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Water Feature Extraction and Enhancement of Satellite Images by Morphological Erosion, DWT, and Wiener Filtering

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Abstract: Water feature extraction is major problem in satellite image processing. Water pixels in satellite image mix-up with built up areas and shadow pixels. Shadow pixels may be due to mountains and other big objects. It is difficult to extract water bodies from built-up areas and shadow pixels. In this research paper, a method is proposed which extracts water bodies from satellite images using morphological erosion, DWT, and wiener filtering. The method is able to detect water bodies in satellite image and this technique suitable for satellite image enhancement. The proposed method has given better results in terms of quantitative parameters such as peak signal to noise ratio (PSNR), root mean square (RMSE), correlation coefficient (CC), mean, variance, standard deviation, and entropy. Error free classification can be done with this proposed algorithm. The proposed method is implemented on Persian-Gulf and Lake-Marion. The main objective of this paper is to extract only water pixels and to eliminate everything in satellite image.

Keywords: DWT, Enhancement, Erosion, wiener filtering.

I. INTRODUCTION

Satellite image processing is playing crucial role now days in many aspects. In satellite image processing feature extraction plays a prominent role. For feature extraction, classification of different land covers is done by segmenting techniques [1]. Edge detection by wavelets and histogram equalization techniques are used for contrast enhancement of satellite images [2], [3]. DWT sub-bands along with manipulated LL (low-low) sub-band used to reconstruct the image with contrast enhancement [4, 5, 6].

Various interpolations has been used in digital image processing such as facial reconstruction and resolution enhancement [7].Out of many interpolation techniques, Bicubic interpolation is used in many cases, because smoother surfaces can be obtained [8]. Different wavelets and curve-lets are used for edge enhancement purpose. Reconstructed images sharpness can be increased by detailed wavelet coefficients [9]. Super resolution techniques are economic [10], so they are widely used in many applications. Blurring effect can be reduced by DWT. DWT also preserves high frequency components [11]. So, DWT is preferred compared to other wavelets.

Morphological operations are used to detect water bodies such lakes, rivers, and seas. To fill the holes in water masks, closed hole operations has been applied to Islands, which avoids loops [12].In proposed algorithm, morphological erosion and white hat transform (WHT) is used to detect water bodies. WHT has given low PSNR and high RMSE, which is demerit. DWT is performed on output of erosion, which will take care of high frequency bands and edges. Wiener filtering is then performed to avoid additive noise. The present algorithm is compared with existing morphological operations and WHT in paper [13].

II. MATERIALS AND METHODS

Different satellite images are processed by using proposed Algorithm. For analysis of proposed algorithm two water bodies are considered. One is Persian-Gulf and other one is Lake-Marion. Persian-Gulf is a Mediterranean Sea in Western Asia. Lake-Marion is the biggest lake in South Carolina, halfway found and with region inside five regions. Lake-Marion is of resolution 532×532 and Persian-Gulf is of resolution 196 × 196. For processing these satellite images MATLAB R2016a is used. These images are downloaded from Google earth. The algorithm is explained in different steps as given below:

1. Satellite image (I) is converted to gray scale image (x).
2. Now gray scale image is converted to binary image (b).
3. Logical not operation is performed, which is the negative of input satellite image (c).
4. This negative image is filled with holes (d).
5. The image x is multiplied by b and the resultant image is denoted by s.
6. Mask operation is performed on s by using adaptive histogram equalization (mask).

7. Structuring element of square shape is used with a size of 5*5.

8. Erosion operation is performed between mask and structuring element. The result is water bodies are detected in satellite image.

9. Bicubic interpolation with scaling factor 2 and discrete wavelet transform (DWT) is applied on the resultant image, which can enhance image quality and preserve high frequency components.

10. Wiener filtering with a mask of 5*5 size is performed on DWT output. This eliminates noise in the image. PSNR, RMSE, CC, mean, and standard deviation is calculated. Finally error free water bodies are detected. The quantitative parameters are improved with this method.

Removing pixels to the boundaries of objects in an image is called Erosion and adding pixels to the boundaries is known as Dilation. It depends on size of structuring elements. The erosion is given by equation 1 and dilation is given by equation 2. These two equations are for gray scale images.

$$\mathcal{E}_B(f) = \inf\{g(f - y)\},\ y \epsilon B \quad (1)$$

$$^{\delta}{}_B(f) = \sup\{g(f + y)\},\ y \epsilon B \quad (2)$$

Opening is the dilation of erosion and closing is the erosion of dilation. The sequences of Opening and closing are given by equations 2 and 3 respectively.

$$^{\gamma}{}_B = {}^{\delta}{}_B(\mathcal{E}_B(f)) \quad (3)$$

$$^{\varphi}{}_B = \mathcal{E}_B({}^{\delta}{}_B(f)) \quad (4)$$

In this research paper, we have calculated 7 evaluation parameters. They are explained in equations 5 to 11 as shown below. The quality of image after recovery is determined by namely Peak Signal-to-Noise Ratio (PSNR). Maximum value is desirable.

$$PSNR = 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \quad (5)$$

Root mean square value is another parameter for defining the quality of enhanced image. It should be low value for good quality images.

$$RMSE = \sqrt{\frac{1}{P\times Q}\sum\sum\left[x(i,j) - x^R(i,j)\right]^2} \quad (6)$$

Variance determines the deviation of pixels from average value. Variance should be low value.

$$\sigma = \left(\frac{1}{P\times Q}\sum_{p=0}^{P-1}\sum_{q=0}^{Q-1}\left(x(i,j) - M\right)^2\right) \quad (7)$$

Mean describes the average value of pixels in an image. Ideal value of mean is 1.

$$Mean(M) = \frac{1}{P\times Q}\sum_{p=0}^{P-1}\sum_{q=0}^{Q-1} f(p,q) \quad (8)$$

Standard deviation is the square root of variance.

$$SD = \sqrt{\left(\frac{1}{P\times Q}\sum_{p=0}^{P-1}\sum_{q=0}^{Q-1}\left(x(i,j) - M\right)^2\right)} \quad (9)$$

Average information in an image can be determined by Entropy. It is one of statistical evaluation metric useful to find out quality of enhanced image. High value is desirable.

$$H(X) = \sum_{i=1}^{n} p(x_i)I(x_i) = -\sum_{i=1}^{n} p(x_i)\log_b p(x_i) \quad (10)$$

Correlation coefficient is the relation between input image and output image. It determines the how much output image is related to input image. High value is desirable and ideal value is 1.

$$CC = \frac{\sum_{p=0}^{P-1}\sum_{q=0}^{Q-1}(p,q)\, f(p,q) - M_p\, M_q}{\sigma_p\, \sigma_q} \quad (11)$$

III. RESULTS AND DISCUSSIONS

The proposed algorithm has given better results in evaluation parameters such as PSNR, RMSE, CC, mean, variance, and standard deviation. Persian-Gulf image has got PSNR of 55.961, RMSE of 0.358, CC of 0.379, mean of 0.428, standard deviation of 0.223, and variance of 0.177. Lake-Marion has got PSNR of 57.316, RMSE of 0.307, CC of 0.385, mean of 0.39, standard deviation of 0.389, and variance of 0.1516.

Figure 1 is the Persian-Gulf input color image. Figure 2 is the Lake-Marion input color image .Figure 3 is input Persian-Gulf gray scale image. Figure 4 is Persian-Gulf image after erosion operation and WHT. Figure 5 is resultant image after performing Erosion-DWT-wiener filtering on Persian-Gulf image. Figure 6 is input Lake-Marion scale gray image. Figure 7 is Lake-Marion image after erosion operation. Figure 8 is resultant image after performing Erosion-DWT-wiener filtering on Lake-Marion image.

The objective of proposed algorithm is to extract water pixels in satellite image. It is very difficult to extract water bodies from built-up areas and shadow pixels. Proposed method is able to extract water bodies from satellite images

using morphological erosion, DWT, and wiener filtering. Morphological operations are used to detect water bodies. DWT is used for enhancement purpose, which performs operation on high frequency bands. Additive noise is eliminated by wiener filtering. The method is able to detect water bodies in satellite image without error. The image resolution has been enhanced by proposed technique and it has given better results in quantitative parameters such as PSNR, RMSE, CC, mean, and standard deviation. Table 1 describes quantitative parameters for Persian-gulf. Table 2 describes quantitative parameters for Lake- Marion.

Figure1. Persian-Gulf color image

Figure2. Lake-Marion color image

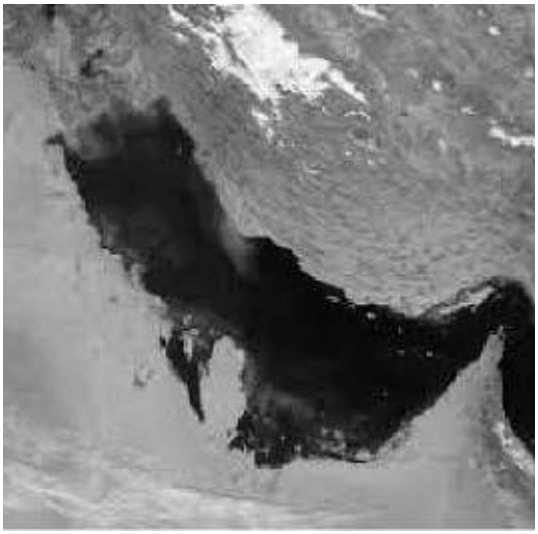

Figure3. Persian-Gulf gray scale image

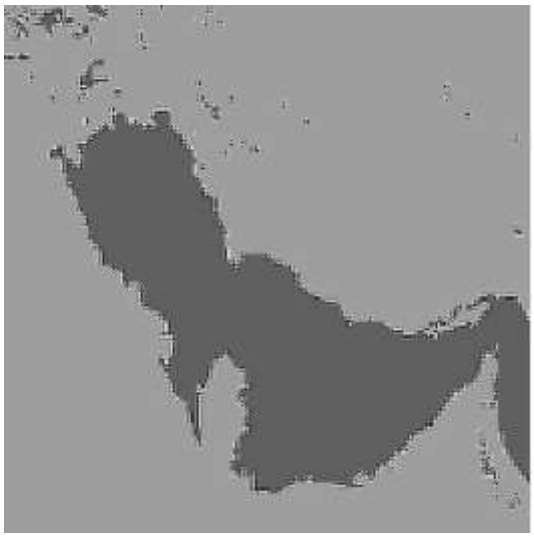

Figure4. Persian-Gulf after erosion and WHT

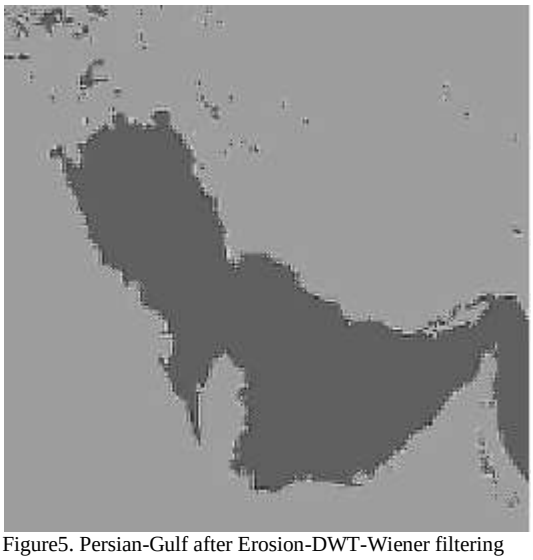

Figure5. Persian-Gulf after Erosion-DWT-Wiener filtering

Figure6. Lake-Marion gray scale image

Figure7. Lake-Marion after erosion and WHT

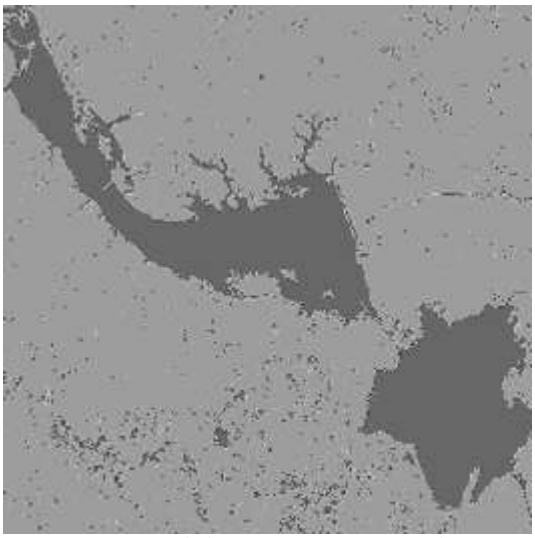

Figure8. Persian-Gulf after Erosion-DWT-Wiener filtering

Table 1: Quantitative parameters for Persian-Gulf (Image 1)

Parameter	Image1 after Erosion and WHT	Image 1 after Erosion-DWT-Wiener filtering
PSNR	8.27	54.762
RMSE	75.64	0.358
CC	0.371	0.528
Mean	1.03	0.378
Standard Deviation	0.851	0.223
Variance	0.724	0.177
Entropy	0.946	2.584

Table 2: Quantitative parameters for Lake-Marion (Image 2)

Parameter	Image1 after Erosion and WHT	Image 2 after Erosion-DWT-Wiener filtering
PSNR	18.392	56.117
RMSE	64.018	0.307
CC	0.329	0.585
Mean	1.01	0.39
Standard Deviation	0.801	0.219
Variance	0.642	0.048
Entropy	0.749	3.481

IV. CONCLUSION

Water bodies are extracted in satellite image with the proposed method. Persian-Gulf and Lake-Marion are processed with morphological erosion, DWT, and wiener filtering. Persian-Gulf is a Mediterranean Sea in Western Asia. Lake Marion is the biggest lake in South Carolina, halfway found and with region inside five regions. The quantitative parameters such as PSNR, RMSE, CC, mean, variance, standard deviation, and entropy are improved with proposed method.

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