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Review of Change Detection Techniques for Remotely Sensed Images

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Abstract: **The use of remotely sensed image has been a wide area in research. Different images of the same scene captured by the satellites at different times can provide information about the significant changes that held on earth with time. Many techniques for change detection has been developed while new techniques are also emerging. This paper gives a review of pixel based and transformation based techniques used for change detection. The paper begins with the discussion on pixel based techniques like image differencing, Image Ratioing and Image regression. Then, transformation based techniques like principal component analysis and change vector analysis has been discussed in detail. The paper has been concluded with the comparison of the discussed techniques based on advantages, limitations and applications.**

Keywords- Change Detection; Principal Component Analysis; Image Ratioing; Image Differencing

I. INTRODUCTION

Change detection on remotely sensed images involves the detection of a group of pixels that have faced a significant change in brightness relative in a previous image sequence. The difference based change detection methods has been presented in [1]. Such change is normally called as the temporal change and it is performed as a change detection study which involves two sets of same scene captured at different times [2], [3]. Before performing any change detection analysis, both the images must be accurately registered with one another. Image registration involves the proper alignment of a pixel in one image with the same pixel in the other image. Mis-alignment may lead to large number of false alarms [4]. In order to get the error rate less than 10% in change detection techniques, the registration accuracy of one fifth of the pixel must be maintained.

After both the Images has been accurately registered, a typical change detection algorithm takes the multi temporal images as input and generates a binary image $I_d(x,y)$, called a change mask.

A thresholding technique is then applied on the subtracted image which converts all the pixels above threshold value into 1 and pixels below threshold value into 0 as shown in equation 1 [3], [5]. So the objects coded as 1 represents the change value while the objects coded as 0 represents the no change value.

$$I_d(x,y) = \begin{matrix} 1 \text{ if} & I_d(x,y) > Threshold \\ 0 \text{ if} & I_d(x,y) < Threshold \end{matrix} \quad (1)$$

$I_d(x, y)$ represents the change vector.

Various change detection methods has been developed in the past depending on the conditions and application. The change detection methods based upon ratio of pixels in multitemporal images has been presented in [7], [8], [9], [10]. Fusion of Mean ratio and log ratio based change detection has been presented in [11]. Image regression based change detection method has been described in [12]. Principal component analysis based change detection method has been described in [15], [16], [17], [18], [19]. In transformation based change detection, the image under consideration is transformed into new dimension. Change vector analysis based change detection method has been described in [20], [21], [24]. Change vector analysis generates the magnitude and direction of the change vector.

This paper is organized into three sections. The next section introduces various popular techniques for change detection in high resolution images. Third section of the paper presents the conclusion.

II. TECHNIQUES FOR CHANGE DETECTION

The change detection techniques can be broadly classified as pixels based, object based, classification based, transformation based, machine learning based and hybrid technique. In this paper, widely used pixel based techniques has been overviewed.

A. Image differencing

In Image differencing, two precisely co-registered images of different times are used where residual image is produced by subtracting a first date image from second date image pixel by pixel to represent the change [1], [3]. In this technique, either radiometric value of the pixels or other parameters like textures and vegetation indices can be used to measure the change in the transformed image [6].

Mathematically, the difference image is:

$$I_d(x, y) = I_1(x, y) - I_2(x, y) \quad (2)$$

Where I_1 and I_2 are images from date 1 and date 2 and I_d is the difference image in the same coordinates. 'x' and 'y' denotes the coordinates of the pixels in both the images.

The advantage of image differencing is that it is very simple to implement and it is very easy to interpret the results. But the limitation with image differencing is that it cannot provide the detailed matrix of change. Also, a threshold value is needed to find the changed information and the difference value given by the technique is absolute. So, same information can give the different meaning. This method requires accurate image registration otherwise it would not be able to produce the proper results. Another limitation is that the threshold needs to be selected separately in changed and unchanged areas.

B. Image Ratioing

Image ratioing divides the brightness pixel value in the first image with the brightness pixel value in second image. It is up to the analyst that which image needs to be considered in numerator or denominator. The no change value will automatically be given as 1 and the value of division which do not represents 1 mean to the changed region in the image [7], [8], [9], [10].

$$I_d(x,y) = a\frac{I_1(x,y)}{I_2(x,y)} \quad (3)$$

Where 'a' represents the scaling factor whose value may depend upon the application. After the division, a decision rule is applied which gives a new set of pixels represents the changes and unchanged areas.

The main advantage of image ratioing lies in its ability to handle the calibration errors like shadow, topography impact and sun angle more efficiently. But the limitation here is that the results with the technique are not distributed normally.

Image ratioing can also be implemented by either using the Log Ratio or Mean Ratio operators. In Log Ratio operator [11], natural logarithms of the ratio of pixels in the images are calculated and finally a change map is generated by converting the logarithmic image into binary.

$$I_d(x, y) = \log\frac{I_1(x,y)}{I_2(x,y)} \quad (4)$$

In case of mean ratio operator, the local mean of the pixel in one image is divided with the local mean of the corresponding pixel in the second image.

$$I_d(x, y) = \frac{\text{mean}(I_1(x,y))}{\text{mean}(I_2(x,y))} \quad (5)$$

Where $\text{mean}(I_1(x,y))$ represents the local mean of the pixel in the first image and $\text{mean}(I_2(x,y))$ represents the local mean of the pixels in second image.

C. Regression Analysis

Image regression analysis technique is used to reduce the effect of atmospheric conditions. In image regression technique, one image is assumed as reference image while the other as subject image. The subject image is adjusted so that radiometric conditions of it can be matched to the reference image [12], [13]. Then regression function is applied on the subject image. Then the regressed image is subtracted from the reference image in order to get the change.

In Change detection using regression analysis, it is assumed that the image I_1 is a linear combination of I_2. So, the estimate of I_2 can be found by least square regression as:

$$I_2(x,y) = aI_1(x,y) + b \quad (6)$$

To find the parameter a and b, the squared error between measured and predicted data needs to be defined [14]. Then the aim is to find out the parameter a and b so as to minimize the error. By substituting the values of a and b, change map can be found by using:

$$I_d(x,y) = I_1(x,y) - I_2(x,y) \quad (7)$$

The advantage of the technique is that it reduces the impact of atmospheric conditions, sensor effects and other environmental differences like Sun angle between the two images. The main limitation of the technique is that the regression function required must be accurate in order to detect the change.

D. Principal Component Analysis

PCA is a transformation based technique and generally used for dimensionality reduction so that it become easy to perform the change detection on a data with less dimensions. This technique is very useful when the multitemporal data is highly correlated [15], 16].

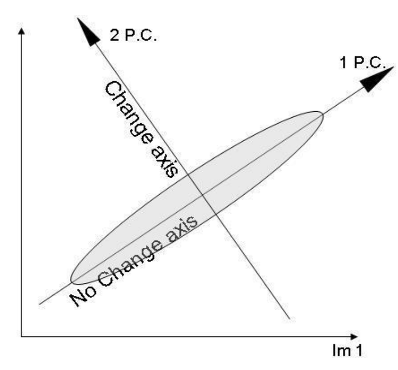

Figure 1: Concept of change in Principal Component Analysis [21]

There are two ways to apply PCA, one is to put the multitemporal images into a single image cube and perform the principal component analysis to get the change information. Other is to perform the principal component analysis separately on both the images and then apply the change detection technique. The unchanged pixels will lie near to the principal axis (P.C.1) called first principal component while the changed pixels will lie far away from the principal axis and will be along second principal component (P.C. 2) [17],[18],[19]. The later principal components includes the change information.

The main advantage in principal component analysis is reducing the redundancy in the data from the images under consideration. The new components obtained from the analysis provide the much accurate information of the change. The main limitation with principal component analysis is that it is scene dependent. So, it becomes very difficult to label the different dates. Also, determining threshold for change detection is also a big limitation of principal component analysis.

E. Change Vector Analysis

Change vector Analysis generates output in the form of magnitude and direction of the change vector. The first step involved in this technique is to remove any redundant data so that the change analysis may be concentrated in the feature of interest [20], [21]. In the next step, magnitude and direction of change vector is calculated. The change vector analysis normally applies to the multi or hyper spectral images containing multiple bands [22], [23].

The main advantage of change vector analysis is that any number of spectral bands can be processed and it produces detailed change information about the images under consideration. This technique is highly beneficial when the details of the change of interest are not well known. The main limitation lies in the difficulty to identify the trajectories of land cover change. The factors on which accuracy of Change vector analysis methods depends include image quality, geometric correction and accuracy of threshold [24].

III. CONCLUSION

In this paper, a review of pixel based changed detection techniques have been presented. The advantages and main limitation of the techniques have also been discussed. The pixel based change detection techniques have been further classified into direct comparison based techniques and transformation based techniques. Direct comparison based techniques are simple to implement but do not provide the changed information more accurately while the transformation based techniques are time consuming but provide better result than the direct comparison based techniques. Change detection from remotely sensed multitemporal images has been a topic of interest for the researchers and many techniques for change detection has been proposed. But it is still a growing area and new techniques are still emerging. There is still no such approach which can be applied to each and every case.

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Authors Profile

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