the image has been divided into small segments (scale = 9) with respect to colour ratio = 0.7 and compactness ratio = 0.8. In the picture fragmented such a way vegetation cover was isolated using NDVI index, and then segments were grouped according to scale factor = 18 and saved in the Level_2. In this level the different categories of green (grass, bushes, and trees) were separated. The rest of the image was segmented twice (scale = 18 and 36 respectively) and then isolated areas of walls and roofs, sidewalks, asphalt pavement, soil and sand were defined. Separation of different classes took place either by binary division based on the dominant attribute, or – according to typical strategy of OBIA: through separation of several classes based on few attributes compared simultaneously. The flowchart of the above steps is presented in Figure 3. For different data sources the parameters (values) of classification criteria were adjusted individually.

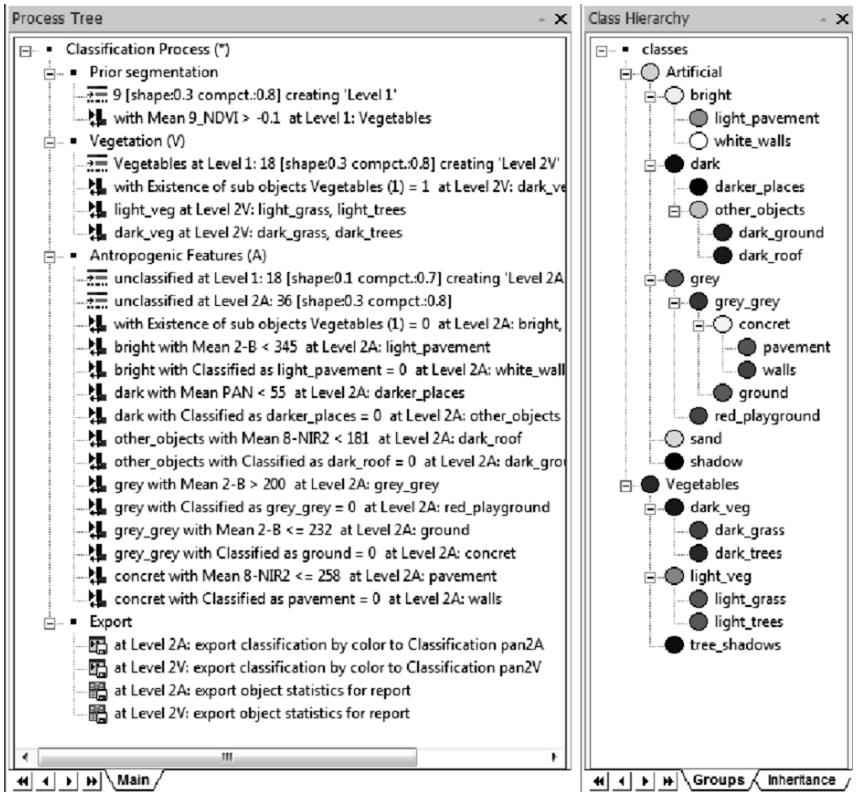

Fig. 3. Process tree and class hierarchy defined in eCognition Developer 8

There are only few points in the process tree when information from new channels was useful because of significant difference between values of compared classes. Mainly using NIR2 it was possible to select darker artificial objects such as roofs and pavements. Also new bands were used together with the other for segmentation, but their influence is not simple to detect. The most interesting was influence of pansharpaning – it was analyzed more carefully in this project.

4.2. The influence of pansharpaning on classification

Classification results for the source image data (Pan + 8MS and NDVI layer) and two fused images are shown in Figures 4a-c. Resulting images have very good separation of different types of land cover. To assess which approach is better the differences between the three images have been considered. For assessment, only points located between various types of land cover were taken into account. It was counted how often the control points are assigned to the correct class. As the best was found this classification, which most often selects correctly proper class. Obtained results are as follows: 68% correct types for original data (source Pan and MS bands), 66% for PCT sharpened and 74% for the image after HCS/W transformation. The results point out, that fused objects can be better classified, but the quality depends on the method used for pansharpening.

Fig. 4. Three results of object-based classification: a) in original image layers, b) after PCA and c) HCS/W sharpening transformation.

Next evaluation was made by comparing the classification results pairwise – namely the classification of the source data (a) and its counterpart on the fused images (b and c). Figures 5 shows differences a-b and a-c, respectively. There are more patches in the second comparison, what suggests that third classification gave significantly different results.

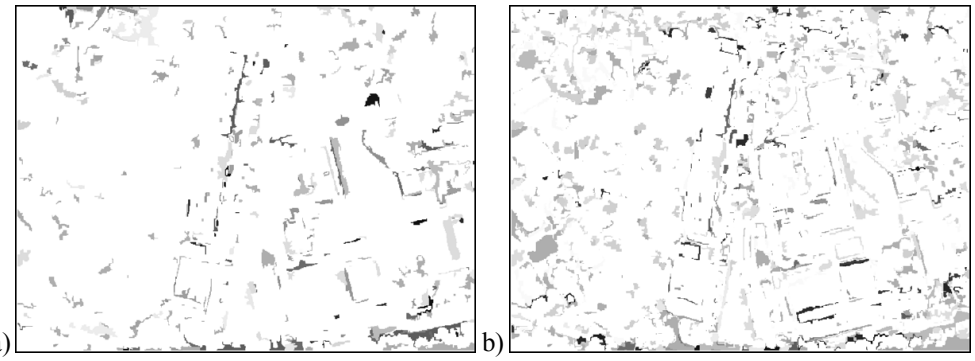

Fig. 5. Differences between results of classification made on the source image data and the image sharpened using PCT method (a) and HCS/W transformation (b)

Counting differences in above mentioned 100 control points one can get results presented in table 2. The numbers in the table say, that in both cases more than 50% control points were correctly classified, but for the remaining points:

- there are no significant difference between variants (a) and (b) – about 50% of points fall into the appropriate class, and the remaining 50% was ill classified,
- there is the difference between variants (a) and (c) – about 50% of points were correctly classified in the fused image, and only 35% in the source image.

This confirms the conclusion about effective influence of Weighted Hyperspherical Color Space (HCS/W) transformation on the classification results.

Table 2. Comparison of classification results on source image data (a) and images sharpened using PCT (b) and HCS/W (c) transformations

correctly classified	both	only a	only b	none
sum	55	13	11	21
percent		28.9%	24.4%	46.7%
	both	only a	only c	none
sum	51	17	23	9
percent		34.7%	46.9%	18.4%

5. DISCUSSION AND CONCLUSIONS

Very high resolution multispectral satellite (VHRMS) images are important source of spatial data for different spatial issues. As it was already mentioned, they are often useful as additional source to image data routinely used in various types of spatial analyzes. These

additional abilities can be referred to one or more forms of image use: the interpretation, classification or visualization of phenomena or area of their occurring (Zhang, 2004). In this paper we focused on object-oriented classification of land cover using all channels of WV-2 image. From this point of view, both techniques were evaluated – pansharpening of multispectral image and the secretion of various sites of different land-cover classes. It was noticed, that mainly NIR2 data was useful in hierarchical classification. Other bands were used only for segmentation.

It was also compared how pansharpening affects the accuracy of classification. The object-based approach discussed here proved to be rather insusceptible to pansharpening. Prerequisite is to conduct analyzes in the image with spatial resolution of panchromatic band, and to take into account tonal differentiation contained in the image.

It was also concluded that there is no good way to evaluate the results of detailed classification, where the main variation in results is at uncertain locations just between individual objects. It was proposed new way of assessing the accuracy of classification based on the selection only such points which lie in those questionable places. It differs from the commonly calculated overall accuracy rate κ (kappa), which is formed on the base of series of points distributed randomly over the entire surface of the image. This way control points are in different locations inside each class, mainly in places that are in most cases identified correctly by any classification procedure. Whereas the percentage of selected points that lay near the borders of classes, the most uncertain, is smaller.

The obtained results show a similar degree of correctness of the definition of objects in uncertain locations, with slight dominance of classifications made in the image fused using Hyperspherical Color Space (HCS/W) transformation, modified by authors by adding weights. It seems that for achieving better results of classification the improvement of the quality of images by sharpening should be intensively developed.

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SŁOWA KLUCZOWE: WorldView-2; pansharpening wielospektralny; klasyfikacja obiektowa

Streszczenie

Nowa informacja zawarta w czterech dodatkowych kanałach spektralnych wysokorozdzielczych obrazów z sensowa satelity WorldView-2 powinna zapewnić widoczną poprawę jakości analizy wielkoskalowych zjawisk zachodzących na ziemi. Analizowano wybrany fragment obrazu Poznania w celu sprawdzenia tych możliwości w odniesieniu do środowiska miejskiego. Obejmuje on nadrzeczną zieleń, obiekty sportowe i szereg sąsiednich budynków. Uwagę skoncentrowano na dwóch elementach analizy obiektowej – wyostrzeniu obrazu i jego klasyfikacji. Z punktu widzenia pansharpeningu celem było uzyskanie czystego obrazu szczegółów obiektów terenowych, co powinno doprowadzić do prawidłowego podziału obrazu na jednorodne segmenty i jego późniejszej szczegółowej klasyfikacji. To miało zapewnić możliwość oddzielenia małych obiektów terenowych w granicach zbioru klas. Zadanie zostało przeprowadzone za pomocą różnych programów komputerowych, które pozwalają na opracowanie i analizę danych rastrowych (Idrisi Andes, ESRI ArcGIS 9.3, eCognition Developer 8) i kilku własnych modułów obliczeniowych.
Głównym celem naukowym tego studium było określenie, jak bardzo informacja z nowych warstw obrazu spektralnego po jego wyostrzeniu wpływa na jakość opartej na obiektach klasyfikacji pokrycia terenu naturalnych i zabudowanych fragmentów krajobrazu miieskiego. Jako podstawa do poprawy jakości klasyfikacji była wyżej wskazana możliwość korzystania z dodatkowych danych z nowych kanałów spektralnych zobrazowania WorldView-2.
Aby ocenić jakość klasyfikacji wykorzystaliśmy test, który sprawdza tylko niepewne obszary obrazu, to jest te, które znajdują się pomiędzy różnymi rodzajami pokrycia terenu. Wynik oceny potwierdza tezę o pozytywnym choć niewielkim wpływie dodatkowych kanałów spektralnych na wynik klasyfikacji obiektowej. Ale także sam pansharpening tylko nieznacznie poprawia jakość klasyfikacji obrazu. Najlepsze wyniki dała klasyfikacja bazująca na ważonej, hipersferycznej transformacji przestrzeni barwnej (HCS/W).

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