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A Survey on Land Cover Change Detection Techniques in Remote Sensing

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ABSTRACT: Remote sensing provides an excellent source of data from which land cover changes can be analyzed. Land cover change detection in images obtained from remote sensing is used to identify the magnitude, direction and rate of land cover changes. Remote sensing change detection has played an important role in many applications such as land cover monitoring, disaster monitoring and urban sprawl. Many techniques have been proposed for land cover change detection. This paper is focused to provide a review of commonly used change detection techniques in remote sensing, their applications, and related issues in conjunction with the comparison of their strengths and limitations.

KEYWORDS: Multi temporal data, Supervised Classification, Topography, Decision Tree Classifier

I. INTRODUCTION

Land use and land cover change has become a vital component in current strategies for managing natural resources and monitoring environmental changes. Digital change detection is the process of determining the changes associated with land use and land cover properties with reference to geo-registered multi temporal remote sensing data. Change detection is defined by Singh (1989) as "the process of identifying differences in the state of an object or phenomenon by observing it at different times" [1]. Change detection technique is used in many applications such as land use changes, habitat fragmentation, deforestation, coastal change, urban sprawl, and other cumulative changes through spatial and temporal analysis techniques such as GIS (Geographic Information System) and remote sensing along with digital image processing techniques. Remote Sensing helps in acquiring multispectral, spatial and temporal data through space borne remote sensors. Image processing technique helps in analyzing the dynamic changes associated with the earth resources such as land and water using remote sensing data. High resolution remote sensing data at different time interval is used in analyzing the rate of changes and the drivers of changes [2]. Land cover area is broadly categorized into six classes such as forest, water bodies, agricultural land/vegetation, fallow land, waste land etc [3]. Many researchers reviewed and summarized various change detection techniques and their applications [1, 4, 14].

Generally, the change detection techniques can be grouped into two classes such as unsupervised classification based methods and supervised classification based methods. Unsupervised approach is the identification of natural groups, or structures, within multispectral data. No prior knowledge about the study area is needed for the unsupervised change detection algorithms. Normally the unsupervised methods get multi temporal images as input and a binary or ternary change map that shows changed versus unchanged areas as output. Image differencing, Image ratioing, vegetation index differencing, change vector analysis, principal component analysis and chi-square transformation are some of the well known unsupervised change detection methods. The main limitation of this type of algorithm is the lack of detailed from-to change information. Supervised classification is the process of using training samples, samples of known identity to classify pixels of unknown identity. Supervised change detection approach compares the classified images on a pixel by pixel basis and extracts the detailed from-to change information. Post classification comparison, artificial neural network, decision tree approach are some of the well known supervised change detection techniques. Supervised

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 7, July 2016

method needs high quality training data to classify each image in the multi temporal dataset. It is very difficult to set training data mainly for older images [5-8]. In this paper, we review the various unsupervised and supervised change detection techniques and analyze the strengths and limitations of each technique.

II. LITERATURE SURVEY

- A. **Image differencing:** In image differencing method, the spatially registered multi temporal images of time t_1 and t_2 are subtracted pixel by pixel to produce the difference image. Pixels with radiance change are distributed in the tails of the distribution curve while pixels showing no radiance change are distributed around the mean [1]. This technique takes into account the difference of radiance values of pixels between two different dates. Differences in atmospheric condition, differences in sensor calibration, moisture condition and illumination condition also affect the radiance of the pixels. Therefore this technique is better suited to cases as changes in radiance in the object scene is larger compared to changes due to other factors [2]. When used with all image bands, however, image differencing afford no information on the nature of change (i.e., from-to classes) and interpretation is difficult. A critical element in image differencing change detection is defining threshold values that specify where significant change has occurred. Frequently, a standard deviation from the mean is used as the threshold value [9].
- B. **Vegetation difference indexing:** Normalized Difference Vegetation Index (NDVI) is used for assessing ecological variables such as vegetation cover, above ground biomass and leaf area index [10]. The NDVI differencing technique was mostly applied for both human-induced and natural forest cover change detection such as forest harvesting, revegetation or afforestation that includes natural forest expansion and human-induced landscape restoration. The NDVI differencing method applied estimated NDVI as the normalized difference between near infrared (NIR) and visible red (RED) bands, which differentiate vegetation from other surfaces based on green vegetation chlorophyll absorption of red light for photosynthesis, and reflection of NIR wavelengths. In addition to the standardized techniques for pre-processing, threshold identification for detection of vegetation changes represents a key issue in the NDVI differencing method. The standard deviation (σ) is one of the most widely used techniques for threshold identification for different natural environments based on different remotely sensed imagery [11]. Tamesgen et al., (2014) used the NDVI method to separate green vegetation from other surfaces based on the vegetation reflectance properties of the area. The study was conducted with two different years of satellite imageries Landsat 5 TM of 1985 and Landsat 7 ETM+ of 2011. The result of NDVI value will be between -1 and 1. The higher the vegetation index value, the higher the probability that the resultant area has a dense coverage of green vegetation. Negative values mean no vegetation. NDVI is calculated using the formula $NDVI = (NIR - RED) / (NIR + RED)$, Where NIR is the near infrared band response for a given pixel and RED is the red response [12].
- C. **Image Ratioing:** Image Ratioing implies the calculation of the ratio of two registered images from different dates, on a band-by-band basis. Depending on the nature of the changes between two dates of the images, the ratio values will be significantly greater than 1 or less than 1 in the changed areas [13]. The image ratioing technique is mainly used for extracting vegetation cover information. The effect of shadows, the radiation change and sun angle can be reduced by this technique [14]. Due to the non normal distribution of change pixel values, it is difficult to select the appropriate threshold [1].
- D. **Change Vector Analysis:** The spectral change vector used the direction and magnitude of change from the first to the second date. The total change magnitude per pixel is computed by calculating the Euclidean distance between end points through n dimensional change space [15]. Rene Ngamabou et al., (2008) implemented the Change Vector Analysis (CVA) technique on multi temporal multispectral Landsat data from the Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) sensors to monitor the dynamics of forest change in the mount Cameroon region. The images were geometrically corrected and topographically normalized to cater for variations in reflection due to sun angle and topography. Also, the technique fails to provide concise from-to information.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

Instead it offers qualitative information concerning the direction in which the vegetation is evolving and the intensity of the change. CVA has the capability of analyzing change concurrently in all selected spectral bands. By applying CVA to the near infrared and short wave infrared bands, the effect of atmospheric scattering can be minimized. A good understanding of the change processes in the area is essential to improve on the interpretation of the direction and intensity maps obtained. A main limitation of this method was stated by Johnson and Kasischke (1998) that the vectors contain dynamic information and not state information [16]. The technique has great potentials in monitoring changes with Normalized difference vegetation index (NDVI) and bare soil index. It is suitable for Landsat ETM+ image and for pure agricultural area. The CVA method is not suitable for cloudy image or foggy image. The accuracy of CVA depends on the image quality, geometric correction and the accuracy of threshold [17].

- E. **Principal Component Analysis:** Principal Component Analysis (PCA) is a mathematical technique for reducing the dimensionality of a data set. In multi-band remote sensing images, some of the original bands may be highly correlated. To save on data storage space and computing time, such bands could be combined into new less correlated Eigen images by PCA. Principal Component Analysis applies either the covariance matrix or the correlation matrix to transfer data to an uncorrelated set. The Eigen vectors of the resultant matrices are sorted in descending order where first principal component (PC) expresses most of the data variation. The next largest variation is defined by the succeeding component and is independent (orthogonal) of the preceding principal component. In PCA the areas of no change are highly correlated where as areas of change are not. In multi temporal image analysis it was assumed that the PC1 and PC2 tend to represent the unchanged areas, where as PC3 and later PCs contain the change information [18]. Christopher et al., (2004) implements Principal Component Analysis method to detect changes in an inland wetland system in southern Zambia using a combination of Landsat MSS and TM images. PCA was found to be useful to identify where changes occurred but it was difficult to interpret the changes. Knowledge of the land cover characteristics of the study area is essential to use PCA as a change detection technique [19].
- F. **Tasseled Cap transformation:** The Tasseled Cap enhanced procedure gave better identification of the changed areas than PCA based method. Tasseled Cap Transformation (TCT) is used to enhance the spectral information of satellite data. In recent years, TCT has been widely used in Land cover change detection. (Dymond et al., 2002; Han et al., 2007; Liu and Liu, 2010) [20]. The TCT indices such as Brightness index (BI), Greenness index (GI) and Wetness index (WI) have widely been used for change detection. Skakun et al. (2003) applied the enhanced wetness TCT difference Index to interpret spectral patterns with red attack damage [21]. Karnieli et al. (2008) found that Brightness Index (BI) was the best spectral transformation for enhancing the contrast between the bright degraded areas and the darker surrounding areas [22]. Madugundu et al., (2014) analyzed the land cover changes in Dirab region of Saudi Arabia between 1980 and 2010, using Landsat TM/ETM+ images. The multi-temporal image data sets were spectrally enhanced separately using Principal Component Analysis (PCA) and Tasseled Cap Transformation (TCT). The TCT enhanced procedure provided better identification of the changed areas than PCA based method. The TCT transform coefficients are independent of the image scenes, while PCA is dependent on the image scenes. Due to the fact the TCT based change detection method provides more accuracy than the PCA based method.
- G. **Post Classification Comparison:** Post-classification comparison technique applies either the un-supervised or supervised classification methods. But literatures show that the supervised classification methods provide more classification accuracy than unsupervised classification methods [23]. Post-classification change detection compares pixels in a pair of classified images (in which pixels have already been assigned to classes). Post classification change detection shows changes as a summary of the “from-to” changes of categories between the two dates. Eric K. Forkuo et al., (2012) applied this technique to map out and analyze the structural changes of forest cover using multi temporal Landsat and ASTER imageries of the study area. In this technique, images of different dates are first classified and labeled individually. The classified images were then compared and changed areas extracted. Since the errors in the individual classified images could be reflected in the final change image,

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

post-classification requires individual classified images to be as exact as possible [24]. Using Post classification comparison method, the analyst can produce change maps which show a complete matrix of changes. Selective grouping of classification results grant the analyst to observe any subset of changes which may be of interest. As data from two dates are separately classified, it minimizes the problem of normalizing the atmospheric and sensor differences between two dates [1].

- H. **Cluster Approach:** Cluster analysis partitions a data set into a reasonable number of disjoint groups where each group contains similar pattern. The partitions should be such that patterns are “homogeneous” within the clusters [25]. G. Doxani et al., (2008) focused on the changes of the urban land cover by classifying two images of different dates. Neighboring pixels are grouped into meaningful areas according to their spectral & spatial homogeneity. This approach considers the texture, shape and also variety of features based on image objects. Fuzzy approach is also used for classification. The segmentation of the recent dataset is based on the base image and the changes are identified by setting the appropriate threshold to the initial level classes [26]. Krishna Kant et al., (2013) presented an unsupervised method based on normalized neighborhood ratio and Gustafson Kessel clustering technique applying on bi temporal images of Reno Lake Tahoe. Initially the difference image is computed using Normalized neighborhood approach and then Gustafson Kessel Clustering algorithm is applied to cluster the difference image into two clusters of changed and unchanged pixels. This algorithm provides the changes very accurately as compared to Expectation Maximization (EM), Markov Random Field (MRF) and Non Sub sampled Contourlet Transform (NSCT) based methods [27]. Kesikoglu et al., (2013) analyzed an unsupervised change detection technique using Principal component analysis and fuzzy C means clustering. Landsat 5 TM images of 2007 and 2011 in North of Keyseri were used. First, the image differencing method was applied and then using the principal Component Analysis method an Eigen vector space was gained. Using Fuzzy C-means Clustering, the feature vector space consisting principal components is partitioned into two clusters to identify the change information [28].
- I. **Artificial Neural Network:** Artificial Neural Networks (ANN) is an important tool for the classification of remote sensing images. Change detection has become as one of the new application areas of ANN. ANN is data driven and self-adaptive and ANN can provide universal functional approximation. The neural classifiers do not require initial hypotheses on the data distribution and they are able to learn non-linear and discontinuous input data [29]. In remote sensing, the usage of ANN has widely been recognized by many researchers [30-33]. Dai et al., (1999) presented a neural network based change detection method applying back propagation training algorithm. The trained neural network detected changes on a pixel-by-pixel basis in real time applications. The trained four-layered neural network provided complete categorical information about the nature of changes and detected complete land-cover change “from-to” information, which is desirable in most change detection applications. In terms of the change detection accuracy, it was found that the neural network based change detection method outperformed the maximum likelihood based post classification comparison. Unlike the post classification comparison method, the neural network method is free from accumulative errors [34]. Sneha Bishnoi et al., (2011) proposed a Hopfield neural network technique for change detection in multi temporal images. It is a supervised change detection method. A difference image is obtained by subtracting the pixel intensity of one image from other image. Each pixel in the difference image is identified by a neuron in the Hopfield network and is connected to all the neurons in the neighborhood. Using a threshold the pixels are segmented into two classes of pixel-changed and unchanged [35]. Mehrotra et al., (2013) proposed a supervised technique which generates the difference image using the Normalized neighborhood ratio and Probabilistic Neural Network (PPN). PPN is efficient as it has fast training process and guaranteed optimal classification performance. The log likelihood ratio test is applied to classify the pixels of the difference image into changed and unchanged classes and create a change map [36].
- J. **Decision Tree Approach:** Decision tree technique has been used for the classification of global datasets. The decision tree classifier performs multistage classifications by establishing a series of binary rules to discriminate between different target categories. As tree based methods are supervised techniques, a training set is required to classify the data. Any error in the training dataset will produce poor results when applied to new data. This

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

classification technique can be applied to any spectral data or GIS data, different sets of features and even different algorithms at each decision tree. Hamid et al., applied post classification analysis using Decision tree classifier and showed notable improvement in classification accuracy in spite of high correlation of multi-spectral data [37]. Zhen lei et al., (Feb 2014) proposed a bi-temporal texton forest method which is an effective and efficient supervised transition detection method for land cover transition detection on remotely sensed imagery. It is an extension of binary decision trees and it utilizes additional spatial contextual information by considering a neighborhood of each pixel. The decision trees in TF work by successively divide the feature space into regions corresponding to the tree nodes in the trees. A maximal information gain criterion is used to choose a best split so that the training samples falling in each sub region should have the least uncertainty about class labels. A Gaussian color space based color invariant gradients are used to minimize the effect of color variation with different lighting conditions on detection or classification which also improve the accuracy of object detection in high-resolution images. This bi-temporal texton forest method shows better accuracy than a post classification comparison method [38].

Table 1 Strengths and limitations of different change Detection Techniques

Technique	Strong point	Limitation
Image Differencing	Simple to implement and interpret	Nature of change not found. Accuracy depends on threshold selection
Image Ratioing	The effect of different Sun angles, shadows and topography is reduced	Non Gaussian distribution of image makes threshold selection difficult.
Vegetation index differencing	Widely applied for both human-induced and natural forest cover change detection	Threshold identification for detection of vegetation changes represents a key issue
Change Vector Analysis	It offers qualitative information of the direction and intensity of change. CVA are applicable to any number of spectral bands	Not providing concise from-to information. Accuracy depends on the image quality, geometric correction and threshold.
Tasseled Cap Transformation	Data redundancy reduced. Scene independent.	Difficult to interpret and label change information
Principal Component Analysis	Useful to identify where changes occurred	Difficult to interpret the result. Knowledge of the study area is essential
Post Classification Comparison	Provides from-to change results. Normalize the atmospheric, sensor differences	Accuracy depends on the classification accuracy of individual images.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

Cluster Approach	Simple & need not require any explicit assumption about the underlying classes.	Labeling change among a matrix of many overlapping classes may be difficult or non informative.
Artificial Neural Network	Provide complete from-to change information and also the nature of change.	Requires accurate training and testing classifications
Decision Tree Approach	This technique can be applied to any spectral data or GIS data.	Error in training data will produce poor result

III. CONCLUSION

This paper is a comprehensive exploration of all the major change detection methods as found in the literature. In this study various unsupervised and supervised change detection methods are discussed. Literatures show that the supervised method provides more classification accuracy than unsupervised classification methods. For a given research purpose, when the remotely sensed data and study areas are identified, selection of an appropriate change detection method has considerable significance in producing good result.

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Vol. 5, Issue 7, July 2016

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