

COMPARISON OF DIFFERENT APPROACHES TO EXTRACT HETEROGENEOUS OBJECTS FROM AN IMAGE USING AN ORCHARDS EXAMPLE

P. Kupidura, L. Gwadera

Warsaw University of Technology, Faculty of Geodesy and Cartography, Laboratory of Remote Sensing and GIS,
Pl. Politechniki 1, 00-661 Warsaw, Poland – p.kupidura@gik.pw.edu.pl

Commission III, ICWG III/VII

KEY WORDS: Digital, Land Use, Classification, Processing, Detection, Quickbird

ABSTRACT:

Traditional, pixel-based classification is very often an useless tool for an automatic extraction of heterogeneous types of land cover. This paper presents the application of mathematical morphology for a semi-automatic extraction of heterogeneous objects using an example of orchards. Thanks to this algorithm it is possible to obtain orchards pixels of unique set of digital numbers, allowing successful application of a traditional pixel-based classification for extraction of this class. The algorithm concerning a sequence of morphological operations of multispectral satellite images of very high resolution (VHR) is then verified on test images. The paper concerns also a comparison of an efficiency of the mathematical morphology algorithm with other methods suitable for that purpose: one based on texture analysis and an object-based classification.

1. INTRODUCTION

Orchards as a land use class are very easy to extract in the process of visual interpretation thanks to their characteristic regular pattern. In the VHR satellite images orchards are presented as a specific structure of trees or bushes on the grass or other type of background. Depending on orchard type or age as well as the date of image acquisition they can show different properties but still they are easy to identify. Simultaneously this orchard feature makes their extraction in the semi-automatic process of pixel-based classification very difficult. This type of classification is based on the similarity of pixel's digital numbers to some model sets of digital numbers called signatures, collected during the "training" process. Due to the heterogeneous nature of orchards there is no set of digital numbers typical and unique for this type of land use, so one obtains two or more classes e.g. of trees and grass or bare soil instead of one class of orchards. In this situation it is obvious, that an extraction of objects characteristic for their contextual features like a texture is characteristic for orchards demands a contextual approach. And the comparison of different contextual approaches as tools for orchards extraction of an image is the aim of this paper.

Three different methods have been compared. The first one is based on a texture analysis – the images obtained by a texture analysis of original satellite or aerial photos have been included as a dataset for a pixel-based classification. This way, the contextual (texture) data can be taken into account in a classification process. The second method is a typical object-based classification. An image is firstly segmented and then a classification of the obtained segments is applied, taking into account different, also contextual features (Definiens AG, 2005). The third method is the mathematical morphology based approach, in some ways similar to the texture analysis based classification (the first presented method). The first step of this approach is a morphological processing of the original image, and the second step is a pixel-based classification of the images obtained during this morphological process. This way also the contextual characteristics of the image can be taken into account in the classification process.

Two images have been used for the tests: a color aerial image and a satellite Quickbird multispectral image.

The methods described briefly above have been tested comparing to the results of the visual photo-interpretation using ArcGIS software. The binary masks representing orchards obtained using methods being tested have been compared to the referential mask obtained during the photo-interpretation. The accuracy of the binary masks of orchards has been measured using the kappa index of agreement – its value expresses the accuracy of the method.

2. COMPARED METHODS OF CLASSIFICATION

Three different methods of contextual classification have been compared: texture analysis based classification, object-based classification and mathematical morphology based classification.

2.1 Texture analysis based classification

Texture of a digital image is a spatial distribution of pixels of different brightness (digital numbers) including its regularity and mutual relations.

Erdas Imagine software has been used for a texture analysis of the test images. In this software texture analysis bases on four different statistical measures:

- Mean Euclidean Distance,
- Variance,
- Skewness,
- Kurtosis.

There are also other texture-based approaches using different measurements like correlation, variograms etc. However, they are not presented in this paper.

Variance was used as a statistical measure for the texture analysis in the presented research. It is a value of the deviation of the variable from its expected value:

$$V = \frac{\sum(x_{ij}-M)^2}{n-1}, \quad (1)$$

where: x_{ij} is a value of a pixel (i,j),
 n is a number of pixels in a window,
 M is a mean value of all pixels in a window:

$$M = \frac{\sum x_{ij}}{n}. \quad (2)$$

Using the texture analysis tool, the new images have been created (a variance was computed for a window of 7x7 pixels size). Products of the texture analysis – images presenting variance values for each pixel have been combined with the original bands of the images and such a dataset has been classified using a supervised pixel-based classification.

2.2 Object-based classification

Definiens Developer v. 7.0 software was used for an object-based classification. This kind of classification is relatively well known, so it will be presented briefly in this paper. The first step of an object-based classification is a segmentation of an image. The second step is a classification of the extracted segments using different parameters (like a mean value of pixels, standard deviation, size of a segment and many more). Following parameters have been used for the classification of the extracted segments:

- GLCM Standard Deviation,
- GLDV Contrast,
- GLDV Mean,
- GLCM Homogeneity,
- GLCM Correlation.

Readers are referred to the books and articles of object-based classification for an extended background to this kind of classification (Definiens AG, 2005a; 2005b).

2.3 Morphological *hi-low* classification

Mathematical morphology is a set theory approach, developed by J.Serra and G. Matheron. It provides an approach to processing digital images based on geometrical shape. Two fundamental morphological operations – erosion and dilation are based on Minkowski operations. There are two different types of notations for these operations: Serra/Matheron notation (Serra, 1982) and Haralick/Sternberg notation (Sternberg, 1986; Haralick, 1987). In this paper, Haralick/Sternberg notation, which is more often used in practical applications (Nieniewski, 1998) is preferred. In this notation erosion is defined as follows:

$$\varepsilon_B = (X) \cap_{y \in B} X_y \quad (3)$$

$$\text{where: } \hat{B} = \{b: -b \in B\} \quad (4)$$

and dilation as:

$$\delta_B(X) = \cup_{y \in B} X_y, \quad (5)$$

where: B is a structuring element and

$$X_y = \{x + y: x \in X\}. \quad (6)$$

Two other principal operations, opening and closing, are simple sequences of erosion and dilation. Opening is defined by the following equation:

$$\gamma_B(X) = \delta_B(\varepsilon_B(X)) \quad (7)$$

and closing as:

$$\varphi_B(X) = \varepsilon_B(\delta_B(X)). \quad (8)$$

Readers are referred to the books and articles of mathematical morphology for an extended background to morphological operators (Serra, 1982; 1988; Nieniewski, 1998; 2005; Kupidura, 2006).

Before the presentation of the morphological algorithm it is important to present also the idea of *umbra*. Originally it is a latin word used in astronomy which means a shade appearing when a star light is covered by another orb. In a mathematical sense we define an umbra as follows:

$$U(f) = \{(x, t) \in R^2 \times R: f(x) \geq t\}, \quad (9)$$

so for a gray-scale image it is its 3D representation, on which mathematical morphology operators may be applied directly.

The *hi-low* classification is an author-developed method (Kupidura, 2006).

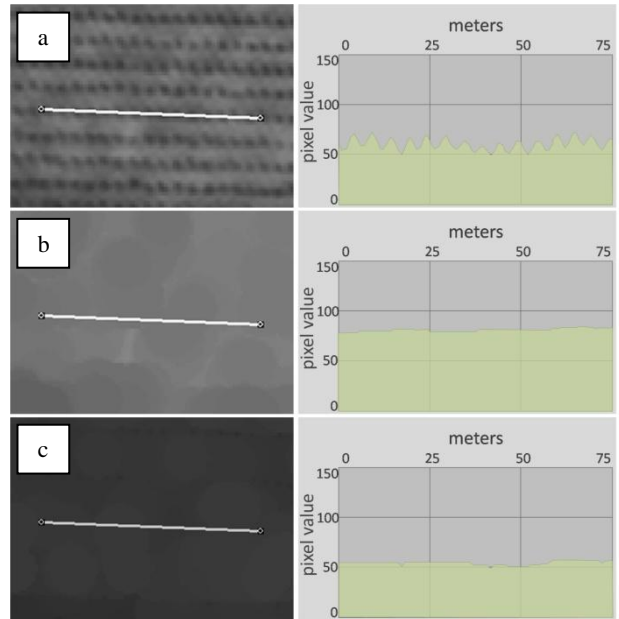


Figure 1. a) original image of orchards, b) its closing, c) its opening; and their spectral profiles

The algorithm bases on a combination of results of opening and closing operations. Figures 1 and 2 illustrate the main idea of this algorithm.

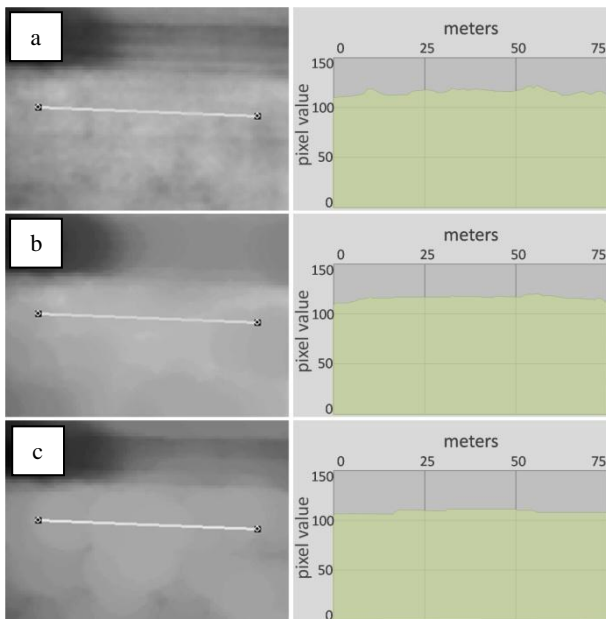


Figure 2. a) original image of grass, b) its closing, c) its opening; and their spectral profiles

The combination consists in the compounding of the results of, independently, opening and closing in a one layer stack.

As mentioned before, heterogeneity of orchards is the main source of difficulty in the extracting their class in the process of a traditional pixel-based classification. However operations of opening and closing due to their specific properties allow to overcome this problem.

Opening and closing are low-pass operations damping spatial frequency of the image. Application of a proper structuring element allows to decrease or suppress heterogeneity of orchard image. Thanks to the nature of these operations and to the “toothed” umbra of orchards (spectral profile in the figure 1) one obtains two completely different umbras of images – one on a higher level of “teeth” after closing and one on a lower level after opening. That is why the “closed” image is much brighter than the “opened” one.

Significant difference between the images of orchards after operations described above is very helpful because it distinguishes this type of land use from other, homogenous types. Remark that the source image pixels of grass look similar to pixels of grass in an orchard. But due to relatively small heterogeneity of the grass image its umbra is not as “toothed” as the umbra of the image of orchard and its opening and closing images are similar.

3. METHODOLOGY AND RESULTS

3.1 Data

Two different images have been used as data for testing an accuracy of different classification methods. First image was a part of a satellite multispectral pan-sharpened Quickbird scene of Lowicz town vicinity (figure 3). The image has been acquired in April 2004.

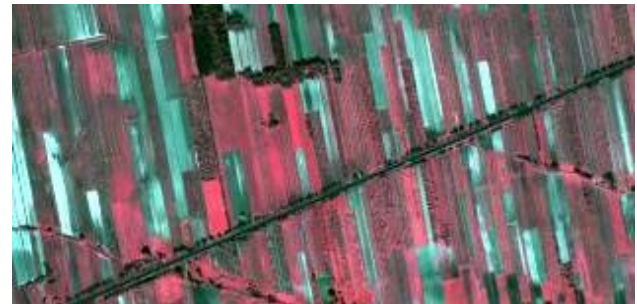


Figure 3. Part of the Quickbird satellite scene from April 2004, composition RGB 432

The second image was a scanned natural colors aerial photo made in scale 1:26000 in April 1997. The photo presents orchards in a Grojec town surroundings (figure 4).



Figure 4. Part of the aerial photo from April 1997, natural colors

3.2 Methodology

Each method of classification among presented in the previous section has been used to create a binary mask of orchards. Simple distinguishing between orchards classes and other (non-orchards) classes has been made in order to verify capabilities of methods being tested to extract land cover classes basing on contextual (texture) features. These binary orchards masks have been compared to referential orchards mask, created manually during a visual photo-interpretation of the images using ArcGIS software.

In order to verify its influence on the accuracy of the orchards mask extraction, additional mathematical morphology operations have been applied on the mask created using different classification algorithms. This post-processing was realized by following sequence:

- Opening of the mask using a small structuring element – size of the element should correspond to the assumed minimal width of an orchard (3 meters in the research presented in the paper), this way thinner objects, probably classified wrongly are removed from the mask.
- Area opening of the already opened mask using a structuring element of a size corresponding to an assumed minimal area of an orchard (50 square meters in the research presented in the paper), so smaller objects, probably classified wrongly can be removed from the mask.

- Closing using a small structuring element – this operation allows to close small disconnections between orchard pixels.

The sequence presented above have been applied on the orchard masks created by each of method being tested, so, additionally, the potential of this process has been verified.

3.3 Results

Firstly, the results for satellite image processing are presented. Figure 5 shows the referential mask of orchards for this image and figures 6, 7 and 8 show the result masks of orchards for different methods, respectively: texture analysis based classification, object-based classification and morphological *hi-low* classification.



Figure 5. The referential masks of orchards for satellite image (orchards marked with white color)

The comparison of an accuracy of the presented methods based on a value of kappa index of agreement and also on values of omission and commission errors. Table 1 presents the results of this comparison.

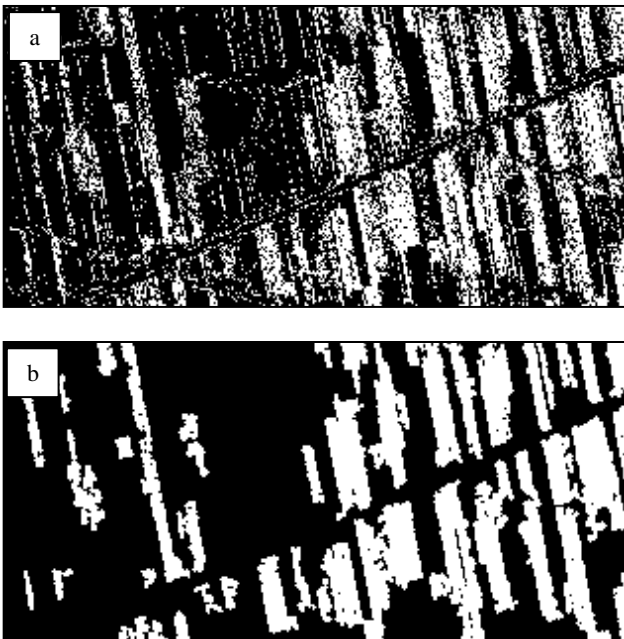


Figure 6. The result of the texture analysis based classification: a) without post-processing, b) with post-processing (orchards marked with white color)

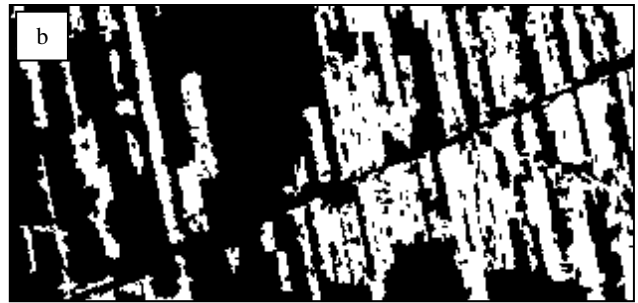


Figure 7. The result of the object-based classification: a) without post-processing, b) with post-processing (orchards marked with white color)

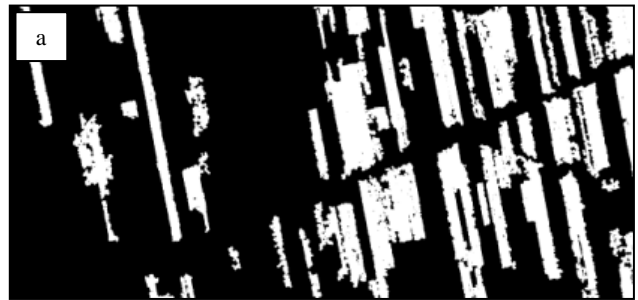


Figure 8. The result of the morphological *hi-low* classification: a) without post-processing, b) with post-processing (orchards marked with white color)

Method	Commission error [%]	Omission error [%]	Kappa
Texture-based	14.6	36.6	0.49
Texture-based with post-process	7.6	24.6	0.68
Object-based	14.3	16.3	0.70
Object-based with post-process	7.5	17.7	0.75
<i>Hi-low</i>	2.4	20.9	0.77
<i>Hi-low</i> with post-process	2.7	17.1	0.80

Table 1. Accuracy of different classification methods for the satellite image

Table 1 shows, that the mathematical morphology based approach has the best accuracy in the presented case. Also the comparison between two figures: 8 and 5 indicates relatively big similarity of two masks: one created using this approach and one referential. What is also important, the proposed morphological post-processing improved accuracy of results of all methods.

The results obtained for the second image – the aerial photo are presented below.

Figure 9 presents the referential mask of orchards, while figures 10, 11 and 12 present the results of the following methods: texture analysis based classification, object-based classification and morphological *hi-low* classification.



Figure 9. The referential masks of orchards for aerial photo image (orchards marked with white color)

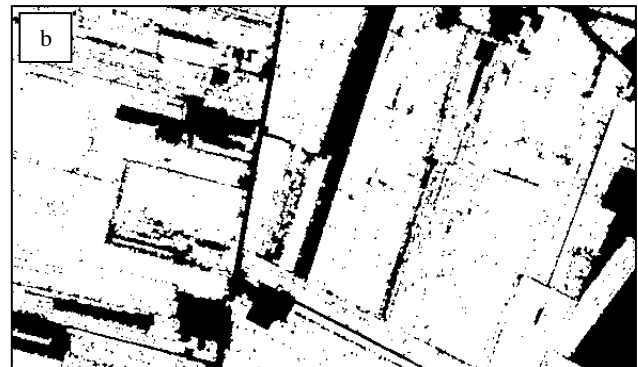


Figure 10. The result of the texture analysis based classification: a) without post-processing, b) with post-processing (orchards marked with white color)



Figure 11. The result of the object-based classification: a) without post-processing, b) with post-processing (orchards marked with white color)

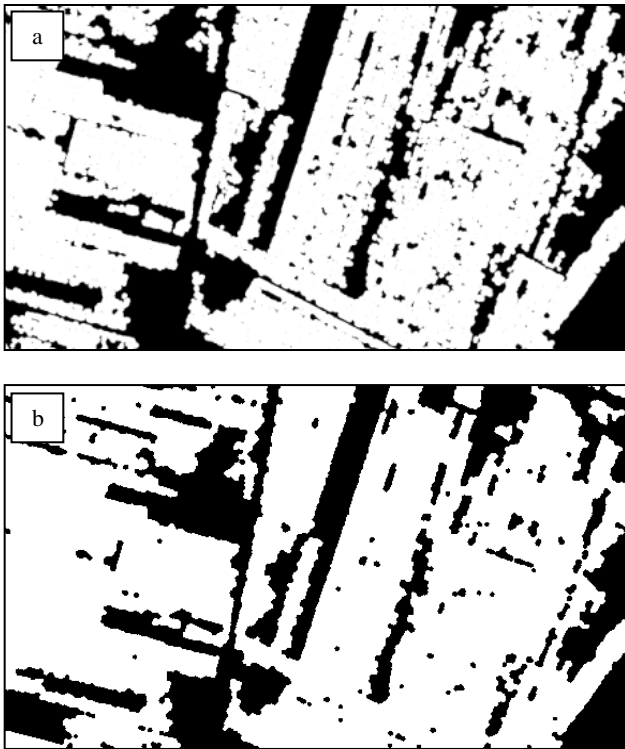


Figure 12. The result of the morphological *hi-low* classification: a) without post-processing, b) with post-processing (orchards marked with white color)

Table 2 presents the comparison of the accuracy of different methods using kappa index values as well as values of commission and omission errors.

Method	Commission error [%]	Omission error [%]	Kappa
Texture-based	32.8	15.5	0.52
Texture-based with post-process	28.7	10.6	0.61
Object-based	38.2	14.2	0.48
Object-based with post-process	30.1	16.4	0.54
<i>Hi-low</i>	16.3	16.5	0.67
<i>Hi-low</i> with post-process	18.3	14.2	0.68

Table 1. Accuracy of different classification methods for the aerial photo

Also in this case, the morphological approach gives the best result among all presented methods. And, as it has been noticed also in the case of the satellite image, the additional morphological operations improved the results of all tested approaches.

The difference between the results obtained for the satellite image and the aerial photo can be noticed – the results of all methods obtained for the aerial photo are significantly worse than ones obtained for the satellite image. The probable reason

is a lack of infrared band where the difference between a vegetation and other types of land cover can be seen very well, much better than in visible bands. This difference makes the texture of orchards “clearer” what is important for all the methods presented in this paper.

4. CONCLUSIONS

The research presented in this paper showed, that the morphological *hi-low* classification, developed for the extraction of heterogeneous classes in aerial and satellite images has an important potential. The additional mathematical morphology operations proposed for the improvement of the results obtained during classification of an image actually improved the results significantly, it is however the determination of parameters for these processes are very important. These facts confirm, that mathematical morphology has a big potential to offer in the matter of digital image processing in remote sensing.

However, this method does not take into account the periodicity and the alignment of trees in orchards, so it might behave similarly in case of other landcover theme consisting of heterogeneous elements but distributed differently. The possible solution of this kind of problem might be an additional application morphological operations with multiple structuring element. This idea should be tested in the future.

The presented results also show, that a infrared band is an important data source not only for vegetation quality assessment, but also for such an object-based approaches as presented in this paper.

5. REFERENCES

2005. Definiens Developer 7. Reference Book, München: Definiens AG.

2005. Definiens Developer 7. User Guide, Munich: Definiens AG.

Haralick, R. M., Sternberg, S. R., Zhuang, X, 1987. Image Analysis using Mathematical Morphology. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 9(4), pp. 532-550.

Kupidura P., 2006. *Zastosowanie wybranych operacji morfologii matematycznej do wydzielenia klas pokrycia terenu na zdjęciach satelitarnych*, Ph.D. thesis, Warsaw University of Technology, Warsaw, 2006.

Nieniewski, M., 1998. *Morfologia matematyczna w przetwarzaniu obrazów*. Akademska Oficyna Wydawnicza PLJ, Warsaw.

Nieniewski, M., 2005. *Segmentacja obrazów cyfrowych*. Akademska Oficyna Wydawnicza EXIT, Warsaw

Serra, J., 1982. *Image Analysis and Mathematical Morphology, Vol.1*. Academic Press, London.

Serra, J., 1988. *Image Analysis and Mathematical Morphology, Vol.2 Theoretical Advances*. Academic Press, London.

Sternberg, S.R., (1986): Grayscale Morphology. *Computer Vision Graphics and Image processing*, 33(5) pp. 333-355