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Research Article

A Valuable approach for Image Processing and Change Detection on Synthetic Aperture Radar Data

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Abstract

In this paper, we proposed an approach for unsupervised change detection technique on SAR data. Change detection is process of automatically identifying and analyzing the regions which undergone some changes such as spatial or spectral changes. As various traditional techniques are available to detect change on satellite images. In order to detect change on SAR images we use PCA technique which involve Singular Value Decomposition Method (SVD) method to process the images. After that we compare the images pixel by pixel and find out the changed pixels and map those pixels to display the changed map.

Keywords: *PCA (Principle Component Analysis), SVD (Singular Value Decomposition), multispectral SAR (Synthetic Aperture Radar) images, Change Detection.*

Introduction

Change detection plays an important role in analysis of satellite images. As our need increases day by day but we are limited to natural resources on the earth and also we need to analyze the atmosphere above the earth surface. Therefore we need to check all these resources availability and this can be done by monitoring those things which are very important because it can provide valuable source of information for decision making process. Also in military application change detection can provide valuable information and help them in making decision process.

We have different existing methods which are used to detect changes under two categories supervised and unsupervised methods. In supervised method we need to perform training additionally in order to classify the information which means that we can predict our output by these classifier training. In unsupervised method we do not require any additional training to classify the information which means output is not predictable. In other words unsupervised method has ability to classify the information by itself so that it attracts more and more researcher to take interest.

Two techniques were introduced to solve unsupervised change detection problem which were expectation Maximum (EM) base and Markov Random Field (MRF) based method. In the first method, selection of decision threshold by which minimum change detection error was to be carried out. In the second method we analyze the difference image through pixel by pixel considering spatial information based on MRFs. These both techniques generally applicable to color image as they are not appropriate methods that can be applicable satellite images which have high resolution as compared to general color image. After change detection based on neural architecture when proposed then it becomes convenient approach to detect change on very high resolution satellite images and this method can deals with both multiband and multi temporal data for real change identification.

SAR (synthetic aperture Radar) data are those satellite images which are captured by this SAR device which is mounted on space aircraft, satellites and military aircrafts. The image captured by SAR is of very high resolution as compare to other satellite devices and are multispectral images and to process those we need to reduce the size of image without loss of necessary information. There are many methods such as K-means clustering, Multivariate Alteration Detection (MAD), and Change Vector Analysis (CVA), image differencing and other various methods. But some unsupervised methods are the best method by which we can easily distinguish between two images.

In earlier days we apply comparison or difference image based technique for low or medium resolution satellite images which employs the Bayesian theory to achieve the analysis of difference images. The technique such as image difference and image rationing are effective in detecting change in low dimension image as because they have to compare each image pixel by pixel. So they check all pixels and then result for changed map comes out. But they are not suitable for high resolution image because there numbers of pixels are of large size and computing all those pixels of images take more time and it also become

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complex to detect changed pixels. Therefore these techniques do not provide best result and also they are not efficient for such high resolution satellite images. But as unsupervised method of change detection came into existence then this method become effective in order to detect change of satellite images which are of good quality and or of good resolution.

In order to provide better change detection in SAR data set we apply unsupervised method which is appropriate to detect change in multi temporal SAR data set. The technique which is proposed in this letter comes under unsupervised method is Principal component Analysis (PCA). As PCA provide good and effective result in order to detect change.

Methodology used for change detection

Let us consider two registered multispectral images $\mathbf{I}_{t1}$ and $\mathbf{I}_{t2}$ captured by SAR of same geographical area and of same size (i.e. of same dimensions) taken at different time t1 and t2. And what we need to do is to detect the changes in the images by analyzing the images using the PCA technique.

Principal Component Analysis (PCA) is a linear transformation of given data set into the new data set such that largest variance by any projection of data set lie on the first axis(also called first principal component), the second largest variance on the second axis, and further on. It is a technique by which it reduces the numbers of related variables associated with the given data set into the new set of variables which are uncorrelated but retain most of the variability that are associated with original variable of the data set.

Suppose that **x** is a vector of *m* random variables, and that the variances of the *m* random variables and the structure of the covariance or correlations between the *m* variables are of interest. Unless *m* is small, or the structure is very simple, it is not always very helpful to simply look at the *m* variances and all of the (1/2) m (*m*-1) correlations or co variances. An alternative approach is to look for a few (<<*m*) derived variables that preserve most of the variability information.

The first step is to look for a linear function $z1= \boldsymbol{\alpha}1'x$ of the elements of **x** having maximum variance, where $\mathbf{a}_1$ is a vector of *m* constants a_{11}, a_{12}, a_{13},……, a_{1m} and ′ denotes transpose, so that,

$\mathbf{z_1}=a_1'x=a_{11}x_1+a_{22}x_2+a_{33}x_3+……..+a_{1m}x_m$

$a_1 = \arg\{\max (\text{var} \ (z_1))\}$

The next step is to look for a linear function $a_1'x$ uncorrelated with $a_2'x$ having maximum variance, and so on, so that the kth stage a linear function of $\boldsymbol{\alpha}_k'x$ is found that has maximum variance subject to being uncorrelated with $z_1, z_2, z_3,……, z_{k-1}$.

The kth derived variable, $a_k'x$ is the kth principal component. Up to *m* principal components could be found, but in most applications the variability in **x** is accounted for by few, n << *m* principal components.

Singular Value Decomposition

Singular value decomposition (SVD) from linear algebra can be used in principal component analysis. Singular value decomposition (SVD) can be looked at from three mutually compatible points of view. On the one hand, we can see it as a method for transforming correlated variables into a set of uncorrelated ones that better expose the various relationships among the original data items. At the same time, SVD is a method for identifying and ordering the dimensions along which data points exhibit the most variation. This tie in to the third way of viewing SVD, which is that once we have idented where the most variation is, it's possible to find the best approximation of the original data points using fewer dimensions. Hence, SVD can be seen as a method for data reduction.

$A = VDV^T$

For any given matrix $A \in R^{m\times n}$ there exists decomposition

$A = UDV^T$

Such that

• U is an m ×n matrix with orthogonal columns

• D is an n×n diagonal matrix with non-negative entries

• V^T is an n×n orthogonal matrix

The most important issue here is that eigenvalue decomposition just exists for a square matrix, i.e. $A \in R^{n\times n}$! However, we want to know whether a similar decomposition exists for non-square matrices, i.e. if $A \in R^{m\times n}$.This is the SVD.

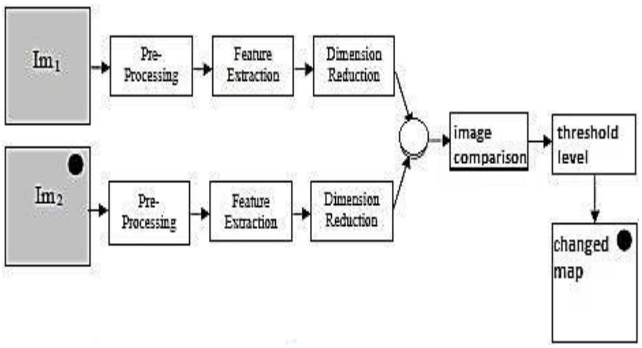


Figure 1: steps for change detection

Change detection using PCA involves following steps to be carried out in order to find those changes in SAR data taken at different time for same geographical area.

Image Pre-processing

In this step or process we compare the two images with respect to their sizes and also compare their spatial and spectral domain. As the size of both the images must be of same, any variation in size of image may lead to wrong output, so dimension of image must be same. In spatial domain we check both the images should co-register to that they associated with same area. Spatial domain contains the pixels which are associated with the particular area. And in spectral domain we check the change in illumination and atmospheric condition between the two acquisition times.

Feature Extraction

This step involves the extraction of new feature which is derived from original feature by means of some functional mapping keeping as much information as possible. Here using PCA technique this feature extraction can be done easily by generating principal component for the two images which are registered. Principal component are those which provide a new set of variable that are uncorrelated and are ordered so that it retain most of the variability present in the original variables. Here set of variables are the pixels associated with both of the two images which are taken and generating principal component for both the images and these principal component gives all information related to both the images. And principal component of image **I***t*1 is different from the principal component of image **I***t*2.

Dimensionality Reduction

One of the most important characteristics of PCA is it provides an effective dimensionality reduction in the feature and retain only those feature which have large variance to represent data. So here we reduce the size of image based on their principal component vector as we reduce the number of pixels associated with the images and we remain with those pixels which are helpful to give all information related to the images. And we perform this process separately for both the two images so that we can easily detect the change by reducing the number of comparison of pixels associated with two of the images.

Image Comparison

After finding the principal component for both the two images and reducing the dimension of the images we have now two different images and we are in state to compare both the images. Comparison of images is done through pixel by pixel and computes those pixels which are associated with the changed areas. Then we map that pixel in order to generate the change map.

Experimental result

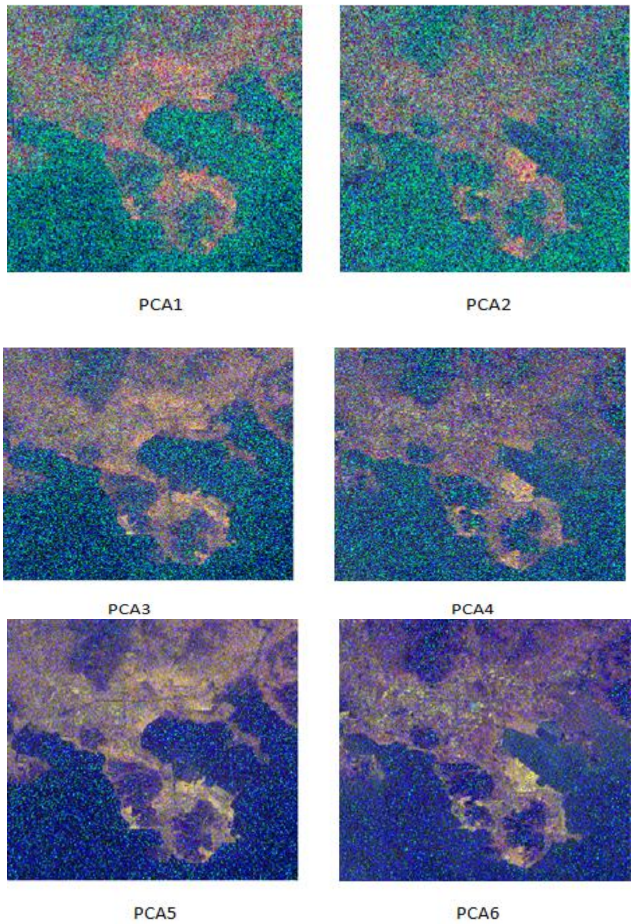
In order to evaluate the performance of the methodology mentioned in this paper can be checked by testing it. In this paper we tested the performance of PCA in MATLAB software. Here we have taken two images at different time but of same dimension that is Location of the Dalian Development Area (DDA) and the corresponding SPOT-5 (Satellite for earth observation-5) images from 2003 and 2007.

From 2003 to 2007, the area covered by water was decreased because of coastal-land reclamation. In addition, building coverage area in the region increased. This shows strong development of urban sector. The rapid decrease of water coverage caused by coastal-land reclamation is a symbolic pattern of the DDA's urbanization, which is driven by the prevailing land-management policy. The drastic reduction of grassland during this short time period implies a loss of ecosystem service.

(a) 2003 images (ba) 2007 images

Figure1. Location of the Dalian Development Area (DDA) and the corresponding SPOT-5 (Satellite for earth observation-5) images from 2003 and 2007.

We therefore interested to find out these changes by analyzing the figure by Principal Component analysis technique. Using this technique we only deals with that component which are enough to provide all the information contained by the information but with minor loss of information. In practical we have to deal with very high resolution image which is of very large size as compared to normal image. In this we take images of normal size contain around of thousand components (1000×952 dimension) in it.



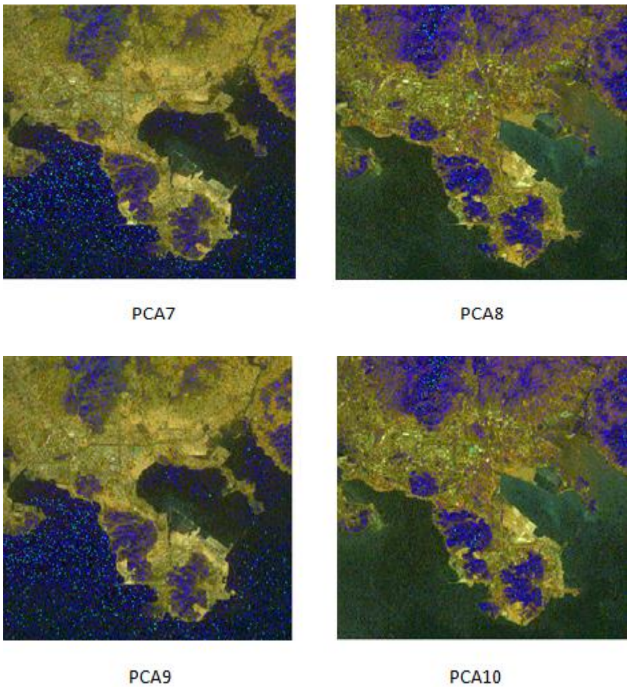


Figure2. Principal Component for different values.

So we have thousand components in both the images as both are of same dimensions. Using SVD we find out the eigenvalues along the diagonal of matrix formed by the images. In order to select those eigenvalues which are important to describe the information we sort out the eigenvalues in decreasing order and select the eigenvalues which are having value larger than other. We can neglect those eigenvalues having small values as because they are not of much significant.

After that using the selected eigenvalues we form the image matrix which is of low dimension and size as compared to original image. Then we display the image through new matrix which shows the information content by the original image in reduced size. We are using PCA in order to process the information more efficiently and effectively and also it reduces the space on the memory. In the given table we show different Principal Component values were taken corresponding to the selected eigenvalues. And result shows that percentage of variance corresponding to the number of principal component used.

Table1. Percentage of Variability and Variance for different Principal Component.

Number of Principal Component	Percentage of variability
10	0.1142
50(PCA1,PCA2)	0.216
75	0.3485
100(PCA3,PCA4)	0.5245
125	0.6879
150(PCA5,PCA6)	0.7931
175	0.8768
200(PCA7,PCA8)	0.9039
225	0.935
250	0.9578
300(PCA9,PCA10)	0.9648

Also it shows that in the example original image component contains around 1000 component out of which using PCA through SVD it uses less component to display the information content by original image. As we increase the number of component the percentage of variation increases and we get more clear information content by original. So if an image is of high dimensional and of large in size we can easily process through PCA and can analyze the image.

After processing the information using PCA the next step is to detect the change in the second image from previous one. In order to detect the change we simply apply comparison technique to compare the image pixel by pixel. And it is easy to perform at this stage because image is of low dimension as such it works effectively. It is difficult or it takes long time to detect the change in very high dimensional image which is of very large size. The figure3 shows the changed map which shows the decrease of water coverage area and development of urban sector in the region.

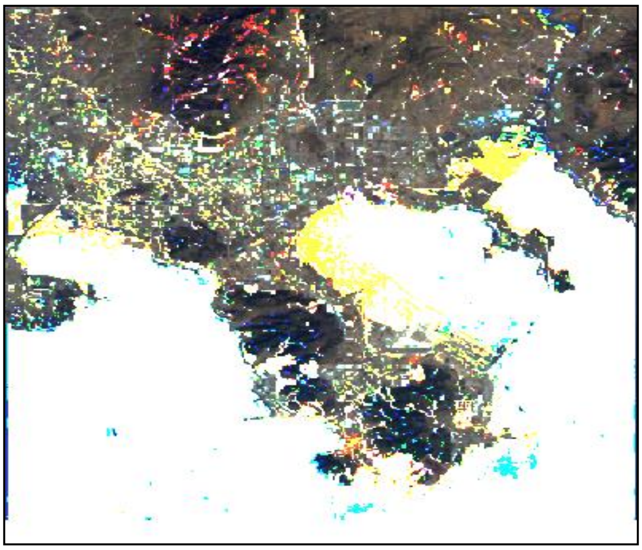


Figure3. Changed map

Conclusion and future work

In this letter, PCA technique can provide best result for change detection in SAR data by processing the two different image of same geographical area and compare both them through pixel by pixel or through principal component vector generated for both image. The PCA technique easily classifies the changed area and the unchanged area by using principal component. This PCA technique not only detect the changes in the images but also convert a very high dimension image into lower one maintaining all information related to original image. So we can easily store as it occupy less storage space as compared to original one and it is an efficient technique.
In future PCA technique can be used in telemedical sciences in which it can be used for detecting diseases related to internal human body organ by comparing the

multispectral images of human body organ of specified location.

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