Review of various Change Detection Techniques for Hyperspectral Images

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Abstract: **Change detection is the process of automatically identifying and analyzing regions that have undergone spatial or spectral changes from multi temporal images. Remote sensing is the most suitable technology used for change detection in many application areas. Hyperspectral remote sensing images deal with a large number of wavelength bands as compared to single band or multispectral images. Thus ample of spectral information provided by hyperspectral images present promising change detection performance. The main objective of this paper is to study the comparative analysis of various change detection techniques for hyperspectral images. This paper presents a review of advantages and limitations of different change detection techniques.**

Keywords: Hyperspectral images, multi temporal images, hyperspectral remote sensing images;

1. INTRODUCTION

Change detection is recognizing dissimilarities that arise in the characteristics of an object, over a period of time. In many applications, remote sensing change detection has played a vital role. Remote sensing technology provides a large-scale view of landscape over a long period of time and has been demonstrated to be an efficient method for change detection. In many applications such as land-use/land-cover monitoring, ecosystem monitoring, disaster monitoring and urban development, change detection by remote sensing has been widely used.

We have different existing methods which are used to detect changes under two categories supervised and unsupervised methods. Unsupervised approach considers only the raw multispectral images to generate further image. It performs preprocessing to make the input images compatible, which are then compared according to individual pixels or features. This leads to generation of the resultant image which is analyzed to detect changes. Different approaches in this category include change vector analysis (CVA), image rationing, expectation maximization, etc. Supervised approaches make use of training sets for learning purpose. This allows easier statistical estimation of the types of changes occurred.

The “hyper” in hyper spectral means “over” as in “too many” and refers to the large number of measured wavelength bands. These hyperspectral images are spectrally over determined, which means that they give ample spectral information to identify and distinguish spectrally unique materials. Hyper spectral sensors measure radiance by a large number of bands covering a wide spectral range. Although multitemporal multispectral images can show spectral changes in several bands yet the spectral information offered by multispectral data is not so elaborate. Hyper spectral imagery provides much detailed information on spectral changes in multitemporal scenes than multispectral images, which helps to improve the change detection performance. Hyperspectral remote sensing combines imaging and spectroscopy in a single system which often includes large data sets and requires new processing methods. In hyperspectral remote sensing, data sets are generally composed of about 100 to 200 spectral bands of relatively narrow bandwidths (5-10 nm), whereas, multispectral data sets are usually composed of about 5 to 10 bands of relatively large bandwidths (70-400 nm). In a hyperspectral image, all the information about reflectance across the entire spectral range of the sensor is contained by a single pixel producing what is called a spectral signature. There will be a resemblance between the spectrum obtained from one image pixel and a spectrum of the same material obtained through laboratory spectroscopy permitting detailed identification of materials.

In the conventional change detection techniques, physical meaning of the continuous spectral signatures is ignored. Comparatively, the foremost advantage of hyper spectral data is that the high-dimensional spectral information can indicate the fine spectral signatures. For hyper spectral data, the change of a spectral signature from one material to another material represents the presence of real change. Therefore, it is more reasonable to directly measure the difference in the spectral signatures of different materials when solving a hyperspectral change detection problem. Several kinds of methods have been proposed for hyperspectral change detection. In post-classification methods, classification maps of multitemporal hyperspectral images are compared to obtain the change detection result. Post-classification provides "from-to" change results and has been widely used; however, its accuracy is limited. Image transformation techniques, and principal component analysis (PCA), transform hyper spectral data into another feature space to label the changed areas. The third possible method of hyper spectral change detection is anomaly change detection. In Anomaly detection algorithms, anomaly changes are considered as outliers in a difference image. Table 1 presents the information regarding some of these techniques as provided by different authors.

To explore the high-dimensional spectral information and the continuous spectrum, the algorithm should directly measure the difference in the signatures to define the detailed changes in the different materials. At same time, considering the practical application, the algorithm should be simple and easily applicable [10].

TABLE 1: FINDINGS OF DIFFERENT AUTHORS REGARDING DIFFERENT CD TECHNIQUES

S. No.	Technique	Authors	Findings
1.	Image Differencing	M. Hussain et al.(2013)	Easy to interpret results.
2.	Image Ratioing	Zhang Shaoqing, Xu Lu (2008)	Simple method to be used for change detection in urban areas.
		M. Hussain et al.(2013)	Better handles calibration errors.
3.	Change Vector Analysis(CVA)	M. Hussain et al.(2013)	Difficult to identify land cover change trajectories.
		Sartajvir Singh et. al(2014)	Good interpretation of change direction and magnitude but problematic in selection of threshold.
4.	Principal Component Analysis(PCA)	Vijay Kumar et. al(2013)	Easily classify the changed and unchanged area.
5.	Independent Component Analysis(ICA)	Vikrant Gulati et. al(2014)	Better removal of correlation among components.

2. LITERATURE SURVEY

Several change detection algorithms have been proposed in past some years. With change in time, several enhancements have been made in these algorithms by different researchers. An overview of these algorithms is being given below.

1. *Image Differencing*

Image differencing is one of the simplest and useful CD techniques. Image differencing involves subtracting of the intensity values at same pixel locations of two images collected at two different periods of time. The two co-registered images are compared pixel-by-pixel and pixels associated with changed areas produce values significantly different from those pixels associated to unchanged areas. The technique is simple, robust and easy to implement but same value may have different meaning because difference value is absolute.

Masroor Hussain et. al (2013) This paper began with a discussion of the traditionally pixel-based and (mostly) statistics-oriented change detection techniques which focus mainly on the spectral values and mostly ignore the spatial con- text. After this a review of object-based change detection techniques was presented. Finally there was a discussion of spatial data mining techniques in image processing and change detection from remote sensing data. The advantages and limitations of different techniques were compared [1].

M. Ilsever C.U et. al (2012) In this paper they present an techniques for detection of hyperspectral images. They used the pixel-based change detection methods such as Image differencing, automated thresholding; Image rationing, Change vector analysis (CVA). The basic premise in using remote sensing data for change detection is that changes in land cover must result in changes in radiance values and changes in radiance due to land cover change must be large with respect to radiance changes caused by other factors [2].

2. Image Ratioing

Image ratios or band ratios involve the same logic, except a ratio is computed and the pixels that did not change have a ratio value near 1 in the ratio image. The technique is simple and may mitigate problems with viewing conditions, especially sun angle.

Zhang Shaoqing et. al, In this paper, author does the comparative study of image subtraction, image ratio and method of change detection after classification. Author found that image ratio method is applicable to be used in change detection of city. Its disadvantage is that it cannot reflect which category is changed [3].

3. Change Vector Analysis (CVA)

The Change Vector Analysis (CVA) technique generates two outputs: magnitude and direction of the change vector. The first step on this method is to eliminate any redundant information in order to focus on the change analysis in the features of interest. The next step is to calculate the magnitude of variation among spectral change vectors between the images pairs.

Sartajvir Singh et. al (2014) this paper comprises a comparative analysis on CVA based change detection techniques such as CVA, MCVA, ICVA and CVAPS. The paper also summarizes the necessary integrated CVA techniques along with their characteristics, features and drawbacks. On the basis of experiment outcomes, it has been seen that CVAPS technique has greater potential than other CVA techniques to evaluate the overall transformed information over three different MODerate resolution Imaging Spectro-radiometer (MODIS) satellite data sets of different regions [4].

Jin Chen et. al (2003) in this paper, a new method was proposed to improve CVA. The method (the improved CVA) consisted of two stages, Double-Window Flexible Pace Search (DFPS), which aimed at determining the threshold of magnitude of change, and direction cosines of change vectors for determining change direction (category) that combined single-date image classification with a minimum-distance categorizing technique [5].

4. Principal Component Analysis (PCA)

Principal Component Analysis is a linear transformation technique and probably the most common of these techniques. The principle of the PCA technique is to use as input a set of images and to reorganize them via a linear transformation, such that the output images are linearly independent. The data is projected such that the greatest variance lies on the first axis or the first principal component and the second greatest variance on the second axis. This technique reduces redundancy but results are scene dependent and difficult to interpret.

Vijay Kumar et. al (2013) the author proposed an approach for unsupervised change detection technique on SAR data. As various traditional techniques are available to detect change on satellite images, author used PCA technique which involves Singular Value Decomposition Method (SVD) method to process the images. After that the author compared the images pixel by pixel and found out the changed pixels and mapped those pixels to display the changed map [6].

Turgay C. et. al (2009) the proposed paper presents a novel technique for unsupervised change detection in multitemporal satellite images using principal component analysis (PCA) and k-means clustering. In this paper, the difference image is partitioned into $h \times h$ non overlapping blocks. Then to achieve change detection the feature vector space is partitioned into two clusters using k-means clustering with $k = 2$ and then each pixel is assigned to the one of the two clusters by using the minimum Euclidean distance between the mean feature vector of clusters and the pixel's feature vector. The algorithm proposed by author is simple in computation yet effective in identifying meaningful changes which makes it suitable [7].

5. Independent Component Analysis (ICA)

ICA concerns not only with second-order dependencies but also higher-order dependencies between variables. The goal of ICA is to linearly transform the data such that the transformed variables are as statistically independent from each other as possible.

Vikrant Gulati et. al (2014) in this paper, a change detection technique for multi-temporal multi-spectral remote sensing images, based on Independent Component Analysis (ICA), is proposed. The environmental changes can be detected in reduced second and higher-order dependencies in multi-temporal remote sensing images by ICA algorithm. Thus the correlation among multi-temporal images can be removed without any prior knowledge about change areas [8].

Xiao Benlin et. al (2008) in the paper, author firstly introduced the algorithm for ICA, as the Fast-ICA algorithm. Then a Fast-ICA based image classification algorithm was proposed. Using this algorithm author made transformation on the original image and extracted some thematic information like vegetation, water bodies in advance, thus gave facilities for the next classification. Next a new change detection model based on Fast-ICA was presented [9].

3. CONCLUSION

The change detection techniques are mainly categorized into supervised and unsupervised techniques. In a supervised classification there is first an identification of the training classes, which are then used to determine the spectral classes that represent those. This approach is advantageous since it is robust and can process images from multiple sources. But the difficulty arises in availability and generation of suitable training sets required. The unsupervised classification does not start with a pre-determined set of classes as in a supervised classification. Traditional change detection methods and their enhancements have been intensively studied; however, almost all of them are based on single-band or multispectral remote sensing images. Recently, hyperspectral images have attracted increasing attention due to the wealth of information contained and the wide range of potential applications.

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