Journal of Engineering Research and Reports

20(12): 15-25, 2021; Article no.JERR.73014
ISSN: 2582-2926

Multi Sensor Image Fusion Using Stationary Wavelet Transform and Feature Extraction from Gabor Filter and GLCM Texture

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2021/v20i1217417
Editor(s):
(1) Dr. Tian- Quan Yun, South China University of Technology, China.
Reviewers:
(1) M.Kalarathi, Mepco Schlenk Engineering College, India.
(2) Lim Eng Aik, Universiti Malaysia Perlis, Malaysia.
Complete Peer review History: https://www.sdiarticle4.com/review-history/73014

Original Research Article

Received 18 June 2021
Accepted 22 August 2021
Published 27 August 2021

ABSTRACT

Image Fusion is a process of adding information obtained from various sensors and intelligent systems. This provides an image which containing complete information. In this process we fuse images of the same scene one is Infrared Image and other is visible image to produce an image that contains more information. In this the Infrared which are low resolution and noisy nature of image and visual image fused using Stationary wavelet transfer algorithm. In this we have used Gabor filter and GLCM to extract feature and compared the two feature extraction method using quality matrix parameters and found which method is the best method of fusion. The fusion is used in satellite image fusion which mostly used in maps also for decision-making process involved in interpreting images from multi sensor data. Images of several different targets (a military vehicle, a wood chipper, a pickup truck, and people) were used to assess how human subjects view and interpret different types of images. The premise is that combining complementing data from several sensors will result in more accurate findings for data processing difficulties. Although significant progress has been achieved in this sector, complete modeling of the human brain remains a distant objective.

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Keywords: Fusion; gabor filter; grey level co-occurrence matrix [GLCM]; quality metric [QM] of fusion; stationary wavelet transform [SWT].

1. INTRODUCTION

Multispectral data is needed in satellite imagery of the earth in order to obtain the maximum amount of information from a scene. Image fusion has been proposed as a way to increase accuracy and lead to mission success in navigation, surveillance, fire control, and missile guidance. These applications rely heavily on the fusion process. To achieve the desired "fusion" of information into a single "photo" for rapid evaluation, imagery from various sensors must be optimized, enhanced, and spatially recorded. This fusion of data must be delivered to the end user in a timely and ergonomic manner in a tactical military environment. Digital Image fusion is a process in which more than two digital images are fused, and the purpose of digital image fusion is to get improved image and remove some of the problem having in one of the image or another image like that we can improve the image information. Most of the satellite images are having Panchromatic as well as multispectral images. Panchromatic images are having high resolution were as multispectral images are low resolution. So both can fill the requirement of research. So some time it is required to multispectral images require high resolution that time digital image fusion is most required to get high resolution in multispectral images. As multispectral sensors are costly as compare panchromatic sensors. In such case we can use image fusion to serve our requirement as well as we can save money. If we want to highlight some of the objects of an image or to get a clear image then we used to fuse two images and get clear objects from an image. There are three processes at which the image fusion will done, they are image fusion at Pixel level, image fusion at feature level and image fusion at decision level. In order to fuse two images we have different tequniques like multiplicative algorithm, subtractive method, principle component analysis (PCA), Intensity-Hue-Saturation technique, Fusion technique based on high pass filter, Bravery transform image fusion technique, color technique also wavelet technique is also used to fuse two or more than two images. In this paper we are going to use Stationary wavelet transform to fuse of two images one is visual image and another is Infrared image.

2. LITERATURE REVIEW

Xn Zhang et al addressed a problem of image texture extraction on high –resolution remote sensing image using GLCM and classification experiment using support vector machine algorithm and found the qualitative and quantitative measure [1]. Padmavathi k proposed a novel fusion algorithm where the texture details of MRI image and visual details of Position Emission Tomography (PET) using Adaptive weighting scheme [2]. Jharna Maunder et al proposed a process of integrating information obtained from various sensors and intelligent systems and comparison of GLCM based fusion method, Tamura Texture and Statistical Features based fusion for multisensory images and also found the performance of these image fusion methods is analyzed based on the quality assessment of the output image [3]. Same au scene that is in diverse focuses to produce an image that contains more information and found GLCM texture based Image Fusion, most of the quality metric parameters gives a good response [4]. Jia-Li Yin et al considered a fusion of pair of Low dynamic range (LDR) images at different exposure level. In this proposed method combined the LDRs with transferring the images into semantic space at the feature level. In this propose a novel encoder-decoder network consisting of a content prior guided (CPG) encoder and a detail prior guided (DPG) decoder for fusing [5]. Mourad Jbene et al in this combining two feature extraction methods: Handcrafted-based and CNN-based in a two-stream neural network architecture. And found that Statistical features could enhance the performance of the CNN architecture [6]. Gangliu et al used multi-scale scheme for image fusion is presented using texture and edge information. The original images are decomposed into texture and edge maps by pyramid structures and fusion is done by fuzzy region based strategy. The proposed method aims to improve the visual quality of images.

3. PROPOSED METHODOLOGY

In the proposed method, the pair of Visual and Infrared Images are used for the study. The images are registered and of size (400 x 400). Features are extracted from each pair of

Images. In the proposed method we have used features derived from Gabor filter and Gray level Co-occurrence Matrix (GLCM), a texture feature extraction method first proposed by Haralick [7]. Gabor filter gave five features extracted by varying angle from 0^0 to 180^0. Six texture features of GLCM are used; they are Angular Second Moment (ASM), Contrast, Entropy, Correlation, Homogeneity and Variance. Each Pair of Feature Images are fused using Stationary Wavelet Transform (SWT). The fused images are then subjected to Quality Metric (QM) analysis. The QM parameter decides the best method of Fusion. The flow diagram of the entire methodology is given Fig. 1, Fig. 2 and Fig. 3.

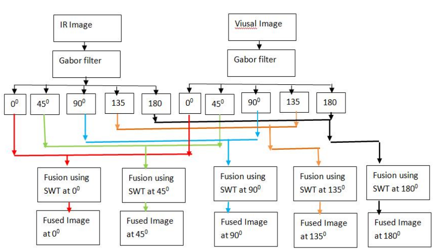

Fig. 1. Feature extraction using Gabor filter

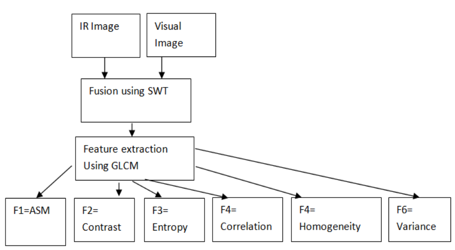

Fig. 2. Feature extraction using GLCM

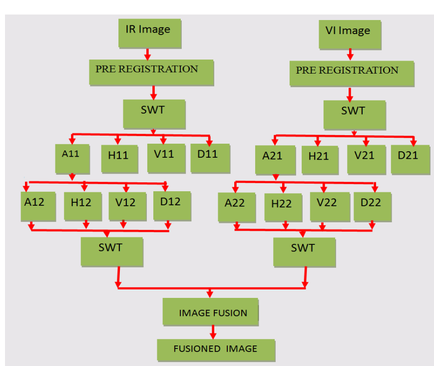

Fig. 3. Working of stationary wavelet transform

The Detail Methodology is given section 3.1 to 3.3

3.1 Feature Extraction Using Gabor Filter

A Gabor filter is used in Image processing to analysis texture of an Image. The Gabor filter is used to analyze whether there is any frequency components in the image in specific directions in given pixel or region to be analysis. Gabor is a convolution filter which is representing a combination of Gaussian and sinusoidal term i.e. there is a Gaussian component and a sine component. The Gaussian component provides weights and the sine component provides directionality. Gabor can be used to generate features that represent texture and edges. Gabor filter is a bank of filter that can be designed to detect texture and extract texture.

The mathematical representation of the Gabor filter is:

$$g(x, y; \lambda, \theta, \psi, \sigma, \gamma) = \exp^{\left(-\frac{x^2+\gamma^2 y\prime^2}{2\sigma^2}\right)} exp^{\left(i\left(2\pi\frac{x'}{\lambda}+\psi\right)\right)} \quad (1)$$

Where

x'= xcosθ + y sin θ

and

y'= -xcosθ + y sin θ
λ= wavelength of the sine component
θ= Orientation of the filter
ψ=phase offset
σ=std. dev. Of the Gaussian envelope
γ=Spatial aspect ratio

When γ is 1 then kernel is circular and if γ is closed to zero then the kernel is elliptical in one direction.

For Feature Extraction by applying Gabor Filter the size of the kernel is 15 x 15, σ =5, λ=90^0, γ=0.002 which is nearly elliptical in one direction, Phase off set ψ is 0.9 and with different for 0^0.

Repeat feature extraction for 45^0, 90^0, 135^0 and 180^0.

3.2 Texture Feature Extraction From Gray Level Co-Occurance Matix (GlCM)

Gray level co-occurrence of matrix is introduced by Haralick, which is used for extracting features. GLCM is a image analysis technique where we can calculate texture feature of an image. GLCM is the matrix gray level co occurred in an image. GLCM of an image is calculated by using a displacement vector d, defined by its radius δ and orientation θ where as θ can be 0^0, 45^0, 90^0 and 135^0, 180^0.

The GLCM extracts six features such as ASM, Contrast, Entropy, Correlation, Homogeneity and Variance from six pair of Infrared and Visual Images.

A. Quantize the image data. Each single image pixel. The intensities are quantized into discrete gray levels.

B. Create the GLCM. It will be a square matrix N x N in size where N is the Number of levels specified under Quantization. The matrix is created as follows:

i. Let us consider an sample image.
ii. Add this to the GLCM itself.

C. Normalize the GLCM:

Divide each element by the sum of all elements.

3.3 Stationary Wavelet Transform (Swt)

Basically it is a wavelet transform, and as we know that in wavelet transform we will take an image which is a matrix of Pixel and then we will apply this wavelet transforms technique so that the Image is converted in to frequency domain. In this Paper we are using Stationary wavelet transform (SWT), In Stationary Wavelet transform there are four components they are Approximation Coefficient, Horizontal coefficient, Vertical coefficient and Diagonal coefficient.SWT is Different from DWT as in DWT at each level hierarchy the image is to be down sample where as in the SWT does not perform down sampling at each hierarchy. So at each level we are losing the half of the resolution of the parent level but in case of SWT as we are not doing down sampling so the resolution of parent image is Preserve. The image is converted into frequency domain after applying of SWT. After applying transformation we will get high and low frequency sub-bands. In first step of SWT decompose the input image using low pass filter and high pass filter. And repeat the decomposition method k times and generating low and high filters representing like a tree called as filter bank.

3.4 Quality Meric Parameters For Fusion

One of the most difficult aspects of digital image processing is determining image quality. Although PSNR is the most commonly used objective image quality metric, it does not correlate well with subjective evaluation. As a result, several objective image quality metrics (IQM) have been established in recent decades to replace PSNR. In general, quality measurements are used to assess the quality of image enhancement after they have been processed and compared to the original and other methods. Here in this paper various objective evaluation algorithms for measuring image quality like MSE, PSNR, SSIM and Cross Entropy are simulated and compared with respect to features of Gabor and GLCM method. In order to judge which method is the best.

Cross Entropy is given in equation (2)

$$CE(a,b;f) = \frac{CE(a;f) + CE(b;f)}{2} \tag{2}$$

Where a and b are two images and f is the fused image

$$\text{CE (a; f)}=\sum_{i=0}^{i=L} h_a(i) log_2 \frac{h_a(i)}{h_f(i)} \tag{3}$$

$$\text{CE (b; f)}=\sum_{i=0}^{i=L} h_b(i) log_2 \frac{h_b(i)}{h_f(i)} \tag{4}$$

Where L is the No of Gray intensity level and h_a, h_b, and h_f are normalized histogram of the image a, b and f respectively.

Mean Square Error (MSE) is the square difference between the actual and predicted image.

$$\text{MSE}=\frac{1}{n}\sum(y - \widehat{y})^2 \tag{5}$$

Peak Signal to noise ratio (PSNR)

$$\text{PSNR}= 10\log_2(\frac{MAX^2}{MSE}) \tag{6}$$

Where MAX is maximum pixel value for 8bit image, it is 255.

4. RESULTS AND ANALYSIS

In the results section the Fig. 4 shows the 6 pair of Infrared and visual Images Using IR sensor and Visual Sensor, and Fig. 5 to Fig. 10 are results of features extracted using Gabor filter with different orientation of the filter i.e. 0^0, 45^0, 90^0, 180^0 for the pair of 6 images. The Fig. 11 to

Fig. 16 shows the results of GLCM features like Angular Secondary Moment (ASM), Contrast, Entropy, Correlation, Homogeneity and Variance extracted for the same pair of images.

Fig. 4. 6 pair of Infra Red and Visual Images using IR sensor and Visual sensor

Apply Gabor Filter and extract features for 0^0. Repeat feature extraction for 45^0, 90^0, 135^0 and 180^0

At θ = 135^0 we got output Image which gives best output after fusion. next feature, which is Texture Feature using Grey Level Co-Occurrence Matrix [GLCM].

From given pair of input image, we have now 11 sets of Fused image. In order to find which method is best we are considering Quality Metric like cross entropy. In order to judge which method is better we have consider Cross Entropy, Mean Square Error (MSE) and PSNR. The Table 1 shows the Quality Metric parameter for Gabor filter and Table 2 Shows Quality metric parameter for Gray Level Co-occurrence Matrix.

Fig. 5. Apply Gabor Filter and extract features for 0^0, 45^0, 90^0, 135^0 and 180^0 to first pair of Image

Fig. 6. Apply Gabor Filter and extract features for 0^0, 45^0, 90^0, 135^0 and 180^0 to second pair of Image.

Fig. 7. Apply Gabor Filter and extract features for 0^0, 45^0, 90^0, 135^0 and 180^0 to 3rd pair of Image.

Fig. 8. Apply Gabor Filter and extract features for 0^0, 45^0, 90^0, 135^0 and 180^0 to 4th pair of Image

Fig. 9. Apply Gabor Filter and extract features for 0^0, 45^0, 90^0, 135^0 and 180^0 to 5th pair of Image

Fig. 10. Apply Gabor Filter and extract features for 0^0, 45^0, 90^0, 135^0 and 180^0 to 5th pair of Image

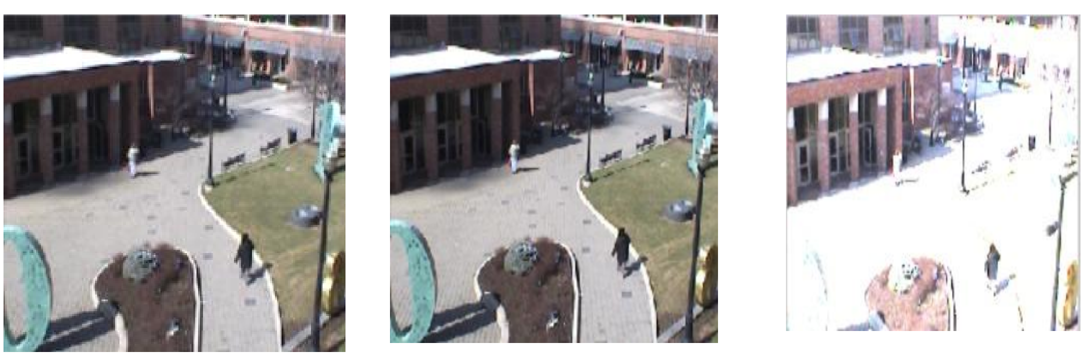

Fig. 11. Apply GLCM and extract features for ASM, contrast, entropy, correlation, homogeneity and variance to 1st pair of image

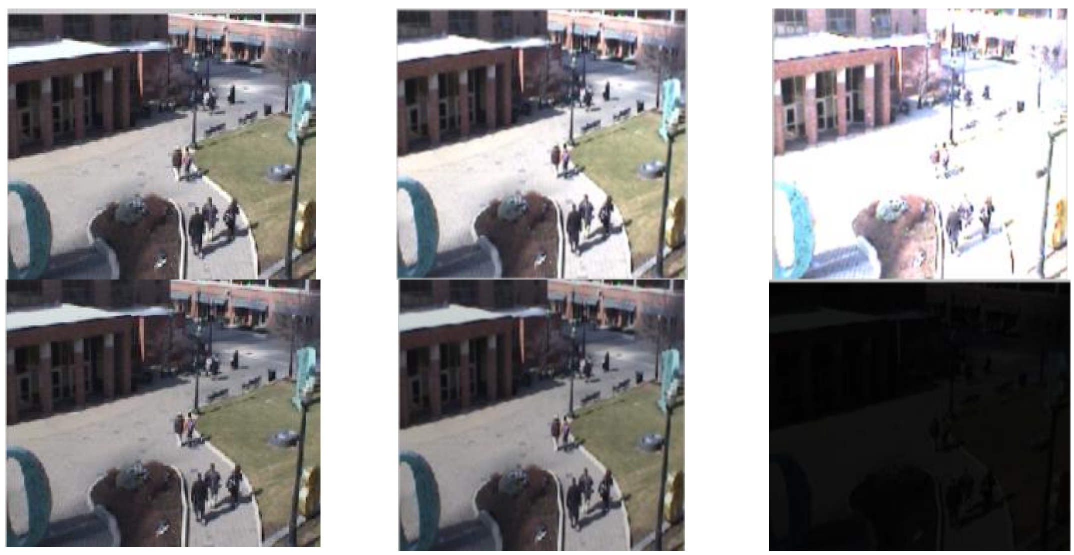

Fig. 12. Apply GLCM and extract features for ASM, contrast, entropy, correlation, homogeneity and variance to 2nd pair of image

Fig. 13. Apply GLCM and extract features for ASM, Contrast, entropy, correlation, homogeneity and variance to 3rd pair of image

Fig. 14. Apply GLCM and extract features for ASM, contrast, entropy, correlation, homogeneity and variance to 4th pair of image

Fig. 15. Apply GLCM and extract features for ASM, contrast, entropy, correlation, homogeneity and variance to 5th pair of image

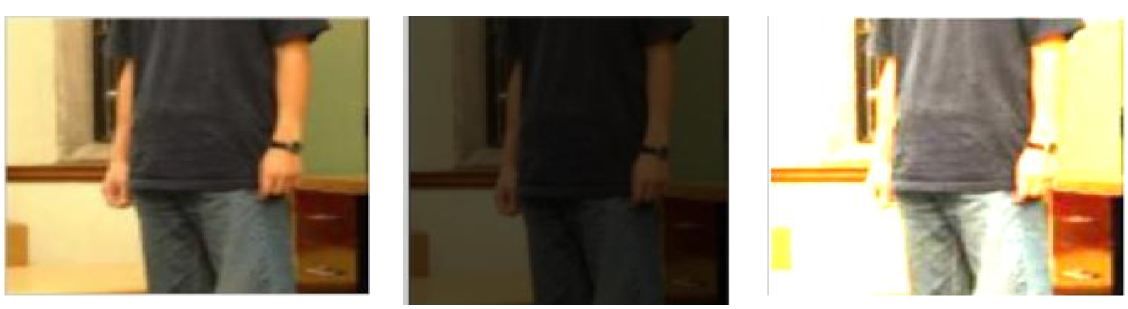

Fig. 16. Apply GLCM and extract features for ASM, contrast, entropy, correlation, homogeneity and variance to 6th pair of image

Table. 1. Quality metric parameter for gabor filter

Image1	**0^0**	**45^0**	**90^0**	**135^0**	**180^0**
Cross Entropy	3.27	2.27	2.76	3.32	2.8
MSE	7O	145	135	7020	12950
	33	53	90		
PSNR	9.6	6.5	6.7	9.8	7.0
Image2	F1	F2	F3	F4	FS
Cross Entropy	2.8	2.9	2.7	3.27	2.8
MSE	12	113	142	7033	12715
	12	14	05		
	6				
PSNR	72	75	6.6	9.6	7.08

Table 2. Quality matrix parameter for gray level co-occurrence matrix

Image 1	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**
Cross Entropy	3.5	3.5	3.7	2.7	3.7	2.9
MSE	44	44	30	1327	2872	1067
	93	93	18	3		4
PSNR	11.6	11.6	13.3	6.8	13.5	7.8
Image 6	F1	F2	F3	F4	F5	F6
Cross Entropy	3.4	3.25	2.9	3.4	3.51	3.007
MSE	52	F2	11	5008	4709	1020
	54	01	42			3
			2			
PSNR	10.3	9.55	7.5	11.13	11.40	8.04

Where F1= ASM, F2= Contrast, F3= Entropy, F4= Correlation, F5= Homogeneity, F6= Variance

5. CONCLUSION

In this paper, from given pair of input image, we have now 11 Sets of fused image. In order to find which method is best we are considering Quality Metric like cross entropy In order to judge which method is better we have consider Cross Entropy, Mean Square Error (MSE) and PSNR. From the results, we arrive as the following conclusion. As already mentioned, feature values are extracted from Gabor filter. For each pair of Visual and IR image, 5 different angles [0^0, 45^0, 90^0, $135^0$and 180^0] of Gabor Filter are used. These features, extracted from Visual and IR image is fused using Stationary Wavelet Transform. Output fused image was subjected to analysis using Quality Metric parameters and the results show "High Cross Entropy and PSNR value for theta $135^{0.}$ Compared to other angles. So we got the cross entropy is 3.32, MSE is 7020 and PSNR is 9.8. A similar study is done for the analysis of texture features GLCM. Where 6 GLCM features are extracted from the pair of Visual and IR Image and images were fused using Stationary Wavelet Transform, Output fused image was subjected to Quality Metric analysis and the results show high value of the quality parameter "Homogeneity". So we got the cross entropy is 3.7, MSE is 2872 and PSNR is 13.5. So we concluded from this comparison that

GLCM is good for feature extraction Method.

ACKNOWLEDGEMENT

The authors express their sincere gratitude to Prof. Supriya patnaik, Vice Chancellor, CUTM and Prof. D N Rao, Vice President, CUTM for giving constant encouragement and support to carry out research at CUTM.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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