Object-Based Change Detection of VHR Imagery Based on Extension of Various Pixel-Based Methods

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ABSTRACT: Change detection (CD), one of the main applications of multitemporal satellite images, is an indicator that directly reflects changes in human activity. Very high resolution (VHR) multitemporal images are useful in CD on the Earth's surface and have abundant information sources, enabling more precise CD analysis. The CD is largely divided into pixel-based change detection (PBCD) and object-based change detection (OBCD). In this study, various PBCD methods were combined with a segmentation result to conduct the OBCD of VHR images. The used PBCD techniques in this study are change vector analysis (CVA), iteratively reweighted-multivariate alteration detection (IR-MAD), and principal component analysis (PCA) and K-means clustering from which the binary CD results (i.e., change and no-change) were derived. In order to expand PBCD to OBCD, major voting technique was applied to binary CD results within each object of segmented image that was created using eCognition software. In this process, registration noise (RN) was combined to further improve CD accuracy. The accuracy evaluation of the proposed CD method was conducted using manually digitized reference map. According to the accuracy evaluation, OBCD results that were made by combining all PBCD were the most accurate with 0.393 f1-score. The OBCD results generated by CVA on the side showed the lowest accuracy with 0.301 f1-score.

1. INTRODUCTION

Recently, a satellite equipped with a very high resolution (VHR) sensor has been launched, and research is ongoing to change detection (CD) in various areas using it. CD is one of the most practical applications in the field of remote sensing using VHR satellite images. Since there are many applications in a variety of areas, including land surveillance, deforestation analysis (Choi, et al., 2017) and infrastructure construction, detecting changed areas from multiple images in the same area taken at different times can be widely used.

Object-based change detection (OBCD) is effective in processing VHR images that contain more spatial information than pixel-based change detection (PBCD). Because an object, which is defined by segmentation approaches, is expressed in polygons, not a pixel, it can provide different types of information depending on segment size. Therefore, Object-based analysis improves not only the accuracy of classification result of VHR images but also the performance of CD (Keyport, et al., 2018).

In this study, change vector analysis (CVA), iteratively reweighted-multivariate alteration detection (IR-MAD), and principal component analysis (PCA) combined with k-means clustering (Khai, 2019) were used to produce 3 types of PBCD results. The results of PBCD were then converted into OBCD result based on segmentation image generated using eCognition software. At this process, the registration noise (RN) (Han, et al., 2016) was combined for carrying out the OBCD to further improve the CD result.

2. STUDY AREA

WorldView-3 multi-spectral images with spatial resolution of 1.24 m were used to compare the accuracy evaluation of CD results acquired in Gwangju city. The area includes industrial estate, residences, agricultural land, and large-scale urban development. Therefore, it has been determined that this area is suitable for comparative analysis of the CD performance. Image acquired on May 26, 2017 was used as reference image, while image on May 4, 2018 was used as subject image. The research site consists of 5,833×5,330 pixels (Figure 1).

(a) **(b)** **(c)**

Figure 1. WorldView-3 Gwangju city imagery. (a) Reference image (May 2017) (b) Subject image (May 2018) and (c) Reference map.

3. METHODOLOGY

The overall process of the study is shown in Figure 2. Fine co-registration was performed as a pre-processing for WorldView-3 bi-temporal images to minimize the geometric difference between the images (Han, et al., 2019). Then, three PBCD methods were carried out; which are CVA, IR-MAD and PCA combined with K-Means clustering. In this study, we used 4 bands (red, green, blue and NIR) in CVA & IR-MAD and 3 bands (red, green and blue) in PCA combined with K-means clustering, respectively. At the same time, the segmentation image was generated based on the subject image using eCognition software. Finally, major voting was used to expand PBCD to OBCD, and RN was also combined in the process.

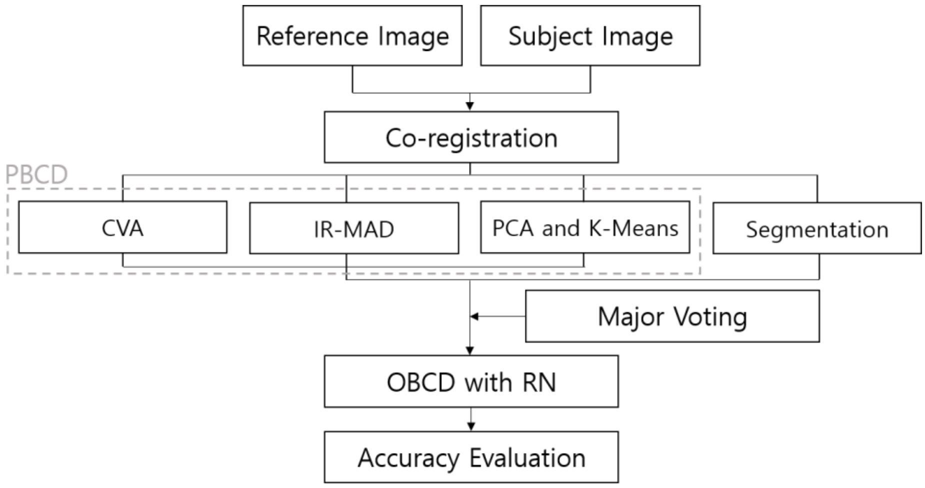


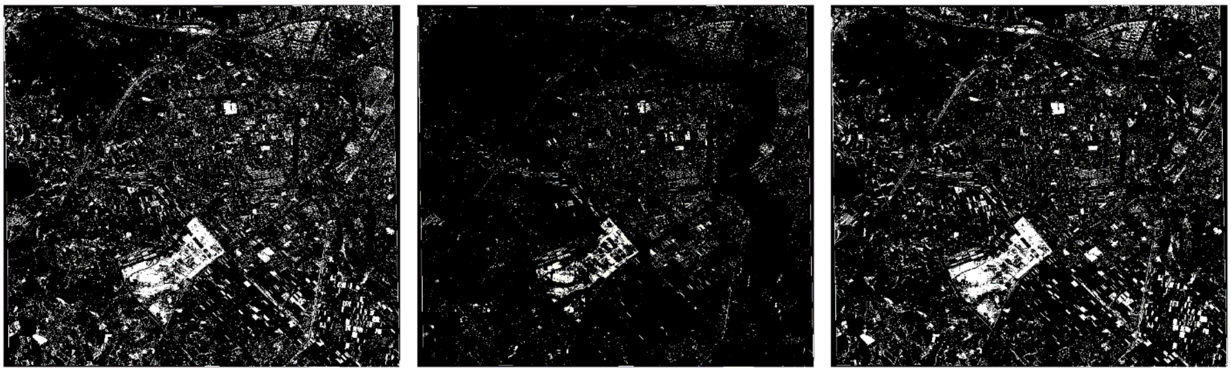
Figure 2. Flow chart

3.1 PBCD

In this study, three PBCD methods were used. The first method is CVA. CVA uses several bands of images, and the Euclidean distance between each pixel value can be used to determine the magnitude of the change. The Otsu threshold was applied to the CVA-based magnitude image to obtain a binary CD image (i.e., change or no-change). The second method used is IR-MAD. IR-MAD is based on the principle of canonical correlation analysis, which finds the coupling vector with the highest correlation to a set of multivariate variables (Choi, 2015). IR-MAD result was also processed to generate a binary image using the Otsu threshold.

The last method used is PCA and k-means clustering. This method analyzes images using the difference image, as in the CVA. After rapping non-overlapping mask ($h \times h$) to the difference image, it extracts eigenvectors using PCA. Feature vectors for each pixel in the difference image are then extracted by projecting $h \times h$ adjacent data into a unique vector space. The feature vector space is clustered into two clusters using the k-means algorithm (i.e., $k = 2$). Finally, CD is achieved by assigning each pixel of the difference image to one of the clusters, depending on the minimum Euclidean distance between the feature vector of the cluster and the mean feature vector (Celik, 2009). The PBCD results are shown in Figure 3.

Finally, before expanding PBCD to OBCD, three results were combined. In the process, only the pixel showing more than two-thirds of the PBCD results was judged as a changed pixel. Accordingly, we can generate the combined PBCD result called multi-PBCD.



(a) **(b)** **(C)**

Figure 3. Result of PBCD (a) CVA (b) IR_MAD and (C) PCA and k-means

3.2 Image segmentation

The eCognition software was used to segment multi-spectral images. In this software, there are three kinds of parameters. First, scale is a parameter with respect to the segment size of the image, and as this value increases, the images become roughly divided. Second, it has a color parameter, which represents the sum of the weighted standard deviations for all layers. This is inversely related to shape parameters and the sum of the two scales is always 1. The last parameter is compactness; as larger this weight indicates the more complex boundaries of the object. This value also has an inverse relationship to smoothness.

In this study, scale parameters were set to 800, and color and compactness parameters were set to 0.1 and 0.5, respectively, the software's default values, to create a segmentation image for the subject image (Figure 4).

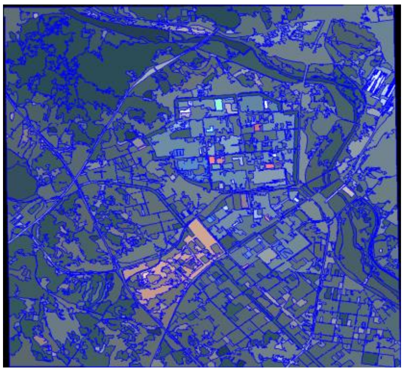
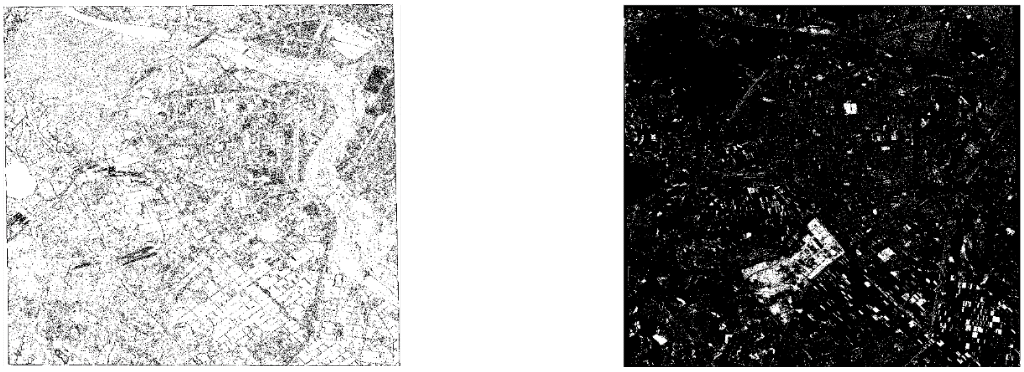


Figure 4. Segmentation image (Scale: 800)

3.3 OBCD combined with RN

Major voting technique was used when segmented image overlaps with the multi-PBCD result. If there is a specific segment that the portion of the changed pixels in multi-PBCD covers more than 50% of the segmentation image's segment area, this segment part is classified as a change area. Otherwise it is classified as a no-change area. Although we performed the co-registration between the images, residual misalignment, also called RN, will appear in the VHR multi-temporal images due to the dissimilarities of the acquisition circumstances. RN has a negative effect when performing CD (Han, et al, 2015). In this study, the RN was combined together in the major voting process to enhance the accuracy of the CD results. Specifically, multi-PBCD and RN results were multiplied so that the pixel with RN is removed when it appears as a change area (Figure 5).

Finally, by using major voting, multi-PBCD result has been expanded to OBCD (i.e., multi-OBCD). The same process was also applied to each single PBCD result.



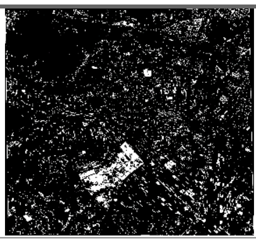
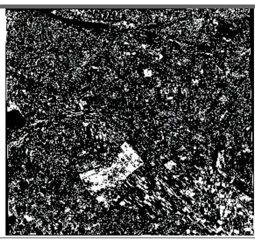
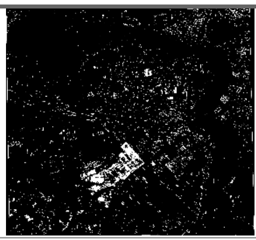
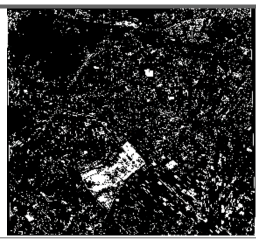
(a) **(b)**

Figure 5. (a) RN and (b) Multi-PBCD combined with RN

4 RESULTS AND ANALYSIS

In this study, we used VHR bi-temporal images to perform CD. 3 types of PBCD results were derived, and based on these, the results of PBCD were extended to OBCD result using segmentation image. Manually digitized reference map was used to evaluate the accuracy of the proposed CD result. We compared the proposed OBCD result created by combining various PBCDs with results created using every single PBCD. The accuracy was compared using the f1- score which is a combined factor of precision and recall. The results of the experiment are shown in the Table 1. The results of the proposed multi-OBCD were the best at 0.393 and showed high accuracy in IR-MAD, PCA with K-means and CVA in order.

Table 1. Results and accuracy

	Proposed multi-OBCD	**CVA OBCD**	**IR-MAD OBCD**	**PCA and k-means OBCD**
CD result				
F1-score	0.393	0.301	0.357	0.335

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