Change Detection in Satellite Images Obtained by Means of Mexican Hat Wavelets and Anaglyph Maker Software

(Article begins on next page)

29 April 2024

_____

Change Detection in Satellite Images Obtained by Means of Mexican Hat Wavelets and Anaglyph Maker Software

Amelia Carolina Sparavigna[1]

1 – Department of Applied Science and Technology, Politecnico di Torino, Torino, Italy.

Abstract: In recent years the research on the Change Detection, applied to data and images obtained by means of satellite remote sensing, has collected a huge number of publications concerning methods and algorithms, based on several different approaches. Here we consider the use of wavelets, and propose an approach for change detection, which is involving an anaglyph maker software for rendering the variations in images. The wavelets used are the Mexican Hat wavelets of ImageJ and the anaglyph maker software is that developed by Takashi Sekitani, Tokyo.

Keywords: Image Processing, Change Detection, Satellite Imagery, Wavelets, Ricker Wavelet, Mexican Hat Filter, Image J, GIMP, Anaglyph Maker

Introduction

Several sets of time series of satellite images and data maps, containing information collected by means of remote sensing technologies, are today available for investigations in the research field of Change Detection. These sets of images and maps allow researchers to examine a given area, over some specific periods of time, and determine the changes inside of it and the related causes at the origin of the variations. Besides monitoring the local environments, the trends extrapolated by the Change Detection can be used to forecast the evolution of the environmental conditions too. Not surprisingly therefore, we find, among the main subjects of the Change Detection, the analyses of deforestation, polar ice loss and all the global and local consequences of the Climate Change.

The methods that are used for studies in the Change Detection research field can be roughly categorized into the two sets of supervised and unsupervised methods. The former set is based on supervised classification methods, which require additional information to obtain the desired features contained in the images or maps. The latter set performs change detection by means of a direct comparison of them, without incorporating any additional information [1]. As explained in [1], Change Detection by means of unsupervised methods uses the automatic analysis of change data, which are generally created as follow. First we have an image (or map) differencing. Then, this processing is followed by a normalization and vector analyses [2]. Let us remember that image differencing-based algorithms accomplish the change detection by subtracting, on a pixel basis, the images acquired at two time instants to produce a new image called "difference image" [1]. The changes need to be identified in the difference image. Some methods to detect the changes in images, referenced in [1], are those given in [3-5]. Some recent works are given in [6-14]. In [15,16], the change detection had been

_____

_____

applied to the motion of sand dunes. Now, let us consider if we can add further approaches to the method proposed in the References previously given.

Wavelets for image feature extraction

In [17-24] we can find publications, which are using wavelets to investigate the features in images. Among the examples considered we can find also satellite images. As told in the abstract of [24], although many methods have been developed for feature extraction, "they commonly focus on only one class of image features". In order to obtain better results for feature detection, extraction and matching, operators based on wavelets, in particular on the Mexican Hat wavelet, are used. The result is a precise registration of images [24]. Of course, we can use the wavelets for the change detection in satellite images too. And here we will show how to obtain some interesting results.

However, what is a wavelet? A wavelet is a wave-like oscillation. Typically, it can be visualized as a brief oscillation having the form of a wave packet. The functions describing the wavelets are intentionally defined to have specific properties to be useful for signal processing. In fact, wavelets can be used to deduce specific information from data, which can be audio signals, images and so on. In fact, wavelets are used for the analysis of seismograms too [25].

One of wavelets is the Ricker wavelet, which is given in [25] in the following manner. It is a zero-phase wavelet with a central peak and two smaller side lobes. It can be uniquely specified with only a single parameter, f, as a function of time as:

$$\psi(t) = \left(1 - \pi^2 f^2 t^2\right) \exp\left(-\pi^2 f^2 t^2\right)$$

The Ricker wavelet is also referred to as the Mexican Hat wavelet, due to its taking the shape of a sombrero when used as a 2D image processing kernel. And here, as told before, we will use this function to have a filter suitable for the edge detection in images. In particular we will use the ImageJ filter based on the Mexican Hat wavelet. The filtering of the image is made by means of a convolution based on a specific kernel. The kernel is a matrix the centre of which corresponds to the source pixel and the other elements correspond to neighbouring pixels. The destination pixel is calculated by multiplying each source pixel by its corresponding kernel coefficient and adding the results. In the tutorial of ImageJ Documentation Wiki , https://imagejdocu.tudor.lu/gui/process/filters, it is shown a 9 x 9 kernel of a Mexican Hat, "which does both smoothing and edge detection in one operation".

Now, let us show the approach that we can use for detecting changes in satellite image.

Mexican Hat Filter and Anaglyph Maker

First, let us consider some time series of satellite images, for instance, those available in Google Earth, and select two images from them (see the Figure 1). We determine the edges in

_____

the image, using the Mexican Hat filter of ImageJ. The result is given in binary (black and white) images (Figure 2). The change detection, that is the differences in images, is made by means of an anaglyph maker software. The software was developed by Takashi Sekitani, stereoscopic 3D photographer and videographer, member of ISU, NSA & Stereo Club Tokyo. Software is available at https://www.stereoeye.jp/software/index_e.html . In the Figure 3, the edges of the older satellite image (the left panels of Figs.1 and 2) are rendered in blue, whereas the edges of the newer satellite image (right panels in Figs.1 and 2) are given in red.
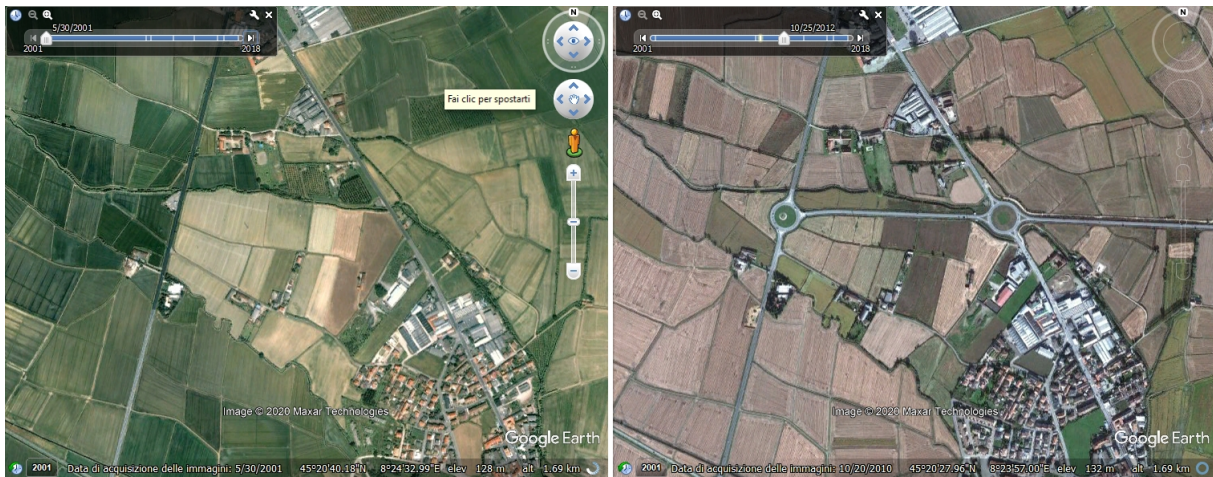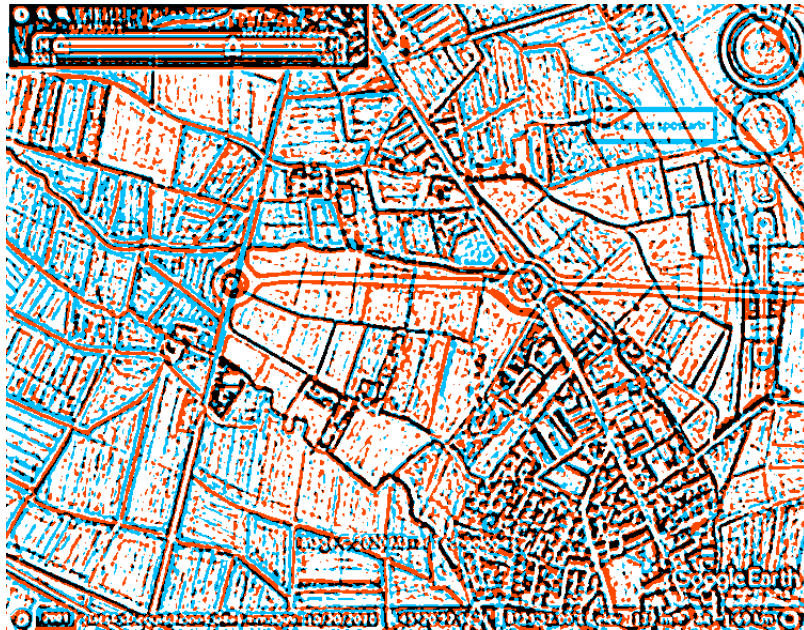

Figure 1: Fields and roads near Vercelli (Courtesy Google Earth).
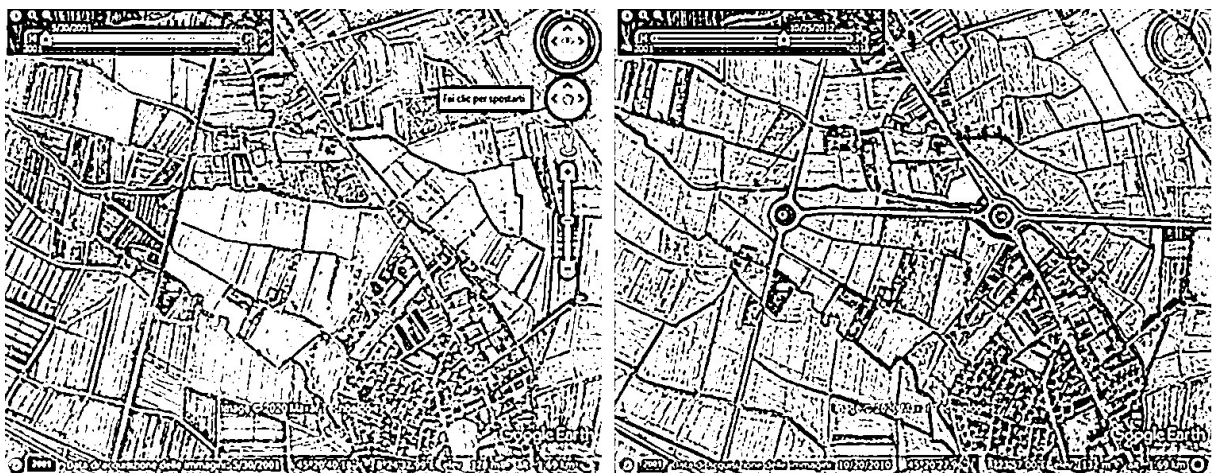
Figure 2: The panels in the Figure 1 after being filtered by means of the Mexican Hat kernel of ImageJ.

_____

Figure 3: The two panels of the Figure 2 have been mixed by means of the Anaglyph Maker filter developed by Takashi Sekitani, Tokyo. We can easily appreciate the new roads in the image, characterized by the red pixels. Black pixels are the edges which are perfectly in the same position in both panels.

Another example is given in Figs. 4-6. In the following image (Fig.4), we see the older (left panel) and the newer (right panel) railway station of Porta Susa in Torino.
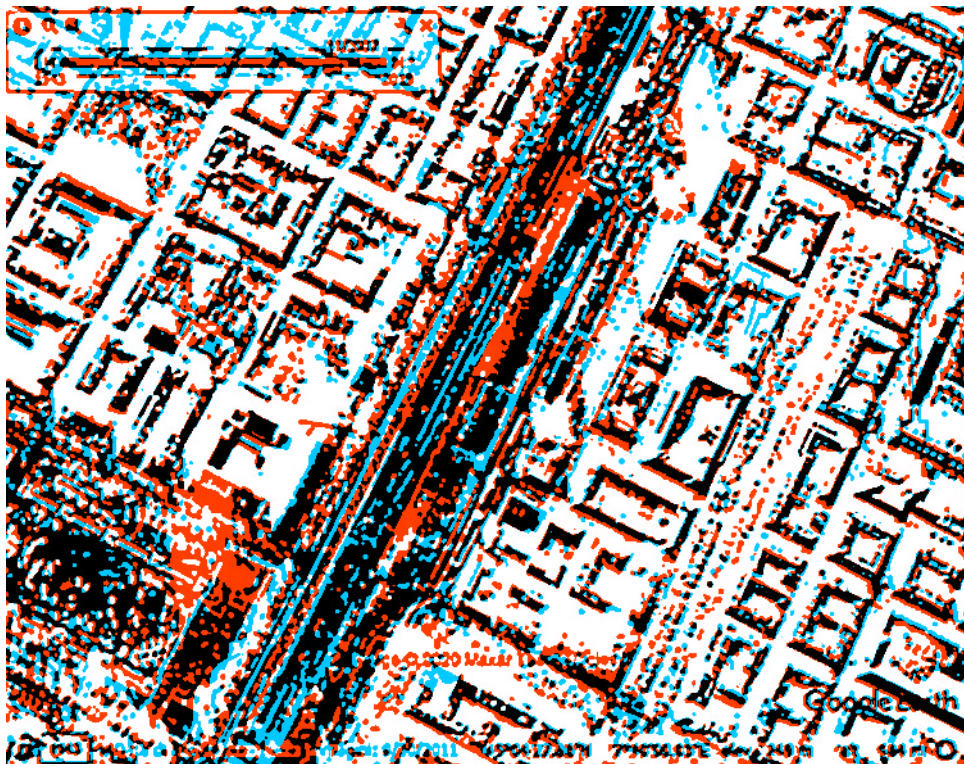

Figure 4: The railway station Porta Susa (Courtesy Google Earth).

_____

_____

**Figure 5:** The panels in the Figure 1 after being filtered by means of the Mexican Hat kernel of ImageJ.

Figure 6: The two panels of the Fig.5 have been mixed by means of the Anaglyph Maker filter developed by Takashi Sekitani, Tokyo. .

_____

_____

As made in [26,27] for showing the changes occurred in sand dunes over time, we can decide to distinguish the edges in the older and in the newer image by the use of different colours. In Figs. 3 and 6, we took advantage of an anaglyph maker software to have this colour rendering. In these Figures, the blue pixels are referring to the older image and the red pixels to the newer image. The black pixels are those which do not change in the images. In the Figure 3, it is easy to find the new roads. In the Figure 6, it is easy to see the part of the town which had a large change: in fact we are evidencing the new railway station of Porta Susa in Torino. Let us note the large red area near the lower left corner of the image. It is the shadow of a new building: a skyscraper designed by Renzo Piano.

A further example is given in Figs. 7 and 8. Also in this case, the wavelet filter of ImageJ has been used on the two upper panels of Fig. 7 to have the lower panels. The anaglyph maker is applied to obtain Fig.8. The images are showing an example of urbanization. In fact, it is easy to evaluate phenomena of urbanization. by means of the proposed approach.

Using wavelets for the edge detection, and giving a different colour code to the pixels belonging to the older image and to the newer image of a time series, we can easily detect the changes and also have a manner for quantifying the amount of the variation. This can be done by means of the numbers of red, blue and black pixels in the combined image. The proposed method for Change Detection can be considered as belonging to the set of unsupervised methods.
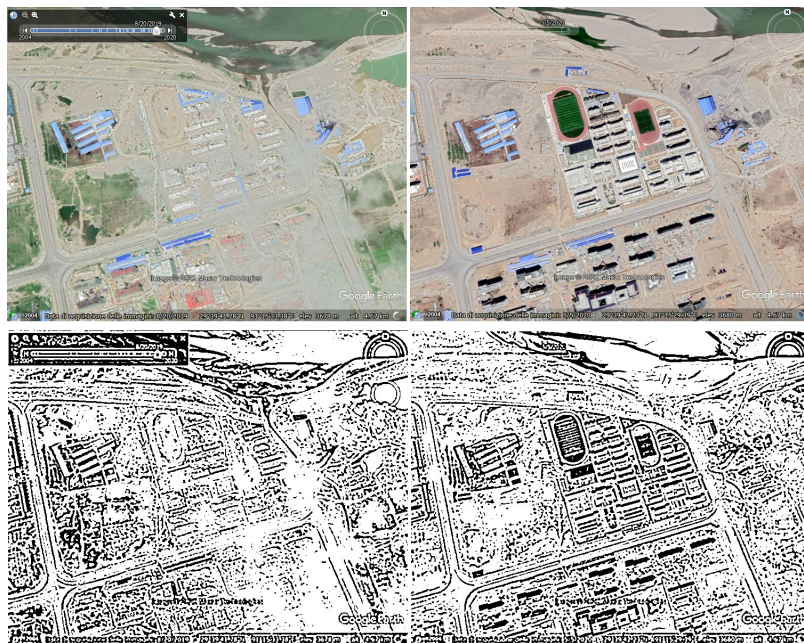
Figure 7: An example of urbanization (Courtesy Google Earth).

_____

_____
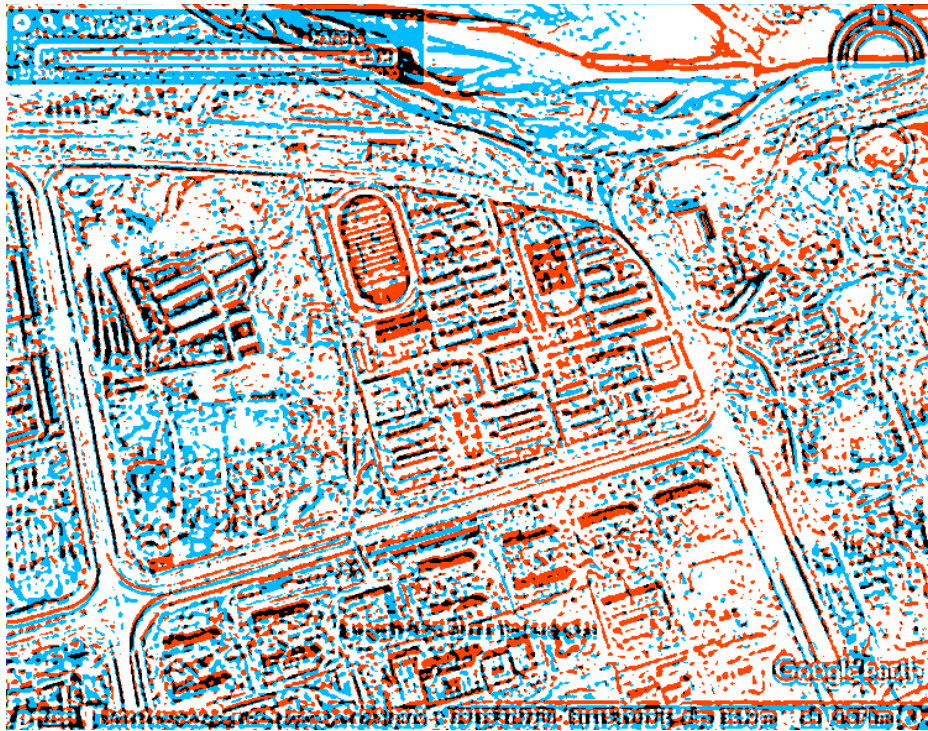
Figure 8: We can easily appreciate a phenomenon of urbanization by the red pixels in the given image.

References

[1] Celik, T. (2009). Unsupervised change detection in satellite images using principal component analysis and k-means clustering. IEEE Geoscience and Remote Sensing Letters, 6(4), 772-776.

[2] Pacifici, F., Del Frate, F., Solimini, C., & Emery, W. J. (2007). An innovative neural-net method to detect temporal changes in high-resolution optical satellite imagery. IEEE Transactions on Geoscience and Remote Sensing, 45(9), 2940-2952.

[3] Bruzzone, L., & Prieto, D. F. (2000). Automatic analysis of the difference image for unsupervised change detection. IEEE Transactions on Geoscience and Remote sensing, 38(3), 1171-1182.

[4] Boucher, A., Seto, K. C., & Journel, A. G. (2006). A novel method for mapping land cover changes: Incorporating time and space with geostatistics. IEEE Transactions on Geoscience and Remote Sensing, 44(11), 3427-3435.

[5] Gamba, P., Dell'Acqua, F., & Lisini, G. (2006). Change detection of multitemporal SAR data in urban areas combining feature-based and pixel-based techniques. IEEE Transactions on Geoscience and Remote Sensing, 44(10), 2820-2827.

_____

---

[6] Leichtle, T., Geiß, C., Wurm, M., Lakes, T., & Taubenböck, H. (2017). Unsupervised change detection in VHR remote sensing imagery–an object-based clustering approach in a dynamic urban environment. International Journal of Applied Earth Observation and Geoinformation, 54, 15-27.

[7] Cao, G., Li, X., & Zhou, L. (2016). Unsupervised change detection in high spatial resolution remote sensing images based on a conditional random field model. European Journal of Remote Sensing, 49(1), 225-237.

[8] Wu, T., Luo, J., Fang, J., Ma, J., & Song, X. (2017). Unsupervised object-based change detection via a Weibull mixture model-based binarization for high-resolution remote sensing images. IEEE Geoscience and Remote Sensing Letters, 15(1), 63-67.

[9] Lv, P., Zhong, Y., Zhao, J., & Zhang, L. (2018). Unsupervised change detection based on hybrid conditional random field model for high spatial resolution remote sensing imagery. IEEE Transactions on Geoscience and Remote Sensing, 56(7), 4002-4015.

[10] Shao, P., Shi, W., He, P., Hao, M., & Zhang, X. (2016). Novel approach to unsupervised change detection based on a robust semi-supervised FCM clustering algorithm. Remote Sensing, 8(3), 264.

[11] Moghimi, A., Mohammadzadeh, A., & Khazai, S. (2017). Integrating thresholding with level set method for unsupervised change detection in multitemporal SAR images. Canadian Journal of Remote Sensing, 43(5), 412-431.

[12] Atasever, U. H., Kesikoglu, M. H., & Ozkan, C. (2016). A new artificial intelligence optimization method for PCA based unsupervised change detection of remote sensing image data. Neural Network World, 26(2), 141.

[13] Touati, R., Mignotte, M., & Dahmane, M. (2019). Multimodal Change Detection in Remote Sensing Images Using an Unsupervised Pixel Pairwise Based Markov Random Field Model. IEEE Transactions on Image Processing.

[14] Dharani, M., & Sreenivasulu, G. (2019). Land use and land cover change detection by using principal component analysis and morphological operations in remote sensing applications. International Journal of Computers and Applications, 1-10.

[15] Boulghobra, N. (2016). Climatic data and satellite imagery for assessing the aeolian sand deposit and barchan migration, as a major risk sources in the region of In-Salah (Central Algerian Sahara). Arabian Journal of Geosciences, 9(6), 450.

[16] Sparavigna, A. C. (2019). Change Detection in Satellite Images Applied to the Study of Sand Dunes. Zenodo. http://doi.org/10.5281/zenodo.3461709

[17] Celik, T., & Ma, K. K. (2009). Unsupervised change detection for satellite images using dual-tree complex wavelet transform. IEEE Transactions on Geoscience and Remote Sensing, 48(3), 1199-1210.

[18] Celik, T., & Ma, K. K. (2010). Multitemporal image change detection using undecimated discrete wavelet transform and active contours. IEEE Transactions on Geoscience and Remote Sensing, 49(2), 706-716.

_____

[19] Carvalho, L. D., Fonseca, L. M. G., Murtagh, F., & Clevers, J. G. P. W. (2001). Digital change detection with the aid of multiresolution wavelet analysis. International Journal of Remote Sensing, 22(18), 3871-3876.

[20] Moser, G., Angiati, E., & Serpico, S. B. (2011). Multiscale unsupervised change detection on optical images by Markov random fields and wavelets. IEEE Geoscience and Remote Sensing Letters, 8(4), 725-729

[21] Raja, R. A., Anand, V., Kumar, A. S., Maithani, S., & Kumar, V. A. (2013). Wavelet based post classification change detection technique for urban growth monitoring. Journal of the Indian Society of Remote Sensing, 41(1), 35-43.

[22] Chauhan, D. S., Singh, A. K., Adarsh, A., Kumar, B., & Saini, J. P. (2019). Combining Mexican hat wavelet and spread spectrum for adaptive watermarking and its statistical detection using medical images. Multimedia Tools and Applications, 1-15.

[23] Sarvaiya, J. N., & Patnaik, S. (2010). Automatic image registration using mexican hat wavelet, invariant moment, and radon transform. IJACSA) International Journal of Advanced Computer Science and Applications, Special Issue on Image Processing and Analysis. Available at the following link: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.220.2524&rep=rep1&type=pdf#page=81

[24] Jin, F., & Feng, D. (2014). Image registration algorithm using Mexican hat function-based operator and grouped feature matching strategy. PloS one, 9(4), e95576.

[25] Ryan, H. (1994). Ricker, Ormsby, Klander, Butterworth – A Choice of Wavelets. Recorder, 19(07), 8-9. Available https://csegrecorder.com/articles/view/ricker-ormsby-klander-butterworth-a-choice-of-wavelets

[26] Sparavigna, A. C. (2013). The GNU Image Manipulation Program Applied to Study the Sand Dunes. International Journal of Sciences, Volume 2, Issue 9, pp.1-8. DOI: 10.18483/ijSci.289

[27] Sparavigna, A. C. (2013). Edge-Detection Applied to Moving Sand Dunes on Mars. International Journal of Sciences, Volume 2, Issue 8, pp. 102-104. - ISSN 2305-3925 ijsciences

_____