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# IMPROVEMENTS OF THE SEGMENTATION OF MULTISPECTRAL IMAGES BY MEANS OF LSMA

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***Keywords:*** *multispectral data, linear spectral mixture analysis, segmentation*

***Abstract:*** *The classification procedure relying on data spectral properties is often preceded by segmentation which in turn might be greatly improved by a preliminary sub-pixel analysis and mixed-pixel decomposition. A generally accepted meaning of the word 'segmentation' in the image processing community is the decomposition of the image under study into its different and homogeneous regions of interest (RoI). In this study, we have been focused on the assumption that, by applying the linear spectral mixture analysis (LSMA) on the border line of an image, one could achieve better segmentation than relying on spectral or geometrical properties only. In the LSMA, the mixed pixels, especially those in the border areas of the image are expressed as linear combinations of the respective spectra of the basic land cover types presented in the image. By implementing the LSMA on the data, the segments' smoothness was improved.*

# ПОДОБРЯВАНЕ НА СЕГМЕНТАЦИЯТА НА МНОГОСПЕКТРАЛНИ ИЗОБРАЖЕНИЯ ЧРЕЗ АНАЛИЗ НА СПЕКТРАЛНИ СМЕСИ

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***Ключови думи:*** *спектрални данни, сегментация, анализ на спектрални смеси*

***Резюме:*** *Процедурата по сегментация е основна при анализа на смесени пиксели в едно изображение и съответната им класификация. В процеса на работа най-общо понятието "сегментация" включва декомпозиция на изображения, които преобладават в градация на сивия цвят, като целта е да се определят различни хомогенни участъци и обекти. В настоящето изследване сме се фокусирали на допускането, че използването на анализа на спектрални смеси в едно изображение би довело до по-добра сегментация спрямо прилагането само на един метод за декомпозиция. При анализа на спектрални смеси смесените пиксели, особено в граничните зони между участъците и обектите в изображението, са представено като линейни комбинации от съответните спектри на основните типове земно покритие, които са представени в изображението. Допълнителното използване на анализа на спектралните смеси повиши гладкостта на контурите на отделните учасъци и обекти.*

## Introduction

The unsupervised classification of different land cover types based on multispectral data, using pixel by pixel method, is the final stage of the process of forming information classes based on those data. In order to achieve better results it is advisable first to delineate the shapes of areas consisting of similar data i.e. pixels being comparable in the spectral domain. This process is referred as segmentation.

Segmentation of satellite images is one of the main tasks that need to be solved in the process of detection of geometric forms belonging to distinct land covers. In recent years a great variety of methods for satellite images segmentation was developed [1]. The aim of this study was to combine applicability of two methods for image processing for information extraction from satellite images - namely object-oriented approach and linear spectral mixture analysis (LSMA). On the first step the multivariate segmentation realized by the eCognition package is used [2]. This patented algorithm is often considered as starting point for comparison of the newly developed ones. On the next stage LSMA is applied on the mixed pixels especially those in the border areas. It was supposed that implementing the LSMA on the pixels forming the line between the segments their smoothness and correctness is seriously improved. This method was applied for segmentation of a satellite image over a region in north-central part of Bulgaria. The obtained results were compared and the advantages and disadvantages of the methods are discussed. Conclusions about applicability of applied method for improving the segmentation of satellite images are also made.

**Materials and methods**

Segmentation procedure has key role in sub-pixel analysis and mixed-pixel classification. A generally accepted meaning of the word segmentation in the image processing community is the decomposition of the image under study (most often grayscale) into different and homogeneous regions of interest (RoI). In this research we have been focused on the assumption that applying the LSMA on the delineating pixels after the segmentation procedure one could achieve better segmentation than relying on grayscale image.

In the recent years two approaches are quite popular.

- The most classical segmentation method of *Mathematical Morphology* is the Watershed segmentation. Mathematical Morphology has been applied successfully in many fields, such as medical imaging, material sciences, and machine vision, and many attempts were related to the processing of remotely sensed images, including segmentation of SAR image.
- eCognition is based on an *object oriented* approach to image analysis. The basic difference to pixel-based procedures is that eCognition does not classify single pixels, but rather image object primitives that are extracted in image segmentation step.

Mathematical morphology – uses the *Watershed algorithm,* which is the standard algorithm allowing the determination of the crest lines. It consists in a simulation of an immersion of the altitude map. To realize this, we make a hole at each local minimum of the gradient image by which the water can enter. If a drop of water falls on such a topographic surface, it will obey the law of gravitation and flow along the steepest slope path until it reaches a minimum. The whole set of points of the surface whose steepest slope paths reach a given minimum constitutes the catchment basin associated with this minimum. The watersheds are the zones dividing adjacent catchment basins.

Object oriented approach - here similar pixels are grouped into segments where the heterogeneity in spectral and spatial domain is minimized. Adjacent segments form a new segment, if the new increase of heterogeneity is minimum and below a specified level. The heterogeneity is assumed to be a compromise between homogeneity in spectral domain (e.g. reflectance values on several wavelengths) and spatial domain of segments is possible. Homogeneity in spectral domain is defined by a channel dependent weighted standard deviation. By definition the homogeneity of shape considers: - the ratio of an object’s border length to the object’s total number of pixels (compactness); - the ratio between the object’s border length to the length of the object’s bounding box (smoothness). Compactness has a minimum value for a square. Smoothness has a minimum value if the object borders are not patchy.

In LSMA the mixed pixels (particularly those at the border areas) in the image are expressed as linear combinations of the respective spectra of basic land cover types presented in the image. In this case the measured spectral reflectance ***r***, for every image pixel in any band, can be modeled as follows:

(1) $$r_{\Sigma}(\lambda_i) = p_1 r_1(\lambda_i) + p_2 r_2(\lambda_i) + \ldots + p_m r_m(\lambda_i) + \varepsilon = \sum_{j=1}^{m} p_j r_j(\lambda_i) + \varepsilon$$

where ***p*** is the fraction cover, ***r*** for the pure component reflectance, $\lambda$ is wavelength and $\varepsilon$ is an error term.

Applying the Eq. (1) we aim:

- ✓ To calculate pure end-member reflectance and given the end-member fractions;
- ✓ To derive end-member fractions and given the pure components reflectance.

Purposely dividing the known land cover proportions derived from the data with high spectral resolution into two data sets – the first one is used for unmixing model creation and the second one is for validation. For the initial research synthetic mixed pixel spectra compiled from in situ measured spectra of ore minerals, embedding ricks, bare soil, pure water and green grass were used for validation.

Three types of data were used in this study: satellite – TM/ETM+ orthocorrected (Fig.1.); aerial – survey made by EUROSENSE in 2006 (Fig.2.); in-situ – gathered by means of TOMS by the authors (Fig.3.).

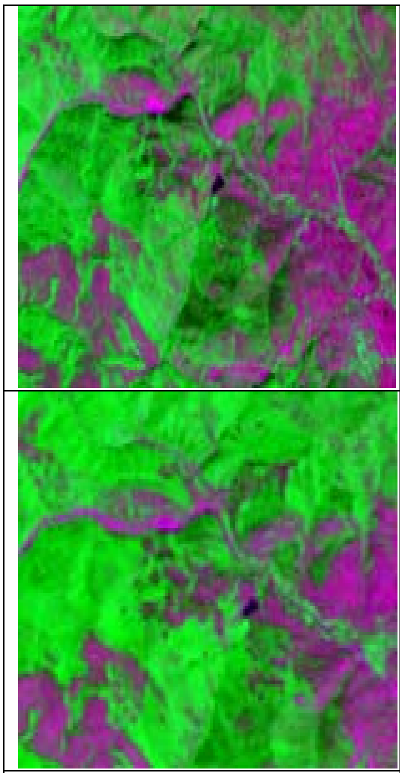


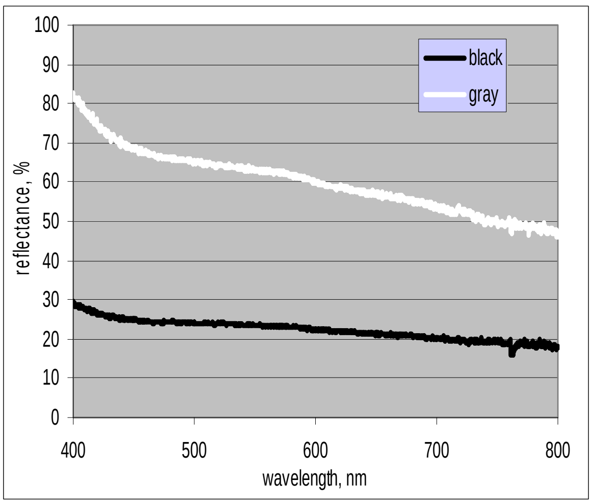
Fig.1. Satellite images

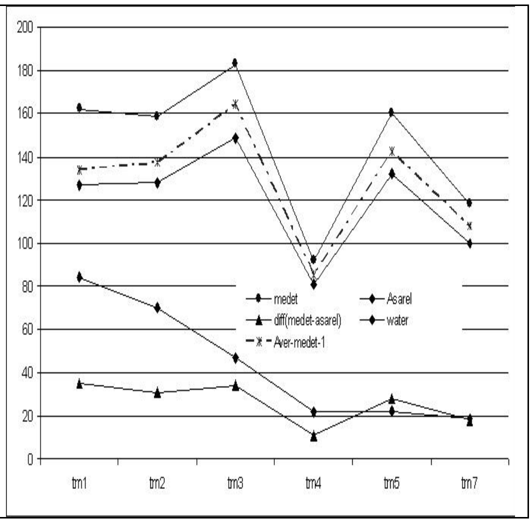
Fig.2. Aerial images

Fig.3. In-situ measurements

**Results and discussion**

In figures below results of in-situ measurements and related satellite data are shown. Figure 4 presents reflectance spectra of embedding rocks – two types of dolomite. Spectra are obtained in-situ by field spectrometer TOMS designed and constructed in Remote Sensing Systems Department [3]. Figure 5 shows spectral reflectance curves of pyrite and chalcopyrite as laboratory data adjusted to Landsat TM/ETM+ channels.



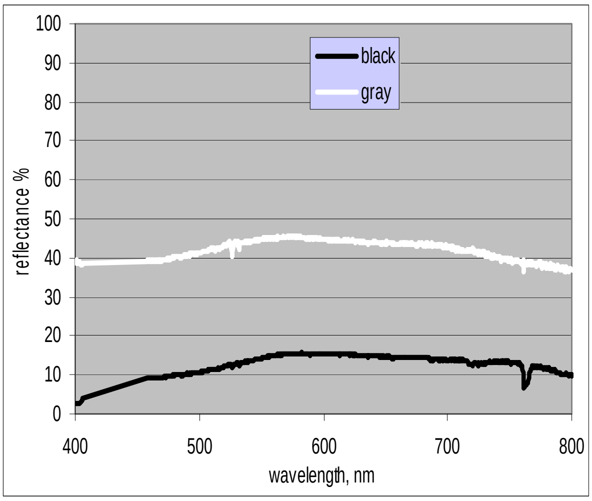



Fig. 4. Reflectance spectra of gray and black dolomites in-situ measured in 2008 and 2010

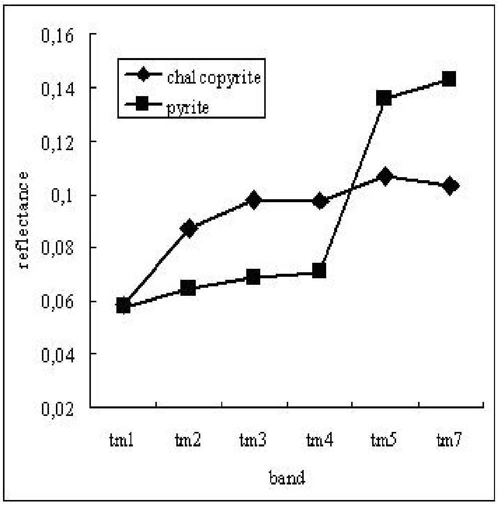



Fig. 5. Spectral reflectance curves of pyrite and chalcopyrite - laboratory data adjusted to Landsat TM/ETM+ channels

In Figure 6 the ratios of laboratory data for soils (●) and minerals and TM ratios for soils (○), manmade materials and vegetation are shown.

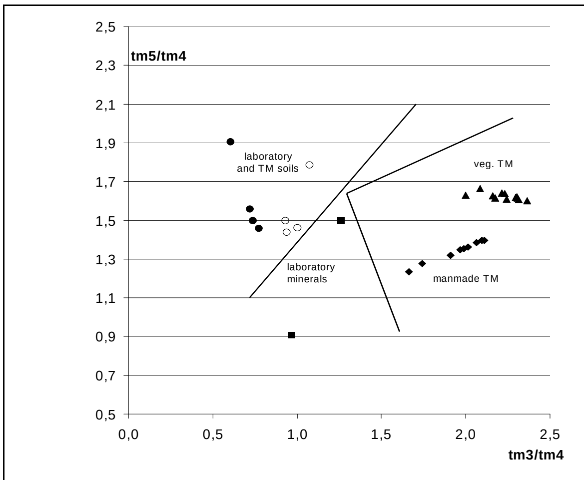



Fig. 6. Land cover segmentation presented in the 2-D space of different spectral reflectance ratios


Fig. 7. DN corresponding to Red and NIR for open mine and slag dump areas

In Figure 7 the minor overlapping of two areas (open pit mine and slag dump) show that two end-members are easily recognized. The values for dump slag were used in process of unmixing before the sub-pixel mapping was done.

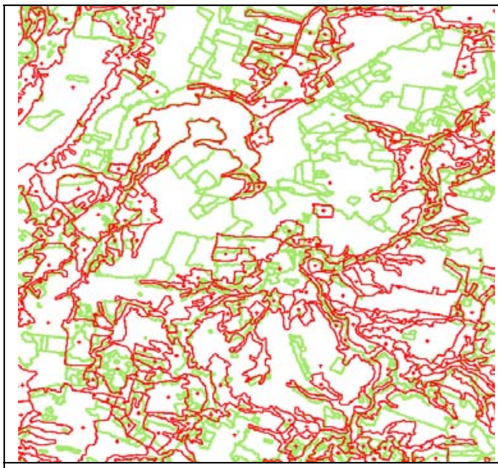


Fig.8. Morpho Bc = 18,5 vs. hand-made

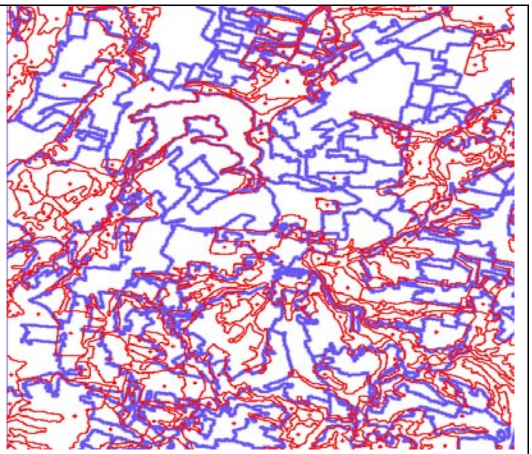


Fig.9. eCognition vs. hand-made

eCognition

In the table below varying with one of the essential parameters (scale) for the segmentation process different number of continuous regions was achieved. The closest to the reference (man-made segmentation) was produced with value 85 of this parameter. This result could be interpreted only quantitatively since notion about the shape and areas of these regions could be obtained only by direct layering of the resulting images.

Table 1. Varying of scale parameter

| | Parameters | | | Number of regions |
|---|---|---|---|---|
| | Scale param. | Shape factor | Compactness/ Smoothness | |
| 1. | 70 | 0.1 | 0.5/0.5 | 295 |
| 2. | 75 | 0.1 | 0.5/0.5 | 258 |
| 3. | 78 | 0.1 | 0.5/0.5 | 241 |
| 4. | 80 | 0.1 | 0.5/0.5 | 228 |
| 5. | 85 | 0.1 | 0.5/0.5 | 208 |
| 6. | 90 | 0.1 | 0.5/0.5 | 182 |

**Conclusions**

As conclusions of this works we could mentioned:

- ✓ Implementing the LSMA on the data it was improved the smoothness of segments
- ✓ In our specific task we found the correct proportion for the boundary pixels between the slag and the water and between the slag and the surrounding agricultural areas
- ✓ The surfaces of the dumps was determinate correctly
- ✓ The better segmentation allowed us to assess the environmental impact of the dumps on the surrounding areas (segments)
- ✓ The dynamics of the segments during the years helped in monitoring the rate of reclamation activities for the dump sites

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