Application of Fusion Technique in Satellite Images for Change Detection

Namrata Agrawal, Dharmendra Singh, and Sandeep Kumar

Abstract. The identification of land cover transitions and changes occurred on a given region is required to understand the environmental monitoring, agricultural surveys etc. Many supervised and unsupervised change detection methods have been developed. Unsupervised method is the analysis of difference image by automatic thresholding. In this paper, an approach is proposed for automatic change detection that exploits the change information present in multiple difference images. Change detection is performed by automatically thresholding the difference image thereby classifying it into change and unchanged class. Various techniques are available to create difference image but the results are greatly inconsistent and one technique is not applicable in all situations. In this work, expectation maximization (EM) algorithm is used to determine the threshold to create the change map and intersection method is selected to fuse the change map information from multiple difference images. MODIS 250-m images are used for identifying the land cover changes.

Keywords: change detection, unsupervised techniques, expectation maximization (EM), information fusion, MODIS data.

1 Introduction

Requirement and advancement of monitoring the dynamics of land cover has led to the development of change detection techniques in remote sensing field. Change

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detection has so many applications that include forest and environment monitoring, land use and land cover change, damage assessment, disaster monitoring and other environmental changes [1]. It is the process of analyzing the multi-temporal images of same geographical area to identify the land cover changes on the earth surface. It is basically of two types: supervised (requires the ground truth information as training data for the learning process of the classifier) and unsupervised (It performs change detection by making a direct comparison of two multi-temporal images considered without using any additional information) [2]. Unsupervised approach is adopted in the paper because it eliminates the expensive and difficult task of collecting the ground truth data.

Typically used automatic change detection techniques adhere to these three phase procedure: (i) data pre-processing, (ii) pixel-by-pixel comparison of multi-temporal images, (iii) image analysis. Pre-processing is performed to reduce noise and improve the visibility of objects (water, urban, grassland, etc.) on the earth surface. After this for pixel-by-pixel comparison difference image is created. Image analysis is then performed to automatically select a threshold to classify the difference image into change and unchanged pixels. Several unsupervised change detection techniques are present in the literature which follows these three steps.

Main challenges of unsupervised change detection technique that are main focus of the paper are 1) it should be fully automatic, unlike some methods [3][4] that require manual parameter tuning, 2) selection of optimal image differencing method is difficult task, 3) context-insensitive techniques [2] are prone to isolated noise pixels, 4) use of MODIS data for change detection is difficult because of low resolution but preferred as it is free and easily available, 5) it should be robust against noise. The proposed technique overcomes all the above problems.

Various combinations of difference image method and thresholding methods exist but there is no existing optimal approach for all cases [5]. Difference image is rich in information and the selection of one of the difference image is a difficult task. Hence the information fusion is performed on the results to get the advantage of all the difference images. Main advantage behind this step is that it gives the common pixels that are assigned changed class in all of the four outputs. “sure change” pixels will be the output after the information fusion.

2 Study Area and Data Used

Study site on which the experiment is performed and the satellite database is discussed.

2.1 Study Area

Study site is the Roorkee region of Uttarakhand and Muzaffarnagar region of western Uttar Pradesh and its nearby area located at 29°35’7.5” N, 77°44’6.17”E. This study area is considered due to its richness in varied landscapes. Two major rivers (Ganga and Yamuna) are present in the study area which is prone to the abrupt changes.

2.2 Data Used

The approach is applied on two sets of MODIS/Terra Surface Reflectance 8-day L3 global 250m data of same geographical area acquired in February 2010 and February 2011. Data of February 2010 and 2011 is selected because river width is changed between this time period. It consists of spectral band 1 with bandwidth of red light (620-670nm) and band 2 with bandwidth of near infra-red light (842-876 nm). Red light is absorbed by the vegetation region and near infra red light is absorbed by the water bodies. So these two bands can distinguish water and vegetation area easily. Figure 1. shows footprint of the data set location on the Google earth LANDSAT image. MODIS image of the region bounded by the black solid boundary is used in the experiment.

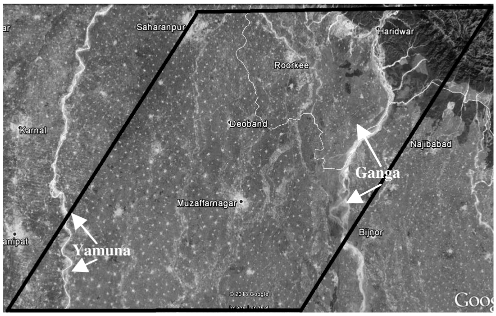


Fig. 1 Google earth image of data set used in the experiment

3 Methodology

For unsupervised change detection, a hybrid approach is proposed in which the change map outputs obtained after the analysis of four main difference image creation techniques are fused for reliable change pixels. Experiment is performed on MODIS data which has low visibility due to low resolution of images. Consequently, to extract the information about the land cover from the images, combination of spectral band is performed which is called the vegetation index calculation. Following four vegetation indexes are used as given in literature [6]: Normalized Difference VI (NDVI), Modified Soil Adjusted VI (MSAVI), Global Environment Monitoring Index (GEMI) and Purified Adjusted Vegetation Index (PAVI). These are helpful in clear identification of different objects on earth surface.

Unsupervised change detection techniques are based on difference image. Pixel by pixel comparison of two images which gives an image is called “difference image”. Simple mathematical operations are performed to create difference image. Four techniques used in paper to create difference image are discussed below. Consider two images of same geographical area, $X_1=\{ x_1(i,j) \}$ and $X_2=\{ x_2(i,j) \}$ such that $1\leq i\leq H, 1\leq j\leq W$, with a size of $H\times W$, acquired at two different time instances, t1 and t2, respectively. Let the output difference image is represented by X_d.

1. Image Differencing:

$$X_d = |X_2 - X_1| \quad (5)$$

Simple absolute valued pixel based intensity values subtraction is performed. If there is no change then it gives a zero value and larger values for higher change [7].

2. Image Ratioing:

$$X_d = |X_1 / X_2| \quad (6)$$

Pixel-by pixel division is performed to obtain the difference image. This helps in enhancing low intensity pixels and it does not depend on a reference intensity level. It also reduces the common multiplicative error [7].

3. Change Vector Analysis:
This method can process multiple spectral bands of image by creating a feature vector for each pixel. Difference image is calculated by calculating the magnitude of spectral change vector that is created by performing feature vector subtraction [8][9]. In experiment vegetation index is used as band1 and near infra-red spectrum is used as band2, representing greenness and brightness in image, respectively. This method also gives information about the direction of change as given in eq.8

$$X_d = \sqrt{((X_{1(band1)} - X_{2(band1)})^2 - (X_{1(band2)} - X_{2(band2)})^2 - .....(X_{1(bandN)} - X_{2(bandN)})^2)} \quad (7)$$

$$(\Theta)\ Angle = \tan^{-1}((X_{2(band1)} - X_{1(band1)}) / (X_{2(band2)} - X_{1(band2)})) \quad (8)$$

4. Image Regression:
It is assumed that X_2 is a linear function of X_1 image in image regression. X_2 is hence can be estimated using least-squares regression:

$$\tilde{X}_2 = aX_1 + b \quad (9)$$

Parameters *a* and *b* are estimated using squared error of measured and predicted data. Difference image is then calculated as:

$$X_d = | X_2 - \tilde{X}_2 | \quad (10)$$

Image analysis of difference image is performed to automatically detect the threshold that classifies the pixels into change and unchanged class. Expectation maximization algorithm is used for image analysis.

3.1 Expectation Maximization Based Change Detection

Expectation maximization algorithm is basically used to estimate incomplete data. It is used as the parameter estimation of probability distribution function. When the data required for the estimation is missing or impossible to use then EM is used. As given in [2] EM follows the same steps on all four difference images. Figure 2. shows the steps followed by image analysis technique to create change map.

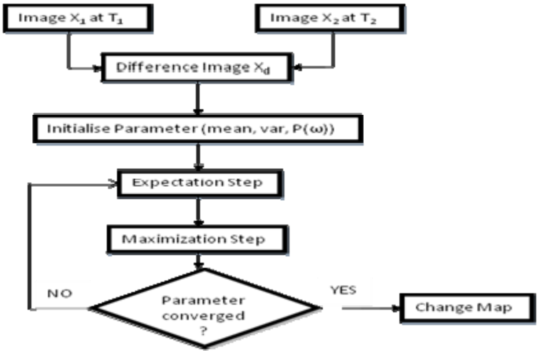


Fig. 2 General scheme of image analysis using EM algorithm

Change map gives the change and no-change pixels. Positive and negative changes are also determined based on the increase and decrease in intensity values in later date image. EM algorithm is fully automatic technique and does not require manual parameter tuning.

EM algorithm is applied on all four types of difference images resulting into different outputs except some common changed areas pixels which are present in every difference image. All differencing techniques have their some disadvantages. For example: Image differencing technique gives the absolute difference but same value may have different meaning depending on the starting class. In image ratioing, scale changes according to a single date so same change on ground may have different score. CVA technique may result in the computation of high dimensional data and it is complex to extract information from such data. Image regression is better for modeling conversion type of change (e.g. Vegetation to non-vegetation change modeling) [9]. Hence experiment is performed to fuse the output of all the four methods to minimize the limitations of the techniques.

3.2 Selection of Common Change

Fusion is performed on the outputs of EM algorithm of all four differencing method to select the common change. Intersection operator is applied for the fusion process. This will give those pixels that are changed in all the outputs. These pixels are sure change pixels. Figure 3 shows all the steps followed in the proposed approach.

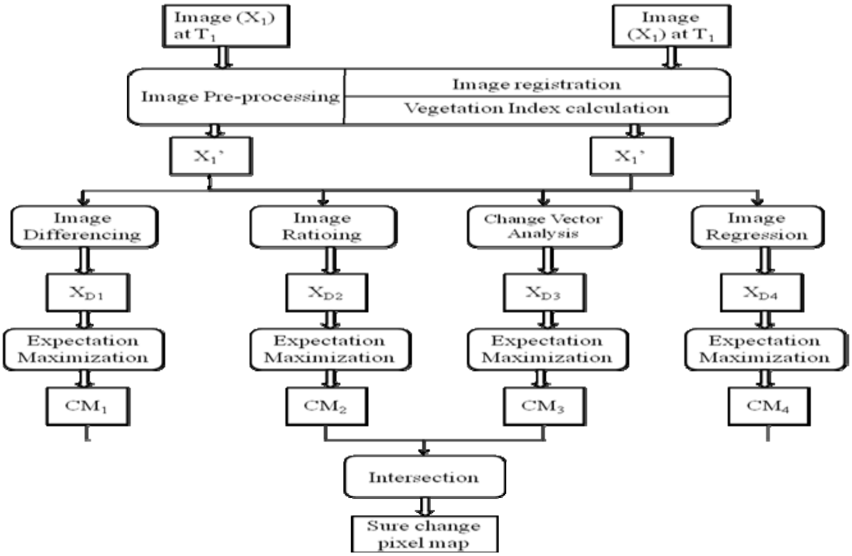


Fig. 3 Architecture of the proposed framework

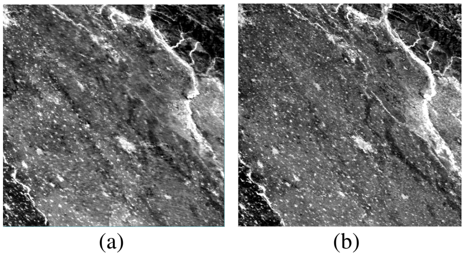
4 Experiment Results and Discussion

Two MODIS 250m images of Roorkee region are used for change detection. Images of size 400x400 pixels are selected and co-registered to correctly align the images. NDVI, MSAVI, GEMI and PAVI images are obtained by applying these vegetation indexes on the pair of input image using ENVI software. Change detection algorithm is applied in MATLAB environment.

Then four difference images are computed for each type of vegetation indexed input images. After the application of EM algorithm on all four types of difference images, four change maps are obtained for each type of VI images. Figure 4. shows the input image of February 2010 and February 2011. Result of EM algorithm is shown in figure 5. In Figure 5(a)-(l) Red pixels are showing the positive change means intensity of pixel is increased in February 2011 compared to February 2010. Green pixels are showing the negative change i.e. intensity of pixel is decreased in February 2011 compared to February2010. In Figure 5(m)-(p) blue pixels are showing decreased greenness and brightness, red pixels are increased greenness and brightness; white pixels are decreased greenness and increased brightness.

It is seen in the output images that the changes are mostly present near the Ganga River and Yamuna River. There is decrement of vegetation near the river in February 2011.

Fig. 4 Band 1 of MODIS input Image of (a) Feb-2010 and Feb-2011



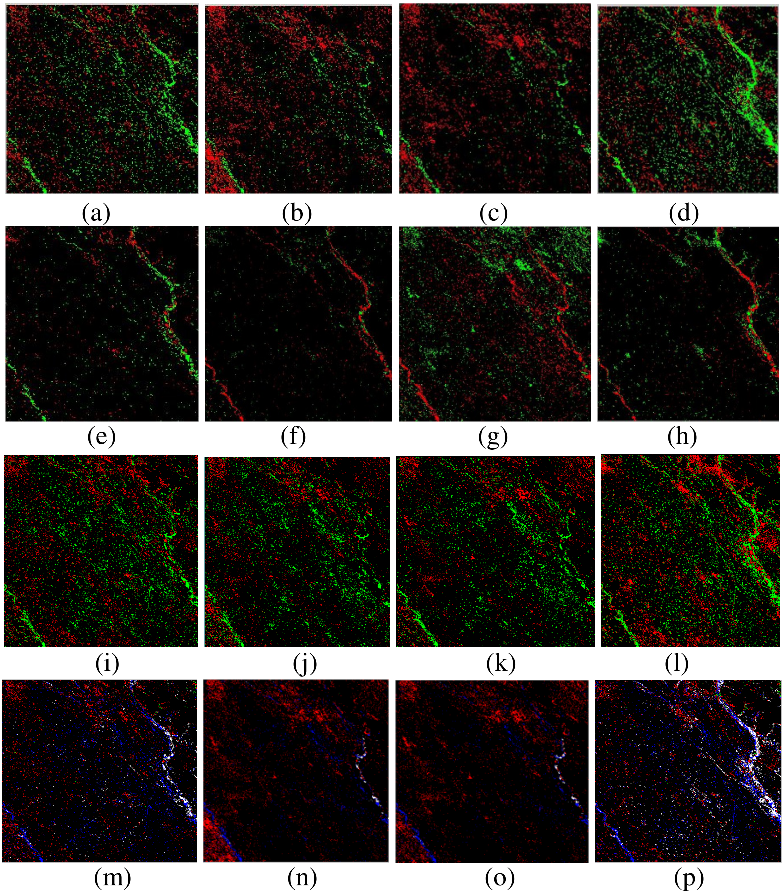
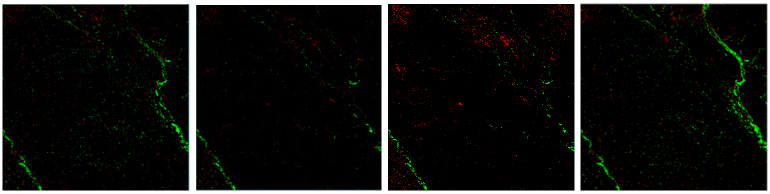


Fig. 5 EM change detection result applied on difference image of (a)-(d) Image Differencing, (e)-(h) Image Ratioing, (i)-(l) Image Regression, (m)-(p) CVA, where input image is Column1: NDVI, column2: MSAVI, column3: GEMI and column4: PAVI

It is clear from the EM outputs that all the outputs are giving different results. So, to reduce this inconsistency, common change pixels selection from all these images is performed in next step. Intersection is performed to get “sure change” pixels. Pixel that is labeled as “change” pixel in all four outputs is marked as “change” in final output. But the pixel that is labeled as “change” in one change map and “no-change” in another change map is marked as “no-change”. Figure 6, shows the output of intersection operation where green pixels are sure negative change and red pixels are sure positive change.



(a) (b) (c) (d)

Fig. 6 (a)-(d)Output of intersection operation when NDVI, MSAVI, GEMI and PAVI image is given as initial input, respectively

This final output helps in inferring the pixel of image that has changed with the period of time. Most of the change is around water area. The reasons behind the water region showing changes are the shifting of river from its original path, widening or narrowing of river, etc. The intersection operator confirms the reliability of ‘change’ pixels obtained by the proposed approach.

5 Conclusions

In this work for change detection purpose February 2010 and February 2011 MODIS data was used. Unsupervised change detection approach is proposed which automatically creates the change map with change and no-change pixels. Fusion approach is proposed in the thesis which helps in removing the difficulty of selection of one type of difference image. Also this approach does not require any apriori information. Intersection operation helps in removing the isolated noise change pixels that might be present because EM algorithm does not consider the contextual information. Experiment is performed on MODIS data and it is giving satisfactory results. This shows the feasibility of low resolution image for change detection operations. MODIS data is free, easily and very regularly available, hence is encouraged to use. Four difference image algorithms are used namely, image differencing, image ratioing, change vector analysis and image regression. Four difference images are created using these algorithms. The automatic threshold technique is applied on all four difference images separately which results in four change maps. All these change maps are similar with slight differences. So the aim was to obtain a fused change map having “sure-change” pixels. Expectation maximization technique is used for automatic thresholding and Intersection is used for the data fusion in the thesis. Final fused change map tells the change and no-change pixels.

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