Spectral Analysis of Remote Sensing Data

Nihad A.Karam, Ban Abdul Razzaq*, Afrah Salah Mahdi
Department of Astronomy and Space, College of science, University of Baghdad, Baghdad, Iraq

Abstract

In the present work, different remote sensing techniques have been used to analyze remote sensing data spectrally using ENVI software. The majority of algorithms used in the Spectral Processing can be organized as target detection, change detection and classification. In this paper several methods of target detection have been studied such as matched filter and constrained energy minimization.

The water body mapping have been obtained and the results showed changes on the study area through the period 1995-2000. Also the results that obtained from applying constrained energy minimization were more accurate than other method comparing with the real situation.

Keywords: Spectral analysis, target detection, constrained energy minimization, minimum noise fraction.

التحليل الطيفي لبيانات الاستشعار عن بعد

نهاد علي كرم، بان عبد الرزاق*، أفراح صلاح مهدي

قسم الفلك والفضاء ، كلية العلوم ، جامعة بغداد ، بغداد ،العراق

الخلاصة

في هذا البحث تم استخدام عدة تقنيات للاستشعار عن بعد لتحليل البيانات طيفيا باستخدام البرنامج ENVI.ان اغلب الخوارزميات المستخدمة في المعالجة الطيفية يمكن تنظيمها بالشكل :كشف الهدف، كشف التغيير ، التصنيف .

تم استخدام عدة طرق للكشف عن الهدف مثل مرشح التناظر وتحقيق الحد الادنى للطاقة المقيدة. وقد تم الحصول على خرائط لتوزيع المياه في منطقة الدراسة وقد اوضحت النتائج بوجود تغيير في هذه المنطقة خلال الفترة 1995−2000. و كذلك فان النتائج التي حصلنا عليها باستخدام طريقة تحقيق الحد الادنى للطاقة المقيدة هي الاكثر دقة من الطريقة الاخرى مقارنة مع الواقع.

Introduction

The term remote sensing was first used by Evelyn Pruitt , a scientist working for the U.S. Navy's Office of Naval Research, coined this term when she recognized that the term aerial photography no longer accurately described the many forms of imagery collected using radiation outside the visible region of the spectrum[1].

Remote sensing can be defined as any process where information is gathered about an object, area or phenomenon without being in contact with it. Human eyes are an excellent example of a remote sensing device, they are able to gather information about their surroundings by measure the amount and nature of the reflectance of visible light energy from some external source (such as the sun or an artificial light) as it reflects objects in their field of view. Contrast this with a thermometer, which must be in contact with the phenomenon it measures, and thus is not a remote sensing device[2].

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*Email: dr.Ban2003@yahoo .com

Spectral imaging for remote sensing of terrestrial features and objects arose as an alternative to high-spatial-resolution, large-aperture satellite imaging systems. Early applications of spectral imaging were oriented toward ground-cover classification, mineral exploration, and agricultural assessment, employing a small number of carefully chosen spectral bands spread across the visible and infrared regions of the electromagnetic spectrum [3].

Target detection:

Target detection refers to the use of high spectral resolution remotely sensed images to map the locations of a target or feature (often a plant species of interest) with a particular spectral or spatial signature. The aim of target detection is to search the pixels of a data cube for rare spectral signatures. In the present work, detection of water pixels for an Iraqi zone in Baghdad city and surrounding area for the year 1995 has been done using methods of target detection such as match filter and constrained energy minimization. The Minimum Noise Fraction (MNF) transform is an important technique as far as target detection is concerned. It works on the principle that it segregates noise from information content and also reduces the variance in the data. MNF transform consists of two cascaded principal components [4]. The difference between Minimum noise fraction (MNF) transform and Principal Component Analysis (PCA) is that MNF takes into account the sensor noise and also it orders the image in terms of signal to noise ratio (SNR). On the other hand, PCA consider the data variance not the sensor noise.

The MNF consists two steps. In the first step transforms the data with unit variance and ensures no band to band correlation (it decorrelates the data). In the second step it applies principal component to the noise whitened data. The images are called eigen images. The more large eigen vales signifies more useful information. Eigen values close to one indicates noise affected data. Now the first requirement in the process is to estimate sensor noise. The major information is contained in first some of the MNF components and information content decreases as number of components increases. Hence, Minimum Noise Fraction (MNF) is a linear transform which reduces the dimension, removes noise and reprojects the input data in which whole of the noise is removed which is better than PCA[5].

There are several methods to applying target detection. The method that used in our work are:

- **Matched Filter MF**

Matched Filter (MF) uses the data cube statistics to both suppress the background and enhance the target SNR. The filter assumes that the target spectra in the image are distinct, i.e., the data cube statistics (mean plus covariance matrix) are approximately equal to the background statistics[6]. The process begins with the application of the MF. For all pixels x in the data cube, the MF score is computed as follows:

$$\mathbf{MF_{score}} = \frac{(\mathbf{L_{T}-L_{M}})^{T}\sum^{-1}(\mathbf{X-L_{M}})}{(\mathbf{L_{T}-L_{M}})^{T}\sum^{-1}(\mathbf{L_{T}-L_{M}})} \tag{1}$$

Where: L_T is the target radiance or class spectra, L_M is the mean spectra of the data cube, X is the image spectra at pixel x, and $\sum$ is the data cube covariance matrix.

Using Eq. (1), image spectra equal to the mean have MF scores equal to zero, while image spectra identical to the target spectra have MF scores equal to 1[7].

- **The Constrained Energy Minimization CEM**

The step of CEM algorithm is: by designing a finite response filter, minimizing the total output energy of the linear combining process subject to a linear equality constraint applied to desired target (d). This problem can be converted to an unconstrained minimization using the method of Lagrange multipliers, using the filter to all pixel vectors to get the target detection.[8] By using filter coefficient equation (2), a CEM detector can detect desired target (d) by using cem(r)= $(w_{cem})^{T}$ r , at the same time, minimum output energy caused by interfere background and unknown signal[8]. Filter coefficient is given by:

$$\mathbf{w_{cem}} = \frac{\mathbf{R^{-1}\,d}}{\mathbf{d^{T}R^{-1}\,d}} \tag{2}$$

Where: R is sample autocorrelation matrix, d is desired target.

Change detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh 1989). Timely and accurate change detection of Earth's surface features provides the foundation for better understanding relationships and interactions between human and natural phenomena to better manage and use resources. In our work, change detection has been applied using Two Color Multi View (2CMV) method [9].

Classification

Image classification define as assigning a label or class to each pixel of the data. The majority of image classification is based on the detection of the spectral signatures (i.e., spectral response patterns) of land cover classes. There are two general approaches to image classification, the first require prior knowledge of the ground cover in the study site known as supervised classification and the second can be used without having prior knowledge of the ground cover in the study site known as unsupervised classification. In our work, minimum distance supervised classification method has been applied[10]. The minimum distance technique uses the mean vectors of each endmember or region of interest and calculates the Euclidean distance from each unknown pixel to the mean vector for each class given by equation:

$$\mathbf{ED} = \sqrt{\sum_{i=1}^{N}\left(x_i^p - x_i^m\right)^2} \qquad\qquad (3)$$

Where N is number of bands, x_i^p is test pixel spectrum, x_i^m is mean spectrum.

Study area and data

The study area belongs to Baghdad city and surrounding areas for years 1995 and 2000 taken by Landsat TM sensor with 7 bands. It bounded between the latitude 33° 17′ 30″ N and longitude 43° 27′ 52″ E. In our work we take the images with band 1 only as shown in Figure-1.
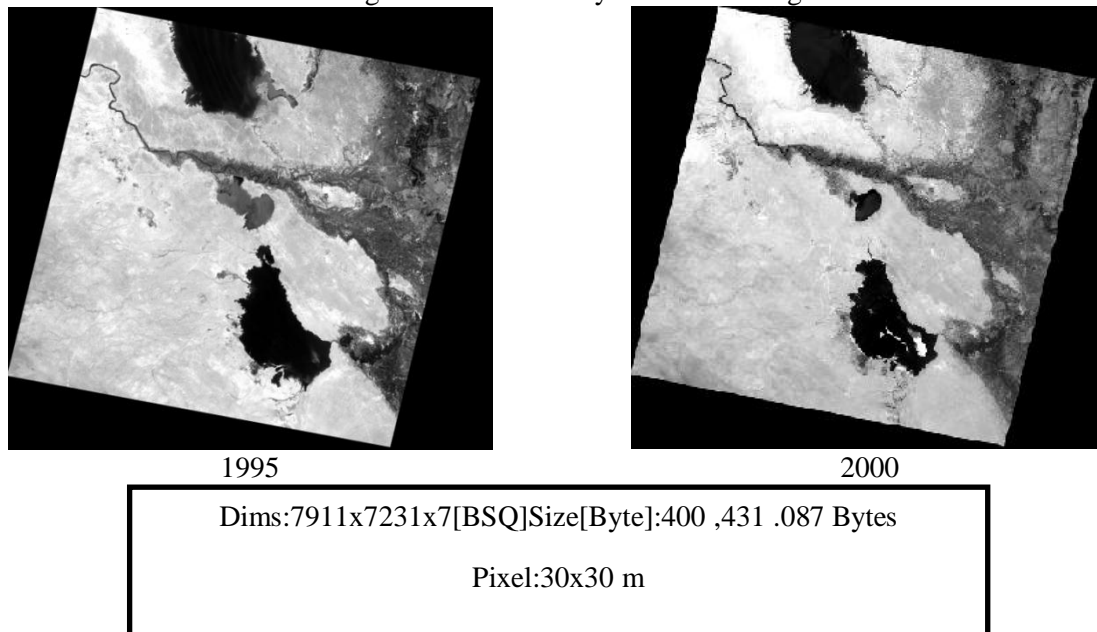

1995   2000

Dims:7911x7231x7[BSQ]Size[Byte]:400 ,431 .087 Bytes

Pixel:30x30 m

Figure 1- Shows the study area of Baghdad city and the surrounding areas for the year 1995 and 2000.

Experimental Result:

A. Target detection processing

1. Applying Atmospheric correction using dark pixel subtraction method. The result is illustrated in Figure-2.
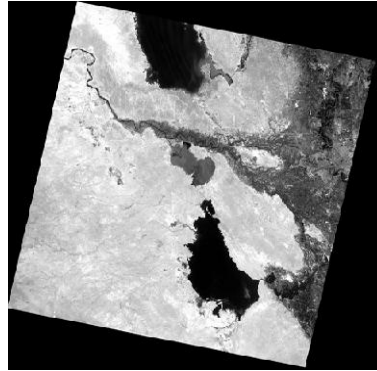
Figure 2- Illustrated the Atmospheric correction (dark subtraction) for the study area for the year 1995.

2. Selection of target. In our work, we select water pixels as region of interest as shown in Figure-3, saved it as statistics file then we used as a target.
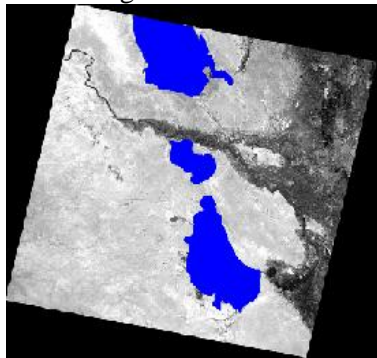

Figure 3- Illustrated the region of interest.
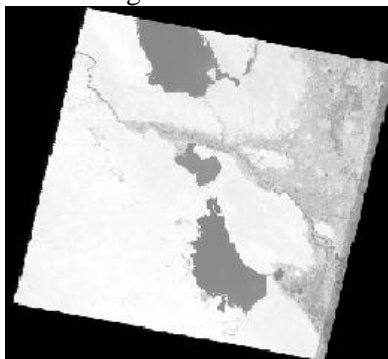**3.** Applying MNF transformation on the image. The results are illustrated in Figure-4.

Figure 4- Illustrated the MNF transformation.

4.Selection of method to apply target detection. The results for each method are illustrated in Figure-5.
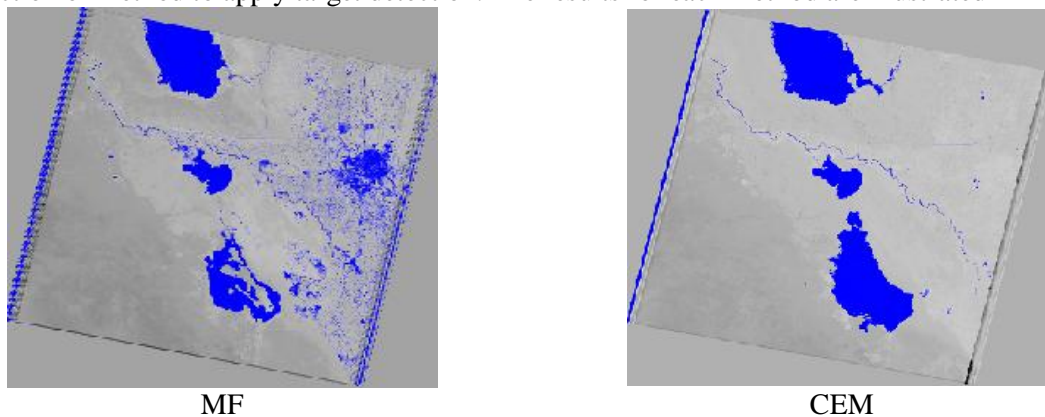

| MF | CEM |

Figure 5- Show the results of the used method for the year 1995.

5. Applying contrast stretching and filtering target. The results are illustrated in Figure-6.

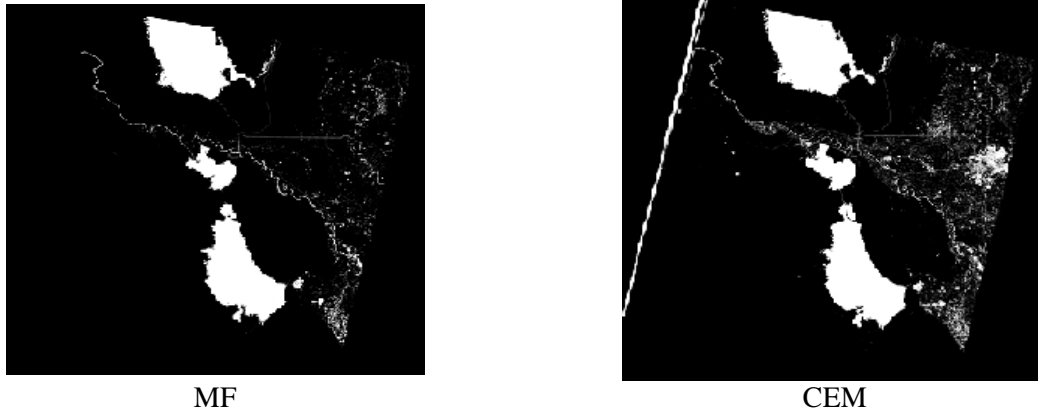MF   CEM

Figure 6- Show the results of target detection, the white areas represented target pixels(water) for the year 1995.

B. Change detection processing

1. Georeference (registration) the two images. The result of georeference the images in 1995 and 2000 shown in the Figure-7.

1995   **2000**
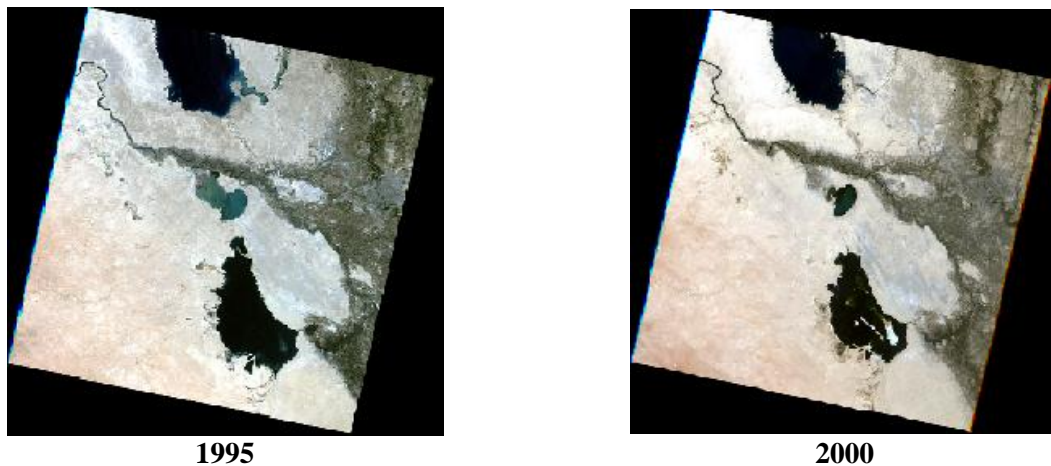
Figure 7- Show georeferenced (registered) images in 1995 and 2000.

2. Select method to apply change detection. In our work, two color multi view (2CMV) method was selected. The result are shown in Figure-8.
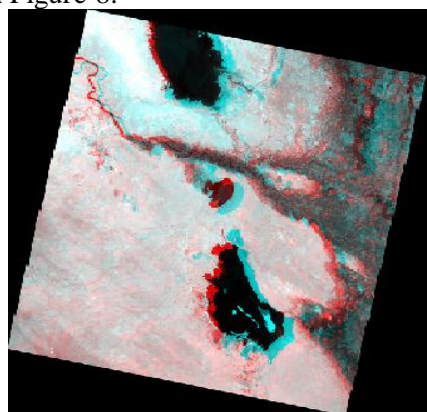

Figure 8- Show an RGB image composite that represent the result of Two Color Multi View (2CMV) change detection method, in which red or cyan colors indicate changed areas.

C. Classification

1. First, defining region of interest (ROI) as shown in Figure-9.Then applying method of classification. The result of classification is shown in the Figure-10.
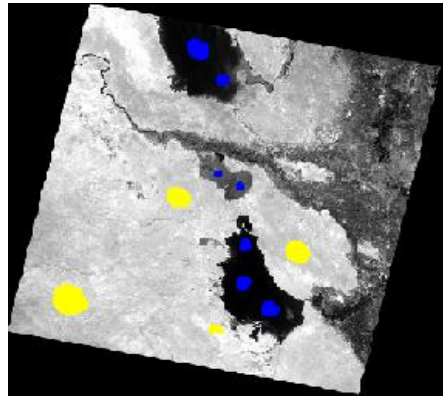
Figure 9- Explain selecting region of interest before applying classification method on images for the year 1995.
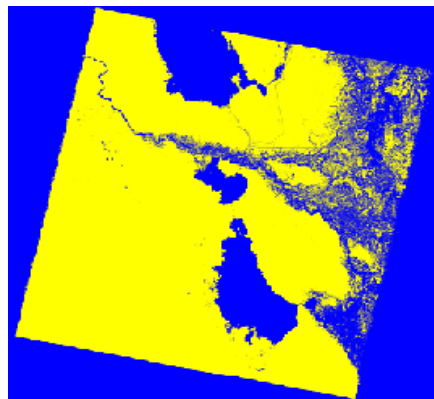

Figure 10- Illustrate the results of minimum distance classification method. The blue regions in the images represent water pixels, while yellow regions represent pixels rather than water.

2. Estimating the fraction of the pixel area occupied by each material present in the pixel as illustrated in the Table-1.

Table 1- Calculated area for water class for the study area using minimum distance supervised classification.

	The scene 1995		The scene 2000	
	Area(pixel)	Area %	Area(pixel)	Area %
Water ▪	27808659	48.6128	25354606	44.3228

Conclusions:

According to the results that have been obtained from this study, we can conclude several important points which can summarize as follow:

1. Accuracy of the results depends on the experience of the analyzer (ability to deal with the software ENVI) and characteristic of the image using in the analysis (spatial and spectral resolutions).
2. When mapping the water body of the study area (the city of Baghdad and surrounding areas), the accuracy of the results are depended on the preprocessing on the images like applying Atmospheric correction, stretching, filtering and data reduction by MNF transformation.
3. The results of the target detection technique that have been obtained for the study area, found that the percentage of water body in year 1995 was greater than for year 2000.
4. The results that have been obtained from applying constrained energy minimization were more accurate than applying matched filter comparing with real situation.
5. The results of applying change detection technique on the study area illustrated the decreasing in water body percentage through the years from 1995 to 2000.

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