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Image Fusion and Change Detection Using Cohen – Daubechies – Feauveau (9/7) Transform

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Abstract

The surface of the world is dynamic every day due to the change in its features caused by nature and other means. The change detection of the world's surface featuresis extremely necessary for understanding relationships and interactions between human and natural phenomena to produce higher cognitive processes. Satellite images will provide valuable information for disaster management like Floods, Earthquakes, Storm Surge, Landslides, Fires, Volcanic Eruptions, and Drought. The causes of the disaster and its assessment can be carried out using a multi-temporal approach that requires a set of images pre-damage and post-damage of the affected place, which is compared to spot the changes. However, the standard of the satellite images is not sensible to spot the changes. Therefore, the image fusion technique is implemented to enhance the image's standard, and the differencing technique is used to spot the changes. Different image fusion algorithms are analyzed with the proposed method using Graphical User Interface in MATLAB. Performance of fusion is calculated based on PSNR, MSE, NCC, CC, SSIM, and the total processing time. The results demonstrate the fusion scheme's effectiveness based on CDF (9/7) wavelet transform.

Keywords — *CDF (9/7), Change Detection, Image fusion, Multi-temporal Images*

I. INTRODUCTION

Satellite images play a vital role in discriminating world surface changes by comparing the imaging suite at a different time of the same place. The images from NASA's Landsat8 satellite sensor have the extensive potential for multi-temporal image analysis. The results of multi-temporal image analysis are more helpful to assess the damage during disasters like Tsunami, earthquakes, and volcanoes. Image fusion is a method of mixing data from two or multiple images of the same place with different timings. The fused image is the house of all required data lead to consolidate the disaster amount. The image fusion method will be generally classified into two ways: spatial domain fusion and frequency domain fusion. The fusion methods like Principal Component Analysis (PCA), IHS based methods, and Brovey technique represent spatial domain approaches. In the fused image, Spatial Distortion will occur, which is the disadvantage of spatial domain approaches, and it will be handled out very well by the frequency-domain method [1]. Change detection detects the changes in images of the same scene that are taken at totally different times. Differencing (subtraction operator) and rationing (ratio operator are well-known techniques for producing a changed image for the satellite images. In differencing, changes are obtained by subtracting the intensity values pixel by pixel between the fused image and the original image. In rationing, changes are calculated by applying a pixel-by-pixel ratio operator on the temporal Images [2].

II. PROPOSED METHODOLOGY

Fig. 1 shows the proposed method of image fusion, which uses the CDF (9/7) wavelet transform for decomposition and reconstruction of the source images**.** Here the Multi-temporal images (same place but different timings) are decomposed using CDF (9/7) wavelet transform. Wavelet and scaling functions are used for the decomposition of source images. No general selection procedure is available for wavelet and scaling function in the literature. Although regularity (smoothness) and vanishing moment of wavelet can be considered to decide wavelet function. The selection of a wavelet with sufficient vanishing moment is essential for image fusion. The CDF (9/7) uses separate wavelet and scaling functions for the analysis and synthesis of a signal. The output from the synthesis and analysis filtering of CDF (9/7) is in the linear phase, which leads to image denoising. The coefficients obtained are fused using averaging techniques of fusion rule. The value of the pixel P (x, y) of each image is added. This sum is divided by two to get the average. The average value is assigned to the corresponding picture element of the output image. This is repeated for all picture elements. Change detection identifies changes between the images of the same scene taken at totally different times. Differencing method is used for classifying changed and unchanged regions to spot the changes.

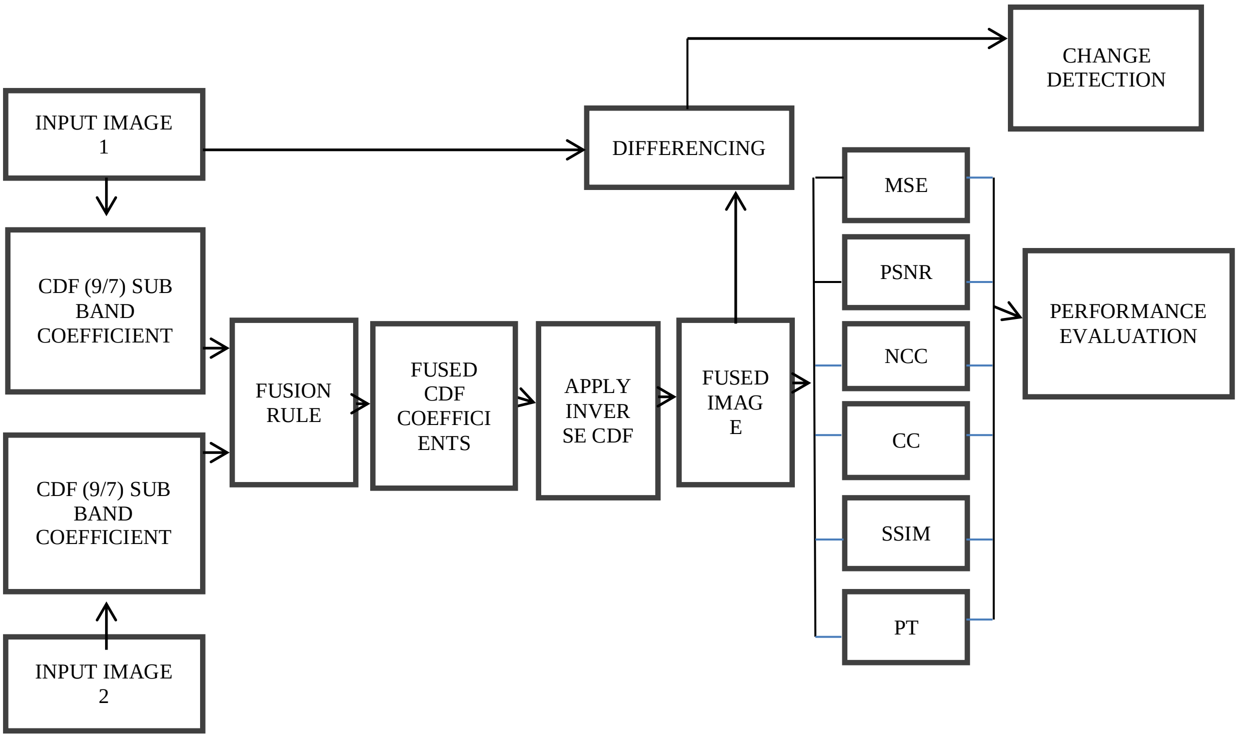


Fig. 1 An Overall System structure

A. Algorithm

The algorithm CDF (9/7) for Image fusion and change detection has been developed and implemented in MATLAB GUI as described below.

a. Read the input images 1 and 2 and convert their size into 256x 256.
b. Convert both images from color to grayscale images to perform wavelet functions.
c. Perform multilevel wavelet decomposition using CDF (9/7) wavelet on both the images.
d. Generate the coefficient matrices and fuse the wavelet coefficients using the averaging technique.
e. Generate a final matrix of fused wavelet coefficients.
f. Compute the inverse wavelet transform to get the fused image.
g. Calculate the MSE, PSNR, NCC, CC, SSIM, and the processing time.
h. Finally, find the change detection of images using differencing techniques and display the result

III. IMAGE QUALITY METRICS

For evaluating the results, various performance metrics are used, like PSNR, MSE, NCC, CC, SSIM, and Processing Time. The quality of a test image is analyzed by comparing it with a reference image that is assumed to have a perfect quality.

A. Mean Square Error (MSE)

The Mean Square Error calculates the intensity of the pixel difference obtained from the fusion process. A lower MSE value indicates a better fusion approach[3].

B. Peak Signal to Noise Ratio (PSNR)

The peak signal-to-noise ratio is used to aspect evaluations between the original and fused image. Higher the value of PSNR implies that the quality of a fused image is better[4].

C. Normalized Cross-Correlation (NCC)

Normalized cross-correlation is the comparison of two-time series images but using a different scoring result. Instead of simple cross-correlation, it can compare metrics with different value ranges. Higher the value of NCC implies the correlation is higher. The maximum value is 1 when two signals are the same. The minimum value is -1 when two signals are opposite[5].

D. Correlation coefficient (CC)

The correlation coefficient calculates the closeness or similarity in small-sized structures between the original and the fused images. It can vary between -1 and +1. Values close to +1 indicates that they are highly similar, while the values close to -1 indicate that they are highly dissimilar.

E. Structural SIMilarity Index (SSIM)

The structural Similarity index is the technique for the measurement of similarity between two images. It is a reference metric that requires two images of the same place- a reference image and a processed image[6].

F. Processing Time

Processing time is the time taken to execute the entire process, which is the difference between process ending time and starting time.

IV. RESULT

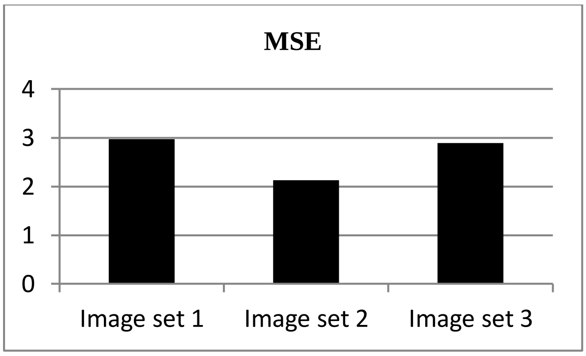
After implementing CDF (9/7) for Image fusion and change detection, various tests have been carried out with different Image sets. Each set consists of two different time images of the same scene. These Image sets are grouped into Class 1- Natural Disaster images (Image set 1- 3), Class 2 - Manmade Disaster images (Image set 4-6). The values of the metrics are tabulated in Table I-II. Some of the Quality metrics charts are drawn in fig. 2&3. Some of the input images and corresponding fused images, and the change detection Image are shown in Fig. 4&5.

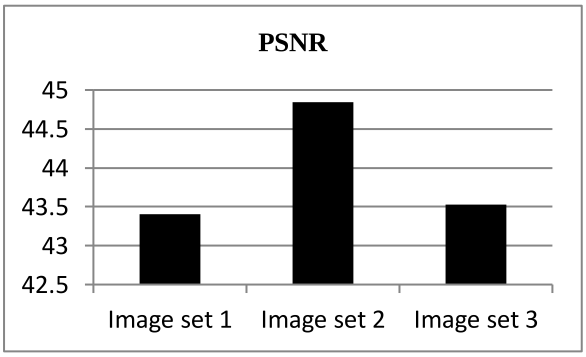
Table I: Quality Metrics for class I (Natural Disaster)

Metrics	Image set 1	Image set 2	Image set 3
MSE	2.96915	2.13139	2.88832
PSNR	43.4045	44.8442	43.5244
NCC	1.08405	1.00876	1.05995
CC	0.793564	0.998652	0.925006
SSIM	0.657731	0.882615	0.865579
PT	0.125	0.078125	0.078125

Table II: Quality Metrics for class II (Manmade Disaster)

Metrics	Image set 4	Image set 5	Image set 6
MSE	2.40146	4.3402	1.01485
PSNR	44.3261	41.7557	48.0668
NCC	1.11339	1.01624	1.1726
CC	0.912956	0.901364	0.380779
SSIM	0.87657	0.795036	0.711324
PT	0.078125	0.109375	0.078125





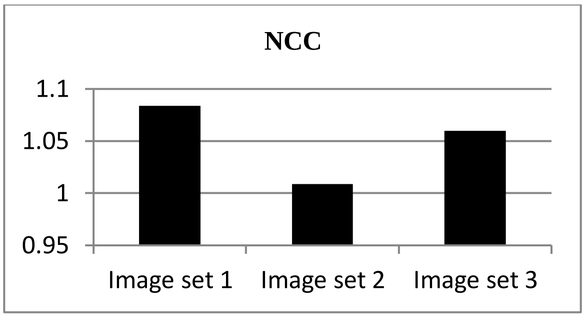
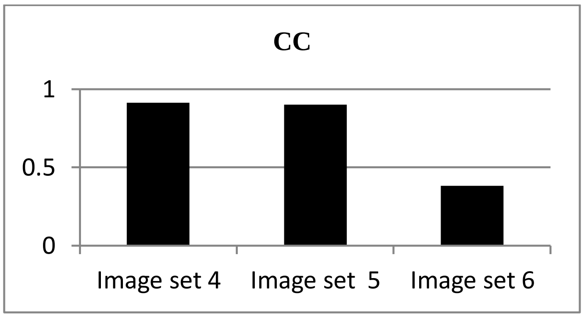
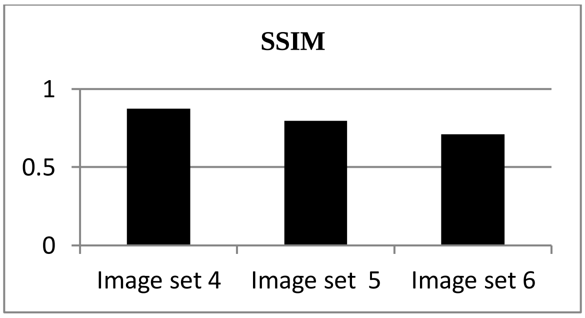


Fig. 2 Quality metric Chart for Class I (Natural Disaster)





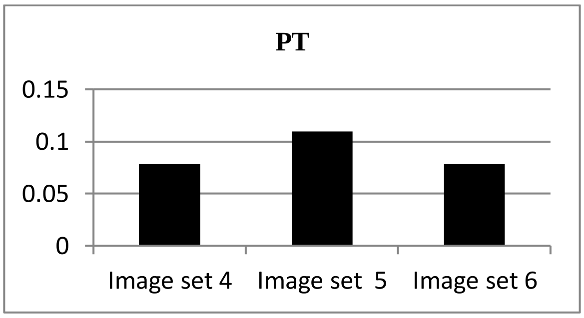


Fig. 3 Quality metric Chart for Class II (Manmade Disaster)

A. *Discussion*

The results of the CDF (9/7) algorithm are consolidated, and from the consolidation, the following things are observed. The Value of the Mean Square Error (MSE) is minimum. The value of Peak Signal to Noise Ratio (PSNR) and the value of Normalized cross-correlation (NCC) are maximum using the proposed algorithm when compared with other techniques. The value of the Correlation coefficient (CC) is not maximum but close to it. Processing time is less for fusion. SSIM is varied on the input images.

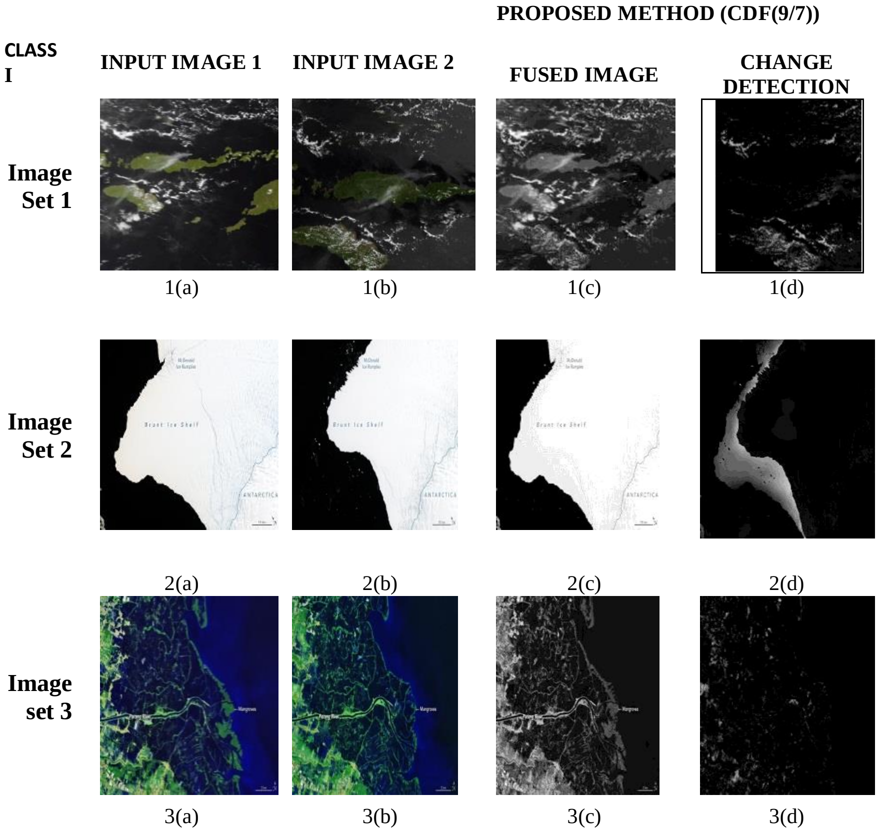


Fig. 4 Input, Output Images of Class –I (Natural Disaster)

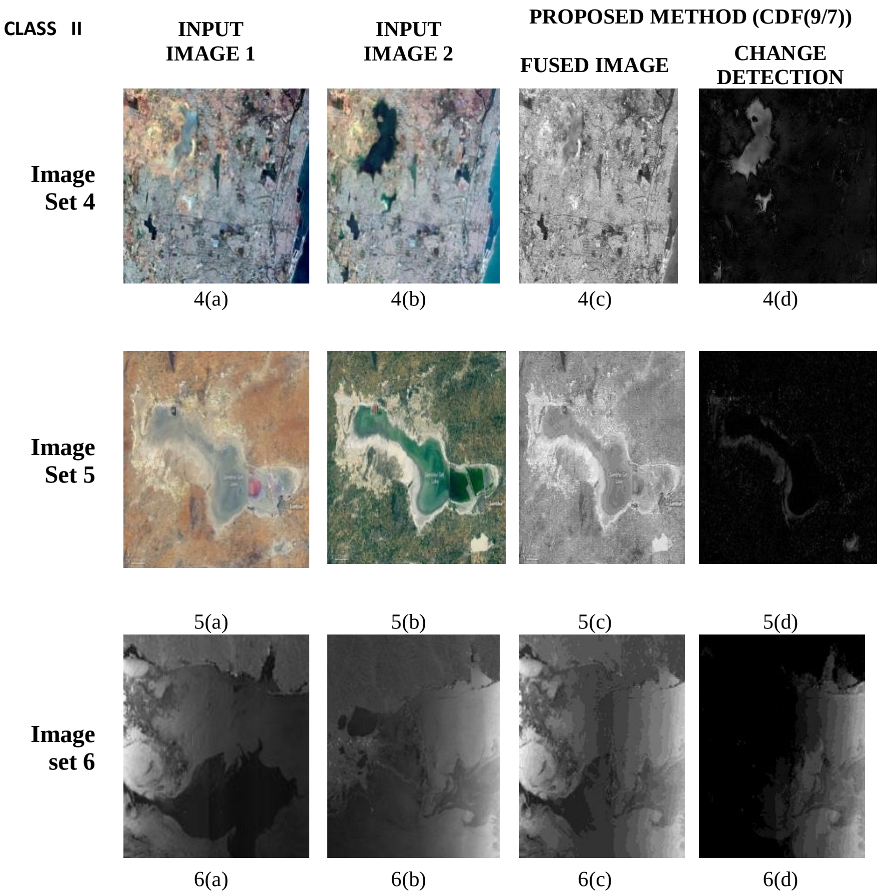


Fig. 5Input, Output Images of Class –II (Manmade Disaster)

V. CONCLUSION

Image fusion using CDF (9/7) wavelet transform has been implemented with a suggested procedure for detecting changes between the involved images. The approach has been tested on real Image sets that showed its effectiveness in the fusion and detecting changes among multi-temporal images. The experimental results provide encouraging results in PSNR, MSE, NCC, CC, SSIM, and Processing Time. The detection of changes is found to be consistent with these visually identified. The fusion techniques realize several applications in reality. It reduces the storage space needed since a single united image is held on rather than multiple images. Economical retrieval is possible since less variety of images (fused) has been held on within the knowledge domain. It conjointly helps to assess the damages due to natural and manmade disorder. Promising results were achieved with the new fusion technique compared to different techniques.

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