AN ADAPTED METHOD FOR REDUCING CHANGE DETECTION ERRORS DUE TO POINTING DIRECTION SHIFTS OF A SATELLITE SENSOR

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ABSTRACT:

Change detections is carried out under the assumption that pixel boundaries of geometrically corrected time series satellite images cover the same location. However that assumption can be wrong when shifts in the pointing direction of a satellite sensor occurs. Currently, although the influence of misregistration on landcover change detection has been investigated, there has been little research on the influence of pointing direction shifts of a satellite sensor. In this study, a simple method for reducing the effects of pointing direction shifts of a satellite sensor is proposed: the classification of two ASTER images was carried out using the linear spectral mixture analysis, the two classification results were resampled into a geometrically fixed grid, and then the change detection of the two ASTER images was carried out by comparing the resampled classification results of the two images. The proposed method showed high performance in discriminating between changed areas and unchanged areas by removing the pointing direction shifts of a satellite sensor.

KEY WORDS: Change detection error, Resampling

1. INTRODUCTION

Nearest neighbor resampling method is a widely accepted for change detection because it does not modify the original pixel values of an image. The resampling method, however, can cause errors in change detection, because incompletely overlaid areas might be compared when the coverage of each time series data is shifted. Figure 1 shows an example of such a situation: although the time series images are pointing the same location after their geometrical correction with nearest neighborhood resampling, the coverage of each image is pointing slightly different location by changing satellite orbit and attitude. In this study, this situation is denoted pointing direction shift.

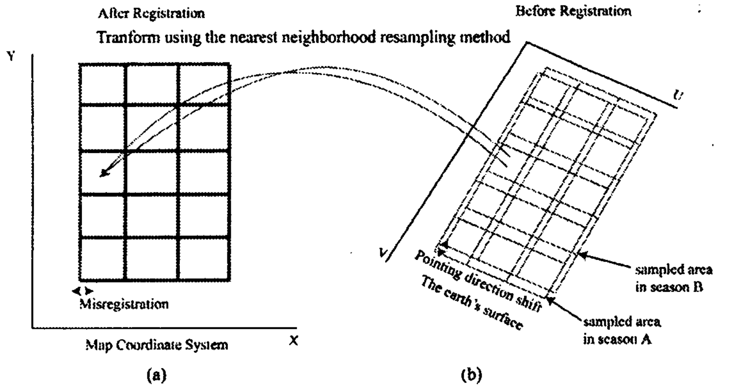


Figure 1 (a): The two geometrically corrected satellite images are pointing to the same location after geometric correction, (b): the two satellite images are actually covering slightly different areas.

The objectives of this study are to develop an adapted method for removing the change detection error due to the pointing direction shifts of a satellite sensor, and to evaluate the performance of the proposed method.

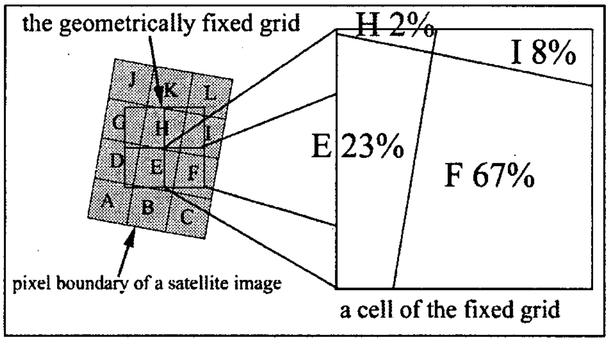
2. METHODOLOGY

The main reason for the change detection errors due to the pointing direction shifts of a satellite sensor is that the pixels of time series satellite images are covering slightly different areas. To minimize the error in comparing incompletely overlaid areas, the classification results of time series images should be transformed in subpixel accuracy. Then, the pixels of the classification result are resampled into geometrically fixed grid data, after which the same coverage of the time series satellite image can be compared. Equation 1 describes the resampling method: the existence ratios of pixels which overlaid on a grid cell were multiplied by their pixel value.

$$\textit{Grid cell value} = \sum_{j=0}^{M} R_j \times \textit{pixel value}_j \quad (1)$$

where j = pixel order
M = the total number of pixels
R = the existence ratio of each pixel which was overlaid on the grid cell.

Figure 2 shows how the value of geometrically fixed grid cell was calculated using proposed method: The source satellite image contains pixels which are named from A to L. A geometrically fixed grid is overlaid with the pixel boundary of a satellite image (figure 2-a). To calculate a sample grid cell value, the existence ratio of the pixels H, I, E and F on the grid cell was calculated (figure2-b). The pixels H, I, E and F take 2%, 8%, 23% and 67% in the grid cell respectively. The existence ratio of each pixel is multiplied by the pixel's value. Finally the summation of the multiplication results becomes the grid cell value.



(a) (b)

Figure 2 Resampling classification results using a geometrically fixed grid: (a) the pixel boundary of a satellite image overlaid with the geometrically fixed grid, (b) the existence ratio of each pixel in the sample cell of the grid is calculated.

3. DATA USED

In this study, two ASTER images for change detection were used. An IKONOS scene was used to make geometric correction of the ASTER images and to make landcover data.

The visible and Near-infrared (VNIR) bands of the two ASTER images acquired on October 2001 and January 2002 were used. The spatial resolution of the VNIR bands is 15m, and the test area is 11km by 11km in Tosayamada, Kochi pref., Japan. The ASTER images used in this study are level 1B data, thus already system correction were applied to the data.

The IKONOS image acquired on Setember 1999 consists of three visible bands and one near infrared band, and its spatial resolution is one meter by pan-sharpen processing. The IKONOS image covers 11km by 11km.

4. A CASE STUDY USING TWO ASTER IMAGES ACQUIRED IN OCTOBER 2001 AND JANUARY 2002

To evaluate the performance of the proposed method, the change detection between two ASTER images acquired in October 2001 and January 2002 was performed using both the pixel by pixel comparison method and the proposed method.

4.1 Relative normalization

Radiometric differences of time series satellite images can be greater than landcover change. To remove the radiometric difference of the two ASTER images, linear transforms of the two images were used; the transforms can be established by using fixed outputs and the average DNs of minimum and maximum inputs from pure sea water and unchangeable bare soil area.

4.2 Spectral mixture analysis for landcover mapping

Almost classification methods represent major landcover in each pixel as classification results, but that may degrade the accuracy of classification when the result is resampled into a geometrically fixed grid. Therefore, spectral mixture analysis of the two ASTER image was carried out to derive the mixing proportions of endmembers. The proportional change of endmembers was examined to perform change detection using the geometrically fixed grid. Water, bare soil (including urban surface) and vegetation were selected as endmembers, and the proportions of the three endmembers in each pixel were investigated. Ten pure pixels per endmember were taken from the unchangeable objects. DNs of pure pixels and existence ratio of endmembers from the training data were input to the Equation 2 in order to obtain the spectral signatures of endmembers (*C*).

$$DN_n = \sum_{i=1}^{M} f_i C_{n,i} \qquad (2)$$

where n = the band
I = the endmember (1: water, 2: bare soil, 3: vegetation)
M = the last number of endmembers.

Then conversely, the spectral signature of each endmember and DNs of the ASTER images were input to the Equation 2 for unmixing the existence ratio of each endmember (*f*) in a pixel.

4.3 Geometric transforms using IKONOS images

Geometric correction of time series satellite images is one of the most important processes in change detection. The geometric corrections of the two ASTER images were performed with the aim of achieving subpixel accuracy. Affine transform was used for the geometric corrections because the test area was small (11km by 11km) enough to be applied the transform.

To achieve subpixel accuracy, image matching between the two ASTER images and a geometrically corrected IKONOS image was performed to obtain highly accurate ground control points. The IKONOS image was geometrically corrected by three dimensional Affine transform, and the RMS error of the geometric correction was less than one meter. To align the ASTER images with the IKONOS image, Affine transform was carried out using GCPs which were obtained by manually, after which the image matching was performed. The similarity between a template and a target image was measured using image correlation (Equation 3).

$$Corr = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}[(A_{ij}-\bar{A})(B_{ij}-\bar{B})]}{\sqrt{[\sum_{i=1}^{m}\sum_{j=1}^{n}[(A_{ij}-\bar{A})^2][\sum_{i=1}^{m}\sum_{j=1}^{n}(B_{ij}-\bar{B})^2]}} \tag{3}$$

where $Corr$ = the correlation between a template image and a target image
A = the array of a template image
B = the array of a target image
i = rows
j = columns.

For the image matching, five templates for the October image and four templates for the January image were used, and manmade objects in the test area were used for templates because they are not significantly affected by the seasonal change.

Template images from green band of the IKONOS images are compared with target images from band 1 of the ASTER image because their spectral responses are close to each other. After the image matching, correlation image could be obtained. Almost correlations of image matchings were over 0.7, which implies good matching (Konecny, 2003).

Table 1 shows the RMS errors in the geometric correction of the two ASTER images. The results show that a maximum registration error of 2.34m (0.16 pixel of the ASTER image) was occurred. The accuracy of the geometric correction was acceptable because it was less than one quarter of the ASTER's pixel size (Lillesand, 2000).

Table 1: the RMS errors in the geometric correction of the two ASTER images (units: meter)

	RMS error X	RMS error Y
October 2001	0.93	1.42
January 2002	1.56	0.60

For the pixel by pixel comparison of the images, the results of spectral mixture analysis of the images were transformed by the established Affine transform with 15m-interval nearest neighbor resampling was performed.

Change detection was performed using the proposed method: the geometric corrections of the classification results of the ASTER images were performed. Then they were resampled into the geometrically fixed grid using the proposed method. Finally the two resampled classification results were compared each other.

4.5 Results

It is difficult to recognize change detection error due to pointing direction shift in the change detection of the areas where covered by homogeneous landcover because the error is included into the change of landcover. Therefore, landing strip around Kochi airport, which have clear boundaries of landcovers, is shown as a result of the change detection (Figure 3).

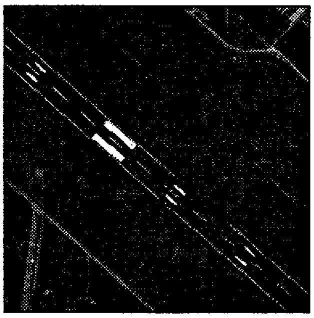


Figure 3. The test area in the IKONOS image which has clear boundaries of landcovers

Figure 4 shows landcover type on the selected area where is covered by asphalt, painted area with white color, grass field and agriculture field. From October 2001 to January 2002, the landcover of only grass field changed.

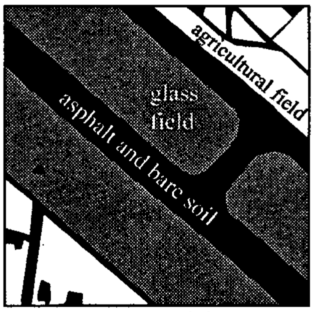


Figure 4. The test area covered by grass field, asphalt with painted areas and agricultural field

Figure 5 and 6 show the change detection results by the two methods: the brightness of each pixel was expressed by the degree of landcover change. Thus, the brightest areas indicate the area in which the most landcover change occurred.

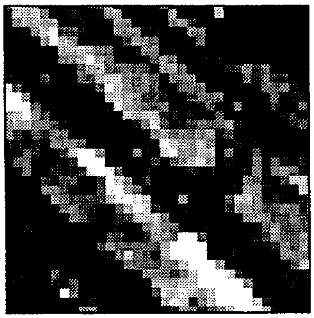


Figure 5. The change detection result of the ASTER images using the pixel by pixel comparison method

Figure 5 shows the change detection result by the pixel by pixel comparison method. Although the landcover along the boundaries between landing strips and the grass field is linear, the degree of land cover change is not linear because incompletely overlaid areas were compared. The pixel by pixel comparison method generates more noises on the asphalt area by the boundary of painted area with white color. The degree of landcover change in result of pixel by pixel comparison method seems more contrasted than the result by the proposed method because it contains noises due to the pointing direction shift.

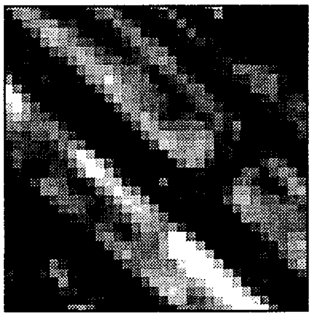


Figure 6. The change detection result of the ASTER using the proposed method

Figure 6 shows the change detection result by the proposed method. The result shows that a more meaningful change detection result was obtained than by the pixel by pixel comparison method. The boundary between the changed area (grass fields) and unchanged area (landing strips) could be clearly discriminated.

5. CONCLUSIONS

The present study pointed out the influence of pointing direction shifts on satellite sensor detection and the weak points of the nearest neighborhood resampling method on change From this study following conclusions were arrived at:

1. An adapted method for removing the change detection error due to pointing direction shift of a satellite sensor was developed.
2. The performance of the adapted method was evaluated by comparing with the pixel by pixel comparison method: the adapted method showed a more meaningful change detection result.
3. The pointing direction shifts of satellite sensors can cause change detection errors, and should be considered in change detection.

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