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Fusion of SAR and Optical Image for Remote Sensing Applications

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ABSTRACT

Image Fusion is a technique where two or more images can be combined to form a high-resolution image that has characteristics of the input images. In this paper, the two main remote sensing images are used, namely SAR and Optical and generates a new composite image that has spectral and spatial characteristics. The Haar Wavelet transform maintains good spectral information. The Gram-Schmidt transform improves the spatial features of the image and maintains the spectral characteristics of the input images. Gram-Schmidt with Haar transform is the proposed method for the fusion of two images and is more efficient to restore the characteristics of the original image for fewer levels of decomposition.

KEYWORDS: SAR image, Optical image, Gram-Schmidt transform, Haar wavelet transform, Image Fusion

1. INTRODUCTION

Image Fusion is used to process, different images in order to get high informative image compared to anyone of the input image [1]. Image fusion is able to achieve in three ways: Pixel level, and other two are Feature level and Decision level. Feature Level Fusion does not require registration of an image therefore the image can be extracted based on features like edges, corners, curves etc. This article concentrates on feature level fusion technique.

Synthetic Aperture Radar and Optical satellite images are the important data types of remote sensing applications. Optical satellite remote sensing data have ability to reflect the real surface,colour, and information about geographical arrangement, hence the analysis of an image is easy, but the quality of an image is limited by weather and time. This type of sensors generates the image over large areas. SAR is a form of radar which dispatches a microwave pulse off to the earth to determine the physical properties, it does not contain spectral information and easily produce layover shadow that will affect the observation. Fusion of these two images will produce a high-resolution image. There are various fusion procedures like Intensity-Hue-Saturation transform which represents spatial resolution of an image [2], Principal component Analysis transform, Brovey transform will give some information distort [3], Wavelet transform, and Gram-Schmidt transform, Non-Subsampled Contourlet transform etc.

The Gram Schmidt transform does not have any restrictions to number of bands and reflects a better fusion effect, after image fusion the SAR image have spectral distortion [4]. In the Non-Subsampled contourlet transform performed on SAR image will increase the spectral fidelity, but the detail of SAR is diminished [5]. In this paper, a method is used with a combination of Haar wavelet and Gram Schmidt transform to resolve the spectral distortion and compare the results with Haar wavelet transform.

2. METHODOLOGY

Gram-Schmidt transform

In this paper, Gram-Schmidt transform is one of the methods used for the fusion of two images, in which orthogonalization is applied to get the matrix of an image, because of that the information redundancy and correlation in the middle of each band can be reduced [1].

In the process, a lower spatial resolution optical image is simulated, and a Gram-Schmidt transformation is applied on the simulated lower spatial resolution optical image and multitude of lower spatial resolution spectral band images, wherein the simulated lower spatial resolution optical image is employed as the first band in Gram-Schmidt transformation. This algorithm is used to calculate the multi-spectral bands, which is based on certain weights to obtain the gray scale image taken as GST1. Now GST1 and the multi-spectral bands undergoes positive transformation, by calculating the standard deviation and mean of GST1 and the high spatial Synthetic Aperture Radar image, to replicate GST1. The GST1 is replaced by matched high spatial Synthetic Aperture Radarimage for inverse Gram-Schmidt transformation to obtain information rich fused output image.

Haar wavelet Transform

The wavelet transform has ability to give information on frequency-time domainconcurrently [6]. The wavelet transform is performed on a two-dimensional figure. The Haar discrete wavelet transform is one of the types, which is a time scale representation that provides sub-band decomposition of images. The Haar wavelet transform is equal to its inverse. In Haar discrete wavelet transform architecture, firstly the image is decomposed into low frequency sub-band and high frequency sub-band components by using high pass and low pass filters, which is the first level of hierarchy, then again, the low frequency sub-bands are divided into further low frequency and high frequency sub-bands. This can be continued for n number of levels. The decomposed image size is same as the size of input image.

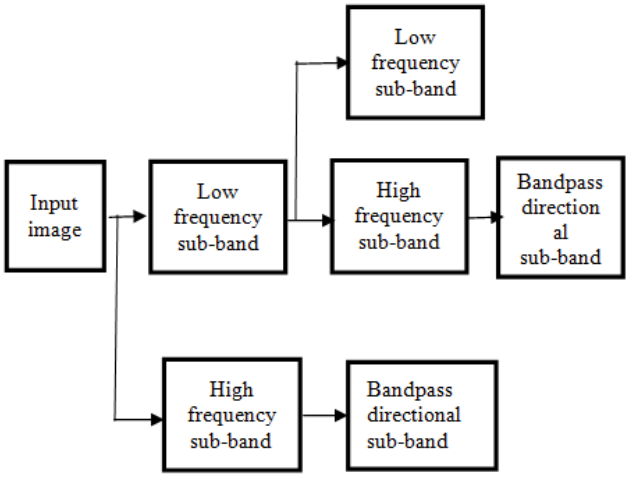


Fig1 Wavelet Decomposition

ImageFusion procedure by merging Gram-Schmidt and Haar Wavelet Transform

The Haar wavelet transform is used for lossless compression of an image, and it produce Sparse matrix [6]. Take SAR and Optical satellite gray scale images as input images, by weighing the average of each and every band of input optical satellite image, the gray scale image J is obtained. Now, the discrete wavelet transform is used to decompose the image J and the Synthetic Aperture Radar image respectively and obtains low frequency sub-band of new image. This low frequency band consists of spectral information. Then the directional sub-bands obtained by decomposition of high frequency bands further, the maximum value of these directional sub-bands coefficients of SAR and optical image is taken as new image. Then apply discrete Haar wavelet transform to get the fused image, that is the new image(N).

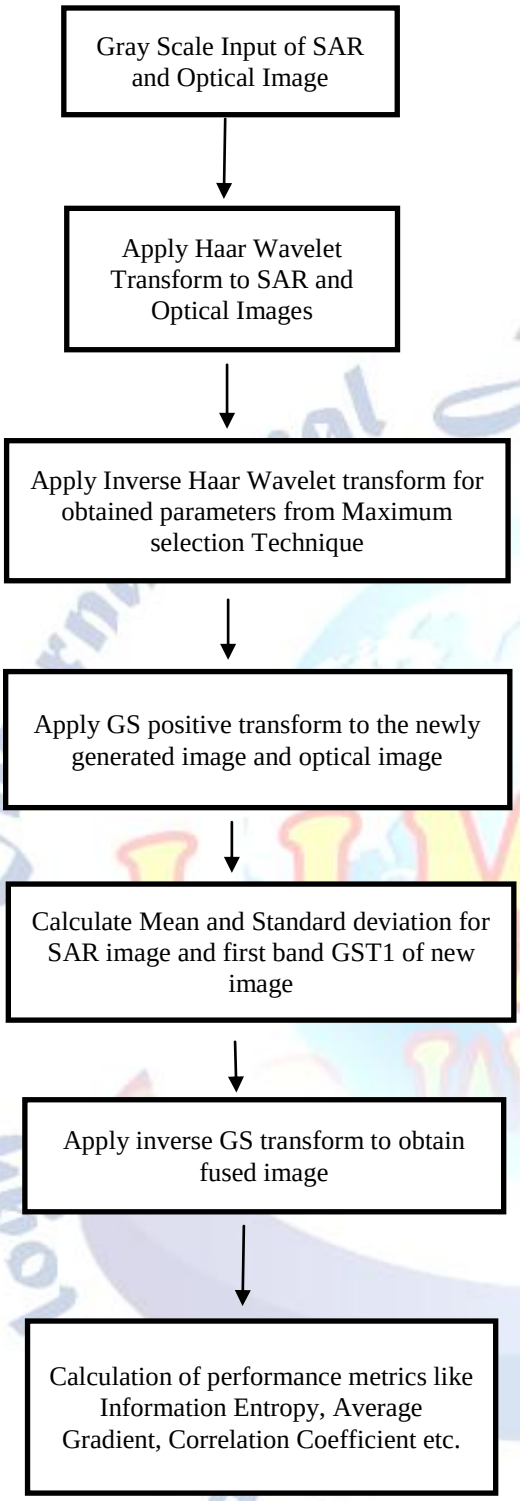


Fig 2 Flowchart for Image Fusion (GS with Discrete Haar wavelet transform)

Then, replace the SAR image with new image and apply Gram-Schmidt transform to them. After Gram-Schmidt transform consider the first band as GST1. Now, calculate the mean and standard deviation for SAR image and first band of GS transform output as GST1. The first component of GS transform, GST1 is matched to new image by making some adjustments, which generates a modified version of new image, such that spectral characteristics of optical image are maintained. Then apply inverse GS transform to modified new image and GST1 to get a fused image with enhanced spatial resolution.

$$GST1 = J \quad (1)$$

The Gram-Schmidt positive transform was performed on each and every band of optical satellite image and GST1.The algorithm is given as follow [1].

$$GST(a, b) = (A_{i-1}(a, b) - \mu_{i-1}) - \sum_{c=1}^{i-1} \emptyset(A_{i-1}, GS_c) * GS_c(a, b) \quad (2)$$

Where:

$$\mu_i = \frac{\sum_{f=1}^{F} \sum_{d=1}^{D} A_i(a,b)}{F \times D} \quad (3)$$

$$\emptyset(A_i, GS_c) = \frac{\sigma(A_i, GS_c)}{\sigma(GS_c, GS_c)^2} \quad (4)$$

$$\sigma(A_i, GS_c) = \frac{\sqrt{\sum_{f=1}^{F} \sum_{d=1}^{D} (A_i(a,b) - \mu_i)(GS_c(a,b) - \mu_c}}{F \times D} \quad (5)$$

3. Objective Evaluation

Information Entropy

Information Entropy is one of the concepts in information theory, which is the measure of randomness that can be used to characterize the texture of input image. The information entropy for GS with Haar Wavelet transform is high compared to that of Haar wavelet transform. Compared to GS and Haar wavelet transform, the GS with Haar wavelet transform minimizes the spectral distortion up to an extent.

Correlation Coefficient:

The Correlation Coefficient gives us information about how close the two images are. If the value of correlation coefficient is near to one, then it indicates the fused image is much closer to source image. The correlation coefficient in this paper is obtained by the squared average of fusion image and input image. Compared to the GS and Haar wavelet transform, the GS with Haar wavelet transform has high correlation coefficient value,

that indicates fused output image obtained after GS with Haar wavelet transform is more related with input image.

SET-1

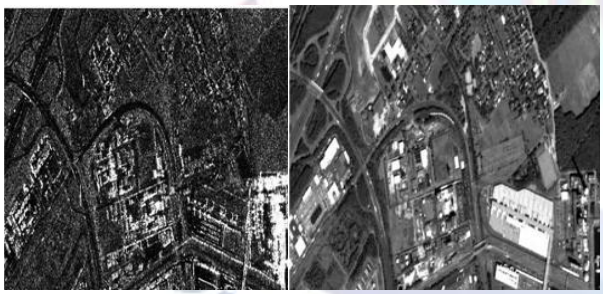
(a) SAR Image(b) Optical Image

(c) GS and Haar Wavelet(d) Haar Wavelet Transform Transform

Fig3 Set1 Original and Fused Images

SET-2

(a) SAR Image(b) Optical Image



(c) GS and Haar Wavelet(d) Haar Wavelet Transform Transform

Fig4 Set2 Original and Fused Images

SET-3

(a) SAR Image(b) Optical Image

(c) GS and Haar Wavelet(d) Haar Wavelet Transform Transform

Fig5 Set3 Original and Fused Images

Table 1 Performance Metrics

Parameters	GS with Haar Wavelet Transform (Set1)	Haar Wavelet Transform (Set1)	GS with Haar Wavelet Transform (Set2)	Haar Wavelet Transform (Set2)	GS with Haar Wavelet Transform (Set3)	Haar Wavelet Transform (Set3)
Information Entropy	7.5467	7.5109	7.4120	7.3964	7.2660	7.1084
Correlation Coefficient	0.4758	0.3842	0.6426	0.5472	0.5168	0.4960

4. Conclusion

The main moto of this work is to compare Haar wavelet transform with a combination of Gram-Schmidt and Haar wavelet transform technique for image fusion. To get fused images effectively, a technique is applied to preserve important features from input images. Multi-resolution analysis tools such as the wavelet are therefore ideally suitable to image fusion. In this paper first Gram-Schmidt transform and Haar Wavelet transform principles and procedures are introduced and

then combined these methods. The image fusion is performed on gray scale images and the performance characteristics between the fused images of the two methods are compared based on different image parametric metrics. It was found that Haar transform is the basic method for image fusion whereas Gram-Schmidt along with Haar transform is the advanced method for the fusion of two images and is more efficient to restore the characteristics of the original image. From the parameters, it is observed that using Gram-Schmidt with Haar wavelet transform technique is more effective than Haar wavelet transform, which is evident through the values of the parameters obtained for cross entropy, Average gradient, Correlation coefficient and Information entropy.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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