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Research paper

Change detection algorithm for multi-temporal satellite images: a review

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Abstract

Change detection (CD) is the process of detecting changes from multitemporal satellite images that have undergone spatial changes due to natural and man-made disaster. The objective is to analyse different change detection techniques, in order to use appropriately in various applications with the help of image processing. Techniques that are used in current researches are Image Differencing, Image Regression, Change Vector Analysis (CVA),Principal Component Analysis(PCA), Tasselled Cap, Gramm-Schmidt(GS), Post Classification Comparison, EM Detection, Unsupervised Change Detection, Li-Strahler Reflectance Model, Spectral Mixture Model, Biophysical Parameter Method, Integrated GIS and Remote Sensing Method, GIS Approach, Visual Interpretation and so on. Effective change detection is required for various applications such as rate of deforestation, costal changes, urban developments, damage evaluation, resource monitoring and land disposition.

Keywords: *Change detection, principal component analysis, remote sensing.*

1. Introduction

Change detection (CD) is the process of identifying changes by observing different satellite images taken at different time period. It quantitatively analysis the temporal effects using the satellite image datasets taken at different times. Effective change detection algorithms are required to assess the changes and analyse for various applications.

There are different change detection techniques such as Algebra Based Approach, Transformation, Advanced Models, Classification Based Techniques, Geographic Information Systems (GIS) and Visual Analysis. The general objective of CD in satellite images includes identifying the locations, recognizing changes, finally assessing the accurate results and so on [1]. Transformation focuses on reducing data based on reliable details and reducing the environmental effects on input images [2]. Multispectral images can be used for change detection because a significant change in object modifies the spectral behaviour of the image. Various software tools that can be used to process images are Matlab, Open CV, Python, R programming, etc.,[3].MATLAB graphical user interface(GUI) is used by most of the researchers for implementing change detection algorithm because it is user friendly and can handle large datasets [4].The paper mainly focuses on change detection algorithms and detailed explanation can be found in section 2,3,4,5,6and 7. Change Detection can be monitored by various approaches such as

1. Algebra based approach
2. Transformation approach
3. Advanced Models
4. Classification Based Techniques
5. Geographic Information Systems(GIS)
6. Visual Analysis

2. Algebra based approach

Algebra based approach uses the threshold of different images to identify the changed area. This approach is simple to implement and it is straight forward, but the challenge is in selecting a suitable threshold that can highlight the changed pixels in the multi temporal images. The different algebra based approaches used for change detection in image processing are Image Differencing, Image Regression and Change Vector Analysis.

Image differencing

Image differencing is performed by subtracting the first image from second image, pixel by pixel. The pixel value of normal image ranges from 0 to 255, the pixel value in subtracted image ranges from -255 to 255. The value of unchanged pixel contains an average value and change pixel value is distributed [5]. Let two images be I_1 and I_2,which are taken at two different time period and image difference is given mathematical as

$$ID(x,y)=I_1(x, y)-I_2(x,y),$$

Where ID is Image Differencing,
I_1 and I_2 refers the Input Image1 and 2
x,y refers the pixels co-ordinates

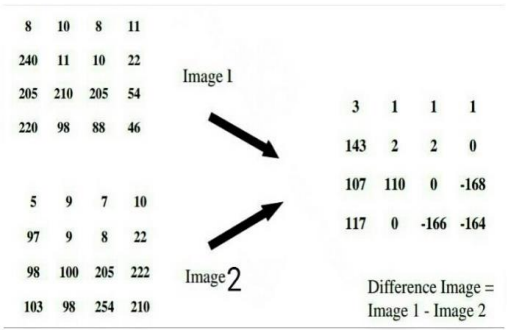

Figure 1: Image differencing

Image regression

Image Regression (IR)can be used to assess the relationship between multi temporal satellite images. Then it subtracts the result of regression function with the first image. The regression techniques contain difference in mean and variance between pixel that have adverse effects in atmospheric condition which are reduced and it can be used in detecting urban land cover and tropical forest changes respectively [6].

$$Id_1(x,y)=a\ Id(x,y)+b$$

$$Id(x,y)=Id_2(x,y)-Id_1(x,y)$$

Where,
Id is Output image
Id_1&Id_2 refers Change image1 and image 2
(x,y) refers pixelco-ordinates

Change vector analysis

Change Vector Analysis (CVA) is a tool for characterizing the dynamic changes in multi-temporal images. It is an enhancement of image differencing approach. It produces an intensity based image and direction based image which are used to classify images [8]. This change vector analysis produces two outputs:

- Spectral change which describes the magnitude and direction of the image from two input images.
- Total change which describes the magnitude per pixel that can be determined by the Euclidean distance between end points through n-dimensional change.

Steps for change vector analysis algorithms are:

- Selecting the threshold.
- Calculating the indices
- Determining the levels of change.

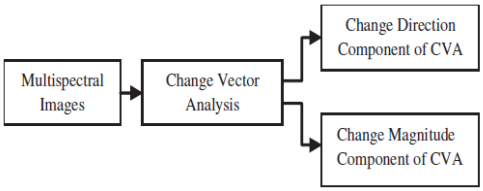

Figure 2: Change vector analysis

Table 1: Advantages and Limitations of Algebra Based Method

Reference	Methodology	Advantage	Limitations
[5]	Image Differencing	Simple and easy to implement.	It doesn't provide a detailed matrix. It requires appropriate threshold.
[6]	Image Regression	Reduces impact of the atmospheric and environmental differences between input images.	It requires to develop accurate regression functions.
[8]	Change Vector Analysis	Ability to process more number of spectrum bands.	It is difficult to identify the land cover change.

3. Transformations

The transformation includes Principal Component Analysis (PCA), Tasselled Cap (KT) and Gramm-Schmidt (GS). The advantage of transformation method is used to reduce the redundancy of data. It is difficult to label the changed information on image.
Different types of transformation approach are as follows:

Principal component analysis (PCA)

PCA is based on linear transformation techniques. The main objective of this analysis is to use an input from a dataset to rearrange them in linear transformation. The output images are linear independent and co-ordinate of biggest variance lies on first axis and the 2ndbiggest variance lies in second axis. PCA will reduce the compression scheme in spectral bands [7].PCA algorithm works as follows:
Input: image 1, image 2
Read the multi spectral images: image 1, image 2.
Compute the mean for image 1 and image 2.
Generate variance and co-variance matrix.
Calculate the Eigen value and Eigen vector of co-variance matrix.
Choose the component and form a feature vector.
Derive the new dataset.

Tasselled cap (KT)

Tasselled Cap transformation is also called as Kauth-Thomas Transformation(KT).PCA is similar to this method where KT is independent [9]. Tasselled Cap is based on three components are brightness, wetness and greenness values [9].

Gramm-Schmidt(GS)

Gramm-Schmidt is spectral methods taken from bi-temporal images. It originates from KT method. This produces 3 stable components to multi-temporal analogue contain brightness, wetness and greenness [10].

Table 2: Advantages and Limitations of Transformation Based Method

Reference	Methodology	Advantage	Limitations
[7]	Principal Component Analysis (PCA)	Redundancy of data can be reduced.	It cannot provide complete matrix for change information and require threshold to identify the changes occurred in the area.
[9]	Tasselled Cap (TC)	It reduce the data reduce between bands.	It is hard to interpret and cannot provide a complete change matrix.
[10]	Gramm-Schmidt (GS)	The transformation with scene characteristic allows the extraction of information cannot access.	Difficult to extract more than one component in the given type of changes.

4. Classification based approach

Classification approach is based on classified images which are of quantity and quality of training datasets which will produce the good image as its results. The advantage of this method is to provide a capability of matrix to change information and reducing environmental difference between the multi-temporal satellite images. The difficult task and time consumption will produce the accurate classification leads to un satisfaction of change detection results. Yeh and Li found [11] PCA for multi-temporal satellite images that is combined with unsupervised classification were it can be effectively monitor the urban level change in river delta. Various classification based techniques are as follows:

Post classification comparison

This technique classifies images based on the intensity values of the pixels. It greatly reduces the impact of atmospheric condition and provides a complete matrix highlighting the changed pixel between multi temporal images. This requires sufficient training sample for classification[12].

EM detection

This approach uses expectation maximization algorithm to find a priori joint class probability at different time intervals. These joint class probabilities can also be estimated directly from image under analysis. It has been proven that it yields an higher accuracy than other change detection techniques.

4.3 Unsupervised Change Detection:

Unsupervised Change Detection is used in clustering the similar groups of pixels in multi temporal images. Similar groups of pixel are grouped as primary clusters in image1 and image2. Finally, it detects the changes between image1 and image2as a result[13].

Table 3: Advantages and Limitations of Classification Based Method

Reference	Methodology	Advantage	Limitation
[12]	Post Classification Comparison	Minimizing the impacts of atmospheric effects.	It takes more time to create this classification. The quality of image taken depends on final accuracy.
[13]	EM Detection	It produces accurate result compared to other change detection method.	It requires estimation of high priority joint class probability.
[13]	Unsupervised Change Detection	This method uses clustering approach to detect changes.	Difficult to identify and label the change trajectories.

5. Advance model

In this method, the image value is often converted to physical parameter through linear model. The transformed are more intuitive and better to extract information. The disadvantage of model is it consumes more time to develop the suitable for image reflectance. Some of categories of advanced model are Li-Strahler Reflectance model, Spectral Mixture Method and Biophysical Parameter Method. Li-Strahler Reflectance model detects changes by developing conifer stand crown for multitemporal images individually. This method is an integration of traditional sampling and field observation methods. It generates map sharing geo metric distribution of changed patterns. This accurately identifies vegetation fields and can be suitable for smart agricultural applications[14]. Spectral Mixture method derives fraction images using spectral mixture analysis where in end members are selected from training set and from spectral library. Biophysical Parameter method develops a biophysical parameter to estimate the integration of remote sensed data. The change detection can be implemented by comparing with biophysical parameter. In change detection techniques [10],we found that a biophysical parameter is used for differencing the forest area.

Table 4: Advantages and Limitations of Advance Model

Reference	Methodology	Advantage	Limitation
[14]	Li-Strahler Reflectance Model	It combines techniques of image processing of satellite image data for observation.	It is suitable for the vegetation change.
[15]	Spectral Mixture Method	The result is stable and accurate.	Implementations are complex when compared to other techniques.
[10]	Biophysical Parameter Method	It accurately detects the vegetation changes.	It is suitable for the vegetation change.

6. GIS

GIS will focus on urban area in change detection techniques. The traditional methods produce poor result due to more complexity of urban areas. Thus, this tool is more powerful for data processing and to effectively handle the change detection. Integrated GIS and Remote Sensing Method incorporates the data image and geographical information systems data. It overlay image data directly on GIS layer. As result it goes for further analysis. The GIS and remote sensing integrated for continuous data coverage for larger area. The multispectral of thematic map data can be handled using remote sensing technology [16]. GIS approach integrates the current and past map land uses with geographical data. The binary mask and image overlying technique are used for changing the dynamic in each category. GIS approach used to detect the land change detection for data access the effect on land area in sensitive environmental area [17].

Table 5: Advantages and Limitations of GIS

Reference	Methodology	Advantage	Limitation
[16]	Integrated GIS and remote sensing method	It allows to access the data to interpret and analysis.	Different data from various sources degrades change detection.
[17]	GIS approach	It allows the image of present and past data to map the changes.	Different in geometric and classification system quality of results.

7. Visual analysis

Visual Analysis will make use of an analysis of human knowledge and experience. The key elements like size, texture, patterns and shape of image useful for visual interpretation. The disadvantage of analysis is consuming more time and difficult to provide a detailed change for change detection results. The one band from image one as red and the same band from image two as green, the same band from image three as blue. It visually interprets the colour to detect the changed areas. The visual interpretation maintain a similar quality compared to digital classification for the analyse of satellite data[18].

Table 6: Advantages and Limitations of Visual Analysis

Reference	Methodology	Advantage	Limitation
[18]	Visual interpretation	Human experience and knowledge is useful during this interpretation. More than two images can be analysed at same time.	Cannot provide changed information in detailed.it consume more time to update results.

8. Conclusion

This paper has presented an overview of various change detection techniques such as algebra based approach, transformations, classification based approach, advanced model, Geographic Information System (GIS) and visual analysis for satellite images which are used for detecting changes in a particular area taken at different time instances. The analysis and usage of different change detection techniques are elaborated. Thus the algorithm mentioned in this paper can be effective to detect changes in satellite images.

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