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COMPUTATIONAL INTELLIGENCE IN ENVIRONMENTAL CHANGES DETECTION

Abstract: *Changes detection is helpful in determining strategies for natural resources management, environment monitoring, for urban development politics and also for natural disasters resilience and mitigation. Changes detection and monitoring involve the analysis of multi-temporal data of different types, obtained from different sources, including common databases, aerial or satellite images and old printed topographical maps. In populated areas, the changes are easily observed and analyzed, but for inaccessible areas, like forested mountain areas, the automatic analysis based on remote sensing imagery is required. Also, some features of the land, like type of soil, land cover type or humidity, are not perceptible by the human eye, so, multispectral images must be used for an accurate analysis of the studied area. In this paper we propose a strategy for environmental changes detection based on multispectral images.*

Keywords: *changes detection, image fusion, multispectral image, features detection.*

1. Introduction

The changes detection domain involves the usage of data for which the geographic position is the main feature. Thus, the Geographic Information Systems are an important component in these applications. Multi-temporal analysis requires data obtained from the same or different sensors or sources, at different times. The time interval may be years or even decades in case of environmental changes analysis and hours or days in case of natural disasters effects analysis (Parece 2013). The data used in analysis is extracted from databases (features based on ground observations), aerial or remote sensing images and also topographical maps in case the analysis covers a longer period of time, including periods for which images are not available or are too expensive (Noaje 2008).

The strategies used in changes detection are classified in (Carincotte 2006): classification of feature extracted from images or maps; classification and comparison of individual objects visible in the available images; direct classification of images pairs. To increase the accuracy of results, the images must have the same resolution, scale and must be acquired from approximately the same position and in good atmospheric conditions (Parece 2013). While images are obtained from different

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sources, some of these conditions are difficult to fulfill. In case of multispectral images, different frequency bands have different resolutions. Useful information is included in all bands, e.g. the panchromatic band which has a higher resolution offers a more precise positioning and border limits discrimination and infrared bands have four times lower resolution but offers more accurate information about temperature or humidity. As a consequence, image processing techniques are used to increase resolution (Bejinariu 2013b). Similarly, image registration methods are required to perfectly overlap images obtained from different sensors or from the same sensor placed in different positions (Bejinariu 2013a). In case of misaligned images the change detection methods will fail by detecting false differences between source images (Parece 2013).

The most common changes detection applications are land cover monitoring (Yadav 2012), (Phukan 2013), land usage monitoring (Zhou 2004), (Uzoukwu 2010) and land damage detection. Environmental changes of hydrological elements and vegetation in the Danube delta and coast area of Black Sea were monitored in (Noaje 2008) using multi-sensor and multi-temporal analysis of remote sensing images. The study is based on medium resolution images and the authors conclude that higher resolution images allow obtaining more accurate results. To can extend the studied period they used also old topographical maps of the area. Similar methods were used in (Noaje 2012) to analyze changes in urban areas. Given the diversity of source image types, the analysis has been accomplished partially through visual analysis.

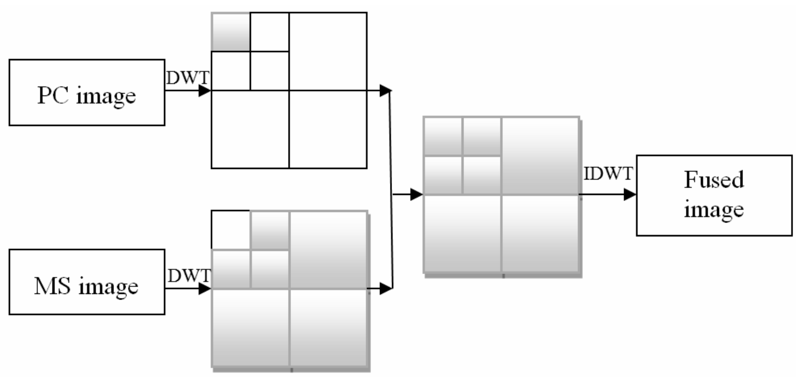
Different methods are used for evaluation and monitoring of forestry areas changes. In (Forkuo 2012) it is used a supervised classification procedure which is able detect eight different classes of land usage and cover. The results of the object detection based method are compared to the forest inventory in (Desclée 2006), obtaining a detection accuracy higher than 90%. The forest cover change was analyzed and also predicted until 2020 using time-series maps and GIS in (Giriraj 2008). Other methods used for forest cover evolution are: Principal Component Analysis and Fuzzy C-Means (Kesikoglu 2013), (Nielsen 2008), combined statistical and fuzzy methods based on Fuzzy Hidden Markov Chains (Carrincotte 2006), fusion of attributes (Jouan 2005). Other methods and case studies are presented in (Hashemi 2011), (Narzary 2013), (Singh 2011), (Skiran 2013), (Sakthivel 2010) and (Wachiye 2013). Another application, which links changes detection to ecology to investigate the effects of forest pathogens, is presented in (DeChant 2009). The proposed method uses high resolution images, finds the polygonal contour of each tree and tracks its change through the subsequent images.

In the following sections some instruments used for the multi-temporal analysis of multi-spectral images are presented. In the second section it is described a pansharpening method used to increase the spatial resolution of the multispecral images. In the third section a contours fusion method is proposed for a more accurate segmentation of satellite images. An experiment based on Landsat images for the analysis of forestry areas multi-temporal evolution is presented in the fourth section of the paper.

2. Multi-spectral images preparation through image fusion methods

The multi-temporal analysis method of remote sensing images proposed in this paper is based on the usage of multispectral images (MS) which offers more accurate details of the studied terrain area, not perceptible by the human eye. A multispectral image contains a set of images obtained by acquiring the reflected or emitted radiation in different spectral bands. The multispectral bands are: Blue (atmospheric and water details), Green (vegetation and water), Red (soil, vegetation and water), Near-infrared, Mid-infrared (vegetation, soil humidity, fire), Thermal-infrared (night images) (Bejinariu 2013b). In most cases, multispectral images are accompanied by a panchromatic image (PC) of finer spatial resolution in which region boundaries (edges) or textures can be more accurately detected.

While multi-spectral bands have the spatial resolution 2 or 4 times lower than the panchromatic image, an enhancement of the resolution is required for a unified analysis framework. The combining process of multispectral (MS) and panchromatic (PC) images is known in literature as pansharpening, an image fusion method which allows enhancing the spatial resolution of multispectral images using detail information from the panchromatic images. The most used pansharpening methods are based on the multiresolution analysis and component substitution. The Wavelet decomposition or Laplacian pyramids are used for multiresolution analysis. The transform is applied to both MS and PC images using a different number of decomposition levels depending on their resolutions ratio and then the scaled signal from the PC transformed image replaces the scaled signal in the MS transformed image. Finally, the inverse transform is applied, as presented in Fig. 1.



Source: Bejinariu 2013b.

Figure 1. Component substitution in the multi-resolution transform based pan sharpening.

3. Changes detection through contours fusion

The contour detection procedure offers different results when it is applied for different spectral bands. While useful information is contained in every band, it is obvious that this information must be unified in a single result. To achieve this, a contour fusion procedure is proposed. As input of the fusion procedure, all the bands of the multispectral image and also the corresponding panchromatic image are used. In the following a number of N spectral bands is considered.

a. For each multispectral band Im_i, $i = 1 \dots N$, the image is binarized and then a contour detection function is applied. All the remaining contours are filled and contours images $Contour_i$, $i = 1 \dots N$ are created for each band. In the same manner, the image $Contour_{PC}$ is created using the panchromatic image.

b. A temporary image *SumContours* in which the value of each pixel is computed as weighted sum of the values of the corresponding pixels in images $Contour_i$, $i = 1 \dots N$ and $Contour_{PC}$.

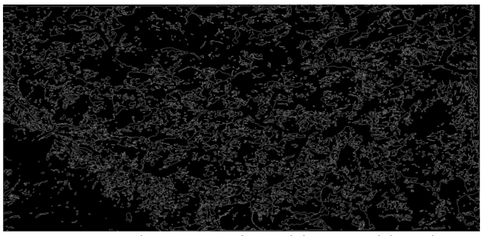
$$SumContours = \sum_{i=1}^{N} Contour_i + N * Contour_{PC}$$

The values of pixels in $Contour_{PC}$ have a greater weight because the panchromatic image offers a more precise border limits discrimination.

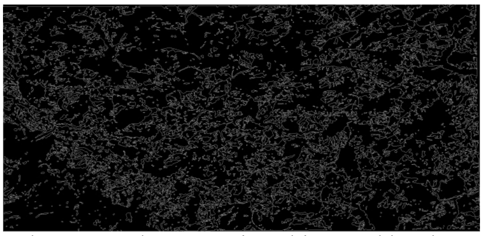
c. The image *SumContours* is segmented using a user defined threshold. The threshold value used for the experiments in the next section is $Thr = 0.2 * MaxCnt$, where *MaxCnt* is the maximum value of the pixels in *SumContours* image.

d. The final result is determined by tracing again the contours in the thresholded image.

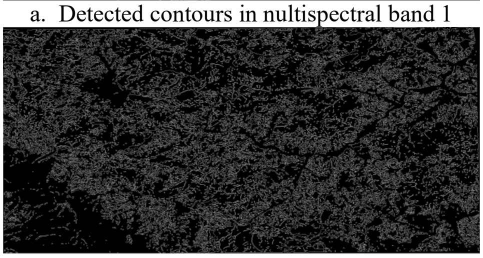
In figures bellow, the results of the image fusion procedure are presented. Figures 2.a, 2.b, 2.c show the contours detected in the Red, Green and Blue bands of the multispectral image and the final fusion result is presented in Figure 2.d.



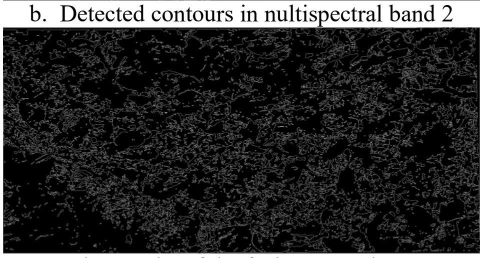
a. Detected contours in nultispectral band 1



b. Detected contours in nultispectral band 2



c. Detected contours in nultispectral band 3



d. Results of the fusion procedure

Source: images processed by author.

Figure 2. Results of the contours fusion procedure applied for 3 spectral bands of the original image in Fig. 3.

4. Procedure for forestry areas changes detection

The proposed procedure is based on the usage of multi-spectral satellite images. This kind of images is available at (Landsat 2015), but only low resolution images can be freely downloaded. The image dataset contains multispectral images acquired at large time intervals (about one year) in good atmospheric conditions, without overcast.

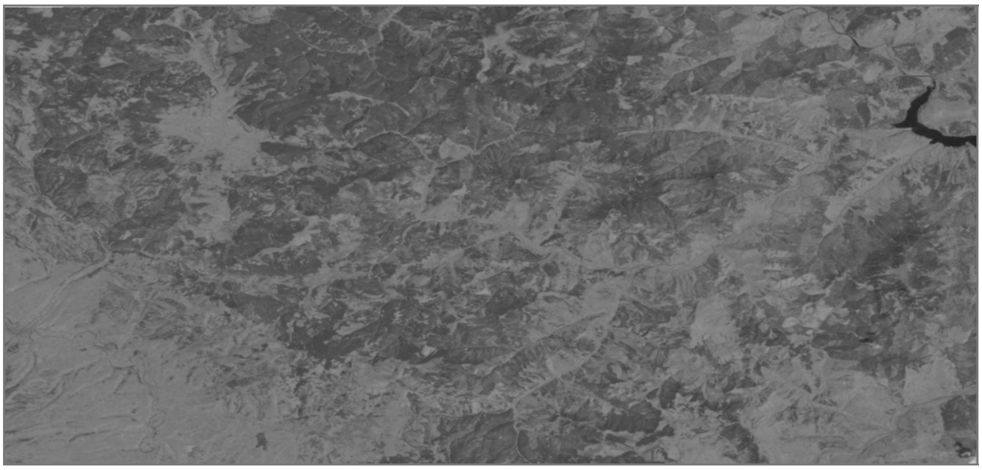
a. **Image registration**. This step is optional. Usually, it is not required, because the multispectral satellite images are acquired simultaneously and are already registered.
b. **Pansherpening**. All multispectral images must be scaled to the higher resolution of the panchromatic image, using the method described in the second section.
c. **Segmentation**. For each multispectral image in the input dataset, the pixels in each band are classified in the two classes of interest: occupied or not occupied by trees. Then, the objects detected in each band are unified in a single segmented image using the method described in the third section.
d. **Evaluation**. The objects detected in each multispectral image are compared by image differencing, in order to detect the changes between each pair of consecutive images which are then reported. The total area of the surfaces not covered by trees is also computed in each multispectral image.

We must note that the proposed procedure may be used for images that contain only forestry areas. In case the images contain also other types of land coverage, like agricultural plots or residential areas, the analysis must be restricted to the interest regions.

5. Experiment

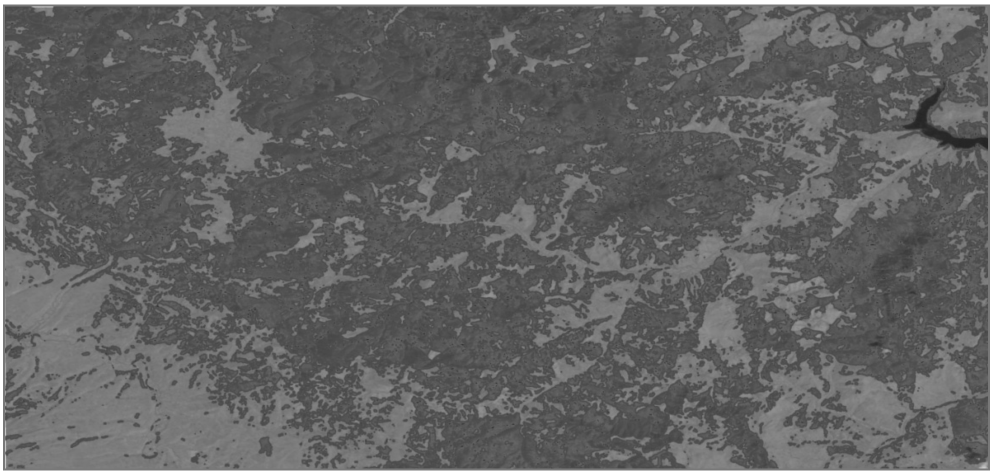
In our experiment, a set of six multispectral Landsat images of a region in Harghita County were analyzed. The images were acquired in the same period (summer) but in different years, as follows: 05.06.2000, 21.08.2002, 15.07.2009, 12.08.2010, 22.08.2011, 24.09.2014 (Landsat, 2015). Atmospheric conditions and clouds coverage are similar in all images. The geographic coordinates of the studied are: 25°20’19”–26°00’25” E longitude and 46°49’48”–47°08’37” N latitude. One of these images is presented in the following figure. We must note that the imaged have o low resolution of about 25m/pixel.

The proposed method was applied for the images set, to detect the contours of the not covered areas. An example of contour detection results is presented in the Fig. 4. The contours are traced in red, but some very small elements whose detection is caused by the noise in the input images were eliminated using geometric criteria. The percent of eliminated contours is about 60% of the total number of detected contours.



Source: Landsat, 2015.

Figure 3. Image acquired on 15.07.2009.

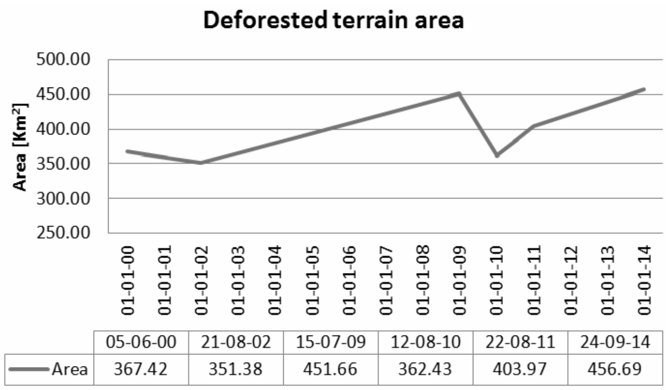


Source: image processed by author.

Figure 4. Contours detected in the image presented in Fig. 3.

Considering the geographic coordinates of each detected contour, their area is then computed. The variation of uncovered surface in forested areas between 2000 and 2014 is presented in Figure 5.

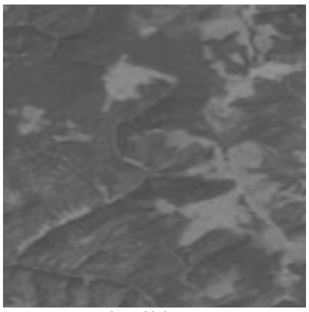
In the next step, the images containing only the detected contours are compared in order to identify the differences. Because the used images have low resolution, the accuracy of the resulted differences is reduced and the interest regions must be either analyzed by an operator or the procedure must be applied locally on each region of interest using high resolution images.

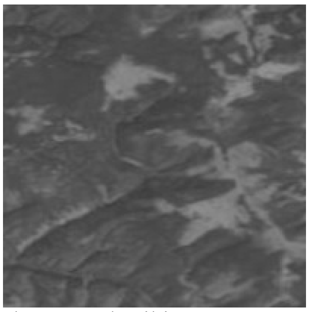


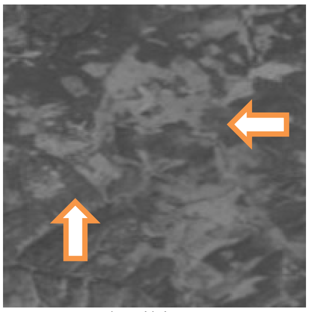
Source: results obtained by author.

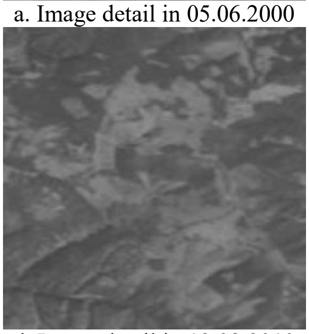
Figure 5. Area variation of deforested surfaces.

Next, we focus on such region of interest of about 25 Km^2, located near the top-left corner of the original images. The deforested area (indicated by arrows in Fig. 6.c) may be easily identified by visual analysis of detailed images, but we can repeat also the analysis procedure. The results are presented in Figure 7 and Figure 8.


a. Image detail in 05.06.2000


b. Image detail in 21.08.2002


c. Image detail in 15.07.2009

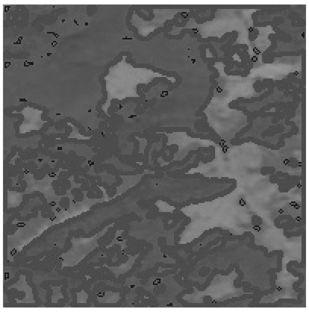

d. Image detail in 12.08.2010

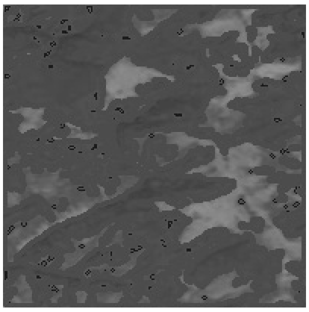

e. Image detail in 22.08.2011

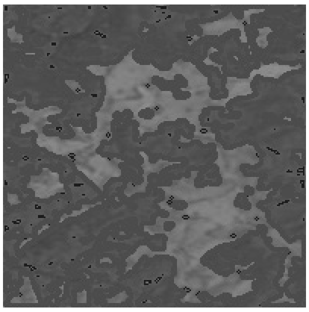

f. Image detail in 24.08.2014

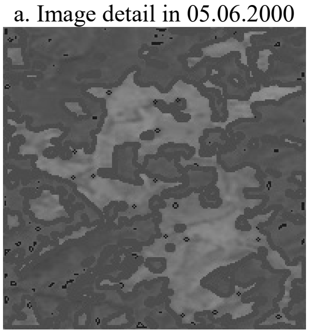
Source: images processed by author

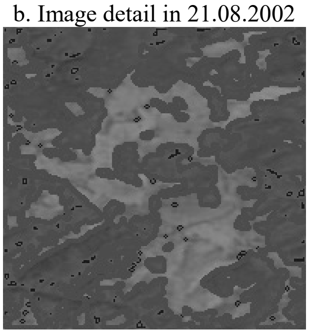
Figure 6. Detail image containing an area in which changes were detected (near the top-left corner of the full image). The arrows in (c) indicate the area which was deforested between 2002 and 2009. The maximum area value of the deforested surface is observed in 2010.

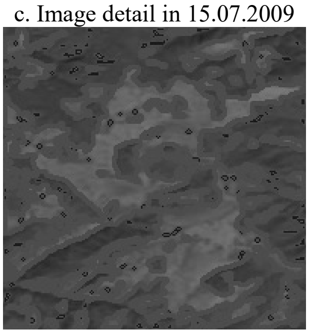

a. Image detail in 05.06.2000


b. Image detail in 21.08.2002


c. Image detail in 15.07.2009


d. Image detail in 12.08.2010

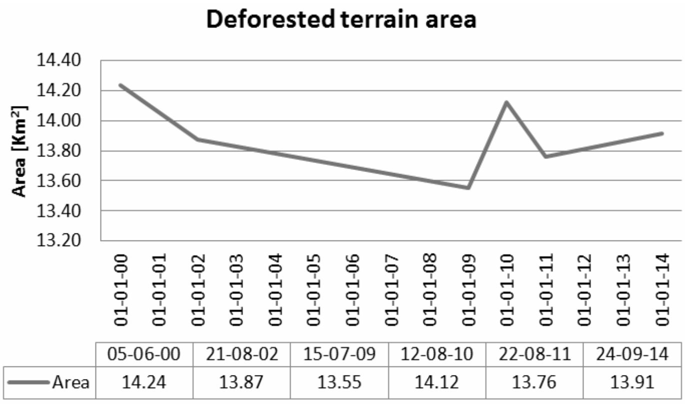

e. Image detail in 22.08.2011


f. Image detail in 24.08.2014

Source: images processed by author.

Figure 7. Contours detected in the detail images.

As it is indicated in Fig. 6.c, the forested area decreased between 2009 and 2010 year by about 0.7 Km^2 in the studied area. The deforested area is centered at coordinates 25°24'01" E longitude, 47°04'42" N latitude. We must note that the accuracy of these results is affected by the atmospheric conditions which were slightly different in some images.



Source: results obtained by author.

Figure 8. Area variation of deforested surfaces.

The proposed changes detection procedure was implemented in C++ using Microsoft Visual Studio 2010 as development tool. The OpenCV open-source library was used for images manipulation and some pre-processing functions.

Conclusion

In this paper it is proposed a features level fusion procedure for contours detection in multispectral images. It was applied in the multi-temporal analysis of satellite images to detect changes in the forestry areas. The proposed method can offer more accurate results than in this experiment, in case higher resolution images are available. The method was implemented and it can evaluate the area of deforested surfaces indicating also the exact geographic position in which the changes occurred.

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