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Introduction to Image Fusion in Various Domain

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ABSTRACT

In several situations, the instruments or camera are not able to provide processing information of inputs like high spatial and spectral information both together. However, the reason is either design criteria or some observable restrains. One of the possible solutions for this is image fusion. Recently, a fusion of information from multi images has become a discipline, which demands maximum general information to a various application area. Image fusion is an integral part of applications like computer vision, surveillance systems, medical imaging and security. Image fusion can be done in two domain namely called spatial domain and frequency domain. The spatial methods analyse the signal with respect to time domain while frequency domain analyses signal with respect to frequency. In this survey paper, both the domain has been discussed after performing literature survey. It has been found that frequency domain works better than the spatial domain.

KEYWORDS: *Spatial domain, Frequency domain, Image fusion*

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I. Introduction

In several situations, the instruments or camera are not able to provide processing information of inputs like high spatial and spectral information both together. However, the reason is either design criteria or some observable restrains. One of the possible solutions for this is image fusion [1]. Recently, a fusion of information from multi images has become a discipline, which demands maximum general information to a various application area. Image fusion has been used in various number of image processing applications like computer vision, surveillance systems, Medical Imaging and security. Image fusion is a process where the multi-image taken from either different or same instruments/cameras are integrate into a single composite informative image which can improved accuracy, more specific inference than source images and more suitable for human visual perception. The need of image fusion is to sharpen images, to detect any changes done in the scene, to enhance the information of the image, to surrogate missing information, replacement of faulty data and to improve a quality of the image [2], [3]. Image fusion has become widely popular because of its following advantages [4]:

- It is a low - cost processing.
- It is the easiest method for content interpretation.
- It will work best for identifying an object or recognizing an object.
- In fog images due to image fusion, the quality of images is increased.
- Basically, it boosts the image in all aspect.
- It reduces the data storage.

Image fusion can be done in two domain namely called spatial domain and frequency domain. The Researchers have done lots of research on spatial domain image fusion in which directly research work can be done on pixel value. Principal Component Analysis (PCA), Averaging, Brovey method and Maximum selection has been used by the researchers. But the problem faced with them are: (1) It suffers from spectral distortion (2) Reduces the contras (3) Color distortion [5]. Because of 4 some unavoidable problems found in spatial domain researcher are moving towards the frequency domain. Here the pixel values converted into frequency coefficient then fusion process will be done on it. Finally, inverse transform has been performed to get back spatial information. All transform domain techniques are based on updating the Fourier transform of the image. In frequency domain, Discrete Wavelet Transform, Curvelet Transform, Contourlet Transform, Ridgelet Transform, and Ripplet Transform are introduced gradually which removes problems of spatial domain methods [6].

II. Related Work

Various image fusion methods have been researched by researchers in the era of fusion. Image fusion process can be done in two domain namely spatial domain and frequency domain. In spatial it refers direct image pixel value itself [7]. The pixel values are manipulated to achieve desire output. Spatial domain methods are predominantly useful for straight altering the gray value of a pixel of the image [8]. The manipulation of a pixel has been done to get better resultant informative image [7]. The spatial domain approaches are Averaging, PCA, Weighted averaging, IHS, Brovey methods, Maximum selection etc. The image fusion methods based on multi-resolution transform investigated for this research works include Discrete Wavelet Transform which includes Haar and Daubechies wavelet, Stationary Wavelet Transform, Dual Tree Complex Wavelet Transform, Contourlet Transform, and Ripplet Transform. In the frequency domain, the pixel values converted into frequency coefficient then fusion process will be done on it. Finally, inverse transform has been performed to get back spatial information.

Principal component analysis (PCA) is a method which converts a number of correlated values into uncorrelated values known as the principal component. The PCA is reduces the dimensionality with retaining original visibility of the image. The purpose of the morphological process is to verify the selected pixel by using filling and cleaning operation. These both methods have to be combined with DWT to generate fused image. For LL sub-band PCA techniques are used and for detailed sub-band larger absolute pixel value has been chosen then applying neighborhood morphological process. This method has been examined with pyramid transform and DWT using RMSE, Entropy, Spatial frequency and Image Quality Index [9]. The comparative result shows that different images have a different characteristic like contrast, intensity, noise etc. The simple DWT and methods of pyramid transform are suitable for different characteristic but not with all. This combined method of PCA and morphological processing with DWT overcome this problem.

The major objective of this method is edge detection and fusion. The First decomposition of the input image is done using SWT. It is done at level 1 as well as level 2. At both level edges, information can preserve. Next, both images are fused using spatial frequency measure fusion rule to get complete edge information of fused image. This method can be evaluated using correlation value. This method is compared with DWT, Sobel operator and LoG filter. In all case SWT, with Spatial frequency measure technique gives better correlation and edge information [10]

In this method spatial fusion rule maximum selection has been applied to DTCWT coefficient. In maximum selection, higher pixel values from both images have been chosen. It shows the focus pixel values from the image. Here first DTCWT decomposition has been applied. The formation of coefficient done with fusion rule called maximum selection rule and finally to reconstruct the image inverse DTCWT has applied. This method is compared with DWT using measuring parameters PSNR and NCC [11].The comparative study shows that DTCWT works better than DWT, as DTCWT provides higher directionality than DWT. It is able to preserve edge information and removing the ringing effects. All good results are achieved at the expanse of increasing computations.

When decomposition occurs on input images using CNT, it will provide low frequency sub – band and high frequency sub – band. To perform image fusion, fusion rules have been applied to decomposition coefficients. In this method, two fusion rules are used. On low frequency sub-band local information entropy is applied where a higher value of information entropy is chosen to construct the fused image. On high frequency coefficient,

local average energy is applied to get detailed information. Finally, reconstruction of fused image is done using inverse CNT. This method is compared with other conventional method that's using Contourlet transform [12].
In this method, simple fusion rules are used to generate fused image. The averaging fusion rule which shows the average of the coefficient is used and another fusion rule is the maximum selection. The maximum selection rule is able to identify focused information which is sensitive to human eyes. After applying decomposition of RT, low and high frequency coefficients are generated. As mention above, the fusion rules are used to format coefficients. Finally, inverse RT is applied to reconstruct the image. The quantitative analysis is done by entropy, standard deviation, mutual information, PSNR, RMSE, and spatial frequency [13].

III. Evaluation parameters

Various evaluation parameter has been used to evaluate the performance of image fusion method in spatial domain and frequency domain.

- Root Mean Square Error

Due to the processing on the image, the amount of information stored in each pixel has been changed. To measure the changes occurred on the pixel, Root Mean Square Error (RMSE) can be used [14], [15]. It is an objective parameter which is used as a reference image to measure the performance. RMSE can be measured by the Eq. 1 [16]:

$$RMSE = \sqrt{\frac{1}{SP}\sum_{k=1}^{S}\sum_{l=1}^{P}(R(k,l) - F(k,l))} \quad (1)$$

Here, the size of an image is SxP, R = Reference Image, and F = Fused Image. For better performance of fusion process, RMSE value should be less [16].

- Peak Signal to Noise Ratio

Here in this implementation grayscale images are used. In grayscale image, each pixel value is of 8 bit, in which maximum value is 11111111 that is 255[16]. Peak Signal to Noise Ratio (PSNR) is the objective parameter which is used to measure a noise from an image. We can define PSNR as a ratio of the maximum power of the signal to the power of humiliating noise that has an effect on the reliability of its representation. PSNR can be calculated using Eq. 2:

$$PSNR = 10\, X log_{10} \frac{{f_{max}}^2}{RMSE^2} \quad (2)$$

Here fmax is a maximum grayscale value of an image. For better performance of fusion process, the value of PSNR should be high. The unit of PSNR is decibel (dB) [17, 18].

- Normalized Cross Correlation

Normalized Cross Correlation (NCC) finds the similarities or closeness between the original image and fused image. Generally, it is used for comparing two images. It is widely used for statistical analysis in image fusion processing. The value of NCC is between 0 to +1. NCC can be calculated using Eq. 3 [14, 15]:

$$NCC = \frac{\sum_{k=1}^{S}\sum_{l=1}^{P} R_{kl}F_{kl}}{\sum_{k=1}^{S}\sum_{l=1}^{P} {R_{kl}}^2} \quad (3)$$

Where the size of the image is S x P, R is a reference image and F is a fused image.

- Standard Deviation

Standard Deviation (SD) is used to measure the contrast information from an image. It is an objective measuring parameter which is not using the reference image. It will find out contrast information from fused image so the contrast is increases or decreases that can be measured. This metric is more efficient in the absence of noise. Contrast information can be calculated by using Eq. 4 [19]:

$$SD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{n}(x_i - \mu)^2} \quad (4)$$

Where μ is a mean of an image.

- Entropy

The entropy is used to measure the average information stored in an image. Entropy can straight forwardly imitate the average information contented in an image. When each pixel value of gray level having a same range frequency then maximum entropy can be achieved. According to Shannon's theory, entropy can be measured by the Eq. 5[20]:

$$E = -\sum_{i=0}^{G} P_i \log P_i \quad (5)$$

Here G is a maximum gray level from an image and Pi is a probability of I in an image. The unit of entropy is bits per pixel. If the entropy of fused image is higher than original image it can be said that, fused image contains more information [20].

- Degree of Distortion

The degree of distortion (DD) [21] directly reflects the degree of spectral distortion of fused image. So the value of DD must be small which indicates lesser distortion in the image. The formula for calculating DD is as Eq. 6:

$$DD = \frac{1}{SP}\sum_{k=1}^{S}\sum_{l=1}^{P}|F(k,l) - R(k,l)| \quad (6)$$

Here the size of the image is S x P, F is fused image and R is the reference image.

IV. Comparative Study

After performing literature survey on spatial domain and frequency domain it has been found that frequency domain works better than the spatial domain. Frequency domain can protect against the various attacks, because it can work with frequency coefficient not with direct pixel value. Below table shows the difference between spatial domain and frequency domain.

Spatial domain	**Frequency domain**
It works with direct pixel value	It works with frequency coefficient value
Computation cost is less	Computation cost it high
Time complexity is less	Time complexity is high
It has fragile Robustness	It provides higher robustness
Poor performance against the various type of attacks like paper salt attack, compression attack etc.	Better performance against the various type of attacks like paper salt attack, compression attack etc.

V. Conclusion

Image fusion process can be done in two domain namely spatial domain and frequency domain. In spatial it refers direct image pixel value itself. The pixel values are manipulated to achieve desire output. Spatial domain methods are predominantly useful for straight altering the gray value of a pixel of the image. The manipulation of a pixel has been done to get better resultant informative image. In general, the researchers have done lots of research on spatial domain image fusion in which fusion process is performing directly on pixel value. But the problem faced with them are: (1) It suffers from spectral distortion (2) Reduces the contras (3) Color distortion. So research move towards the frequency domain. In the frequency domain, the pixel values converted into frequency coefficient then fusion process will be done on it. Finally, inverse transform has been performed to get back spatial information. Hence frequency domain works better compare to the spatial domain. After performing literature survey and basic implementation n both domain, it has been found that frequency domain works better for image fusion.

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