

Land Cover Change Detection using Change Vector Analysis in Matlab

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Abstract. The surface of the earth is changing everyday due to both natural and manmade causes. Timely and accurate change detection of Earth's surface features is extremely important for understanding relationships and interactions between human and natural phenomena in order to promote better decision making. Change detection involves quantifying temporal effects using multi temporal data sets obtained from Earth-orbiting satellites which provide repetitive coverage at short intervals with consistent image quality. The Change vector analysis method is an effective tool to research change dynamics of land cover, but there is not a specific application of this method. The innumerable softwares that are available for remote sensing data analysis prove to be useful; but the time and effort required to implement the algorithm each time for every image makes the process cumbersome. Hence, this project aims to develop a comprehensive learning package by building a Graphical User Interface in Matlab. Basic Matlab tools have been used for thresholding and the implementation of the Change Vector Analysis algorithm. The merit of this work lies in its simplicity and ease of usage and this package can be used to extract useful information such as the threshold, Bare soil Index values, Normalised Difference Vegetation Index values, Change Vector, direction of change and the nature of change.

Keywords: remote sensing data, change vector method, reflectance, threshold, normalised difference vegetation index, bare soil index.

1. Introduction

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Change detection is useful in such diverse applications as land use change analysis, monitoring of shifting cultivation, study of changes in vegetation phenology, damage assessment, crop stress detection, day-night analysis of thermal characteristics and other environmental changes. Research on change detection techniques is still an active topic and new techniques are needed to effectively use the increasingly diverse and complex remotely sensed data available from satellite and airborne sensors. There are two main types of remote sensing: passive remote sensing and active remote sensing. Passive sensors detect natural radiation that is emitted or reflected by the object or surrounding areas. Reflected sunlight is the most common source of radiation measured by passive sensors. Active sensing, on the other hand, emit energy in order to scan objects and areas where a sensor then detects and measures the radiation that is reflected or backscattered from the target. The basic premise in using remote sensing data for change detection is that changes in land cover must result in changes in radiance values and these changes must be large with respect to radiance changes caused by other factors. These other factors include differences in atmospheric conditions, differences in Sun angle and differences in soil moisture. The impact of these factors may be partially reduced by selecting the appropriate data. For example, Landsat data belonging to the same time of the year may reduce problems from Sun angle differences and vegetation phenology changes. Several procedures of land cover change detection using digital data have been proposed which could aid in updating resource inventories. These methods include comparison of land cover

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classifications, multi-date classification, image differencing ratioing, vegetation index differencing, principal components analysis and change vector analysis [1, 5]. Accurate spatial registration of the two images necessitates the use of geometric rectification algorithms that register the images to each other or to a standard map projection. Also most of the methods require a decision as to where to place threshold boundaries in order to separate areas of change from those of no change [3, 6].

2. Data Processing

Remote sensing works on the principle of the inverse problem. While the object or phenomenon of interest (the state) may not be directly measured, there exists some other variable that can be detected and measured (the observation), which may be related to the object of interest through the use of a data-derived computer model. The quality of remote sensing data consists of its spatial, spectral, radiometric and temporal resolutions [4, 7].

2.1. Spectral Reflectances

Reflectivity is the fraction of incident radiation reflected by a surface. In general it must be treated as a directional property that is a function of the reflected direction, the incident direction, and the incident wavelength. However it is also commonly averaged over the reflected hemisphere to give the hemispherical spectral reflectivity: $\rho(\lambda) = Gr(\lambda)/Gi(\lambda)$;where $Gr(\lambda)$ and $Gi(\lambda)$ are the reflected and incident spectral (per wavelength) intensity, respectively. This can be further averaged over all wavelengths in the given band of interest to give the total hemispherical reflectivity, or reflectance factor: $P = Gr/Gi$.

If the spectral reflectance of targets is known, the spectral contribution of the atmosphere can be calculated by looking at the difference between the reflectance measured by the instrument and the actual spectral reflectance. The logical extension of this procedure is to simply figure out the reflectance of any unknown target based on the reflectance of known targets.

2.2. NDVI and BI indices

NDVI (Normalised Difference Vegetation Index) and BI (Bare Soil Index) are the two indices that need to be calculated in Change Vector Analysis method. NDVI displays the relationship between the quantity of chlorophyll in leaves with red and near infrared wavelength. Hence, it helps in estimating biomass, plant productivity, fractional vegetation cover, etc. BI is calculated to distinguish agricultural land and non-agricultural Land[2].

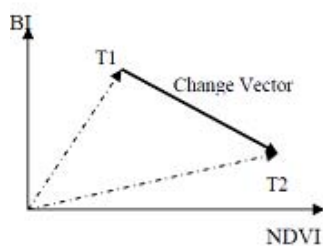


Fig 1. NDVI Change

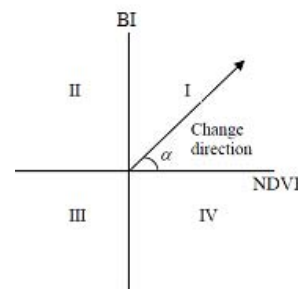


Fig 2. BI Change

The objective of the project is to build an interactive Graphical User Interface (GUI) in Matlab that processes any kind of image to determine the NDVI and BI indices which in turn help in ascertaining the direction of change and the nature of change. Two images on different dates can be selected from the drop down menu and information on Visible Red, Near Infrared, Shortwave infrared and Blue Bands and plots such as CIR Composite, NIR vs. Red Scatter Plot, NDVI with Threshold can be obtained. UI control of Matlab is used to develop the GUI and simple image processing functions are used to read and process the images.

3. Methodology

3.1. Threshold selection

A simple iterative process is used to calculate the optimum threshold. The background pixels at each corner of the image help in deriving an initial threshold, calculated as the mean of the gray levels contained in the corners. The width and height of each corner is a tenth of the image's width and height respectively. Firstly, the mean of gray levels corresponding to objects in the image is calculated and then the actual threshold is used to determine the boundary between objects and background. This process is now repeated for the background pixels and the new threshold is calculated as the average of the mean of the object and background pixels. This iterative process is repeated till the new threshold and the calculated threshold match. Alternatively, graythresh() function of Matlab can be used for calculating the threshold.

3.2. Change vector analysis method

3.2.1. Calculating the indices and the change

The change vector of every pixel in the image comprises of 2 components, NDVI and BI. These vectors are drawn on the Cartesian plane for the two images corresponding to 2 dates. The change intensity is given by the magnitude of the NDVI vector and the change dimension is given by the direction of vector[2]. The matlab function multibandread() is used to obtain the different bands of the lansat image where near infrared, red, short waveinfrared and blue correspond to bands 4, 3, 5, 1 respectively. The NDVI and BI indices are calculated for every pixel of both the images by:

$$NDVI = (NIR - red) / (NIR + red)$$

$$BI = (Swir+red)-NIR+Blue)/(Swir+red)+(NIR+Blue)$$

The amount of change is given by the magnitude of the change vector and the direction by its angle.

3.2.2. Determining the level of change

The level of change is calculated with respect to the threshold calculated. A Matrix for change levels is created and the change corresponding to each pixel is given one of the levels according to Table 1.

Table 1: Description of the change dimensions

The dimension change	BI index	NDVI index	Description
III	-	-	Water or high moisture land
II	+	-	Bare soil expansion
IV	-	+	Chlorophyll increase
I	+	+	Moisture reduction

4. Results and Discussion

The figures show the various screen shots of the GUI package. As evident from fig.3, the user only needs to select the two images he needs to compare. The next window shows the different information that the GUI extracts from the images. Fig.5 shows the end result on implementing Change Vector Analysis on the images. Any number of images can be included in the images folder, which get automatically listed in the drop down menu. The complete code for the package is provided in the Appendix.

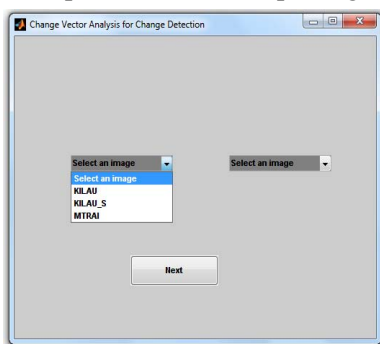


Fig. 3: Two images on different dates are selected

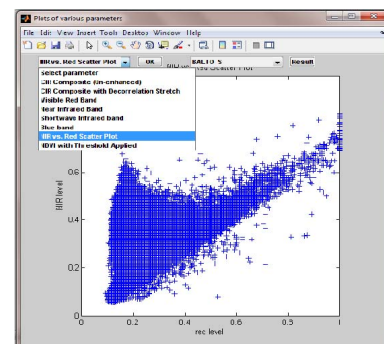


Fig. 4: A menu that plots the various characteristics of the image

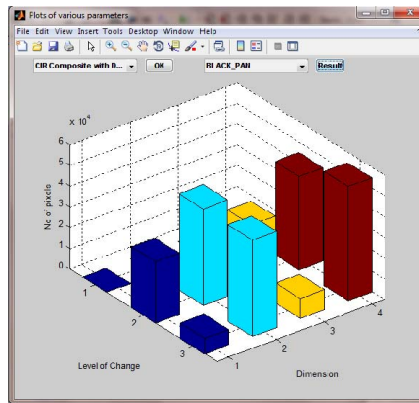


Fig. 5: Change levels in different dimensions

5. Conclusion

Change vector analysis is a valuable technique for land-cover change detection. However, determining thresholds for change magnitude and change direction is a bottleneck to its proper application. This project finds the indices for every pixel of the image. This is time consuming and tedious. Hence, clustering of pixels can be done for simpler calculations. Although many such softwares are available for analysis of remote sensed data, the advantage of this project lies in its ease of use. Any number of images of any type can be included and compared with each other any number of times. This package hence proves to be an effective study tool which helps in quick analysis of satellite images without explicitly going through each of the data processing steps every time.

6. Appendix

6.1. Code for threshold calculation:

```
col_c=floor(cols/10);
rows_c=floor(rows/10);
corners=[I(1:rows_c,1:col_c);
         I(1:rows_c,(end-col_c+1):end);
         I((end-rows_c+1):end,1:col_c);
         I((end-rows_c+1):end,(end-col_c+1):end)];
T=mean(mean(corners));
mean_obj=sum(sum((I>T).*I))/length(find (I>T));
mean_backgnd=sum(sum( (I<=T).*I) )/length(find(I<=T));
new_T=(mean_obj+mean_backgnd)/2;
```

6.2. Calculating the indices: (for lansat image)

```
CIR = multibandread(lansatfile, [512, 512, 7 ], 'uint8=>uint8', 128, 'bil', 'ieee-le', {'Band','Direct',[4 3 2]});
CB = multibandread(lansatfile, [512, 512, 7 ], 'uint8=>uint8', 128, 'bil', 'ieee-le', {'Band','Direct',[5 1 2]});
NIR = im2single(CIR(:,:,1));
red = im2single(CIR(:,:,2));
Swir = im2single(CB(:,:,1));
Blue = im2single(CB(:,:,2));
And the NDVI and BI indices are calculated
ndvi = (NIR - red) ./ (NIR + red);
BI=((Swir+red)-NIR+Blue)./((Swir+red)+(NIR+Blue));
```

6.3. Calculating the change:

```
S=sqrt(((ndvi2-ndvi1).^2)+((BI2-BI1).^2));  
alpha=atan((BI2-BI1)/(ndvi2-ndvi1));  
BIchange=BI2-BI1;  
ndvichange=ndvi2-ndvi1;
```

6.4. Determining the level of change:

```
level=[0 0 0 0;0 0 0 0;0 0 0 0];  
for k=1:512*512  
    if((BIchange(k)<=0)&&(ndvichange(k)<=0))  
        if((abs(S(k))==0))  
            level(1,3)=level(1,3)+1;  
        end  
        if((abs(S(k))>new_T))  
            level(3,3)=level(3,3)+1;  
        end  
        if((abs(S(k)<new_T)))  
            level(2,3)=level(2,3)+1;  
        end  
    end  
end
```

This gives the third column of the change levels matrix.

Similarly, the three other columns are calculated.

This matrix is then plotted as a bar graph.

```
bar3(level,0.5);
```

7. Acknowledgement

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