Fusion of images using DWT and fDCT methods

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Abstract - *Image fusion methods has played an important role in the development of extracting inherent image information. The applications of image fusion are considered in fields pertaining to medical imaging, military applications, commercial applications and satellite imagery. This necessitates the development of more robust and effective image fusion techniques. However, when it comes to practicality of these techniques such as noise considerations (AWGN based channel noise, etc.), many these methods suffer limitations. In this paper, two stages are considered, the first stage consists of pre-processing where the Gaussian noise is considered along with the removal of noise using median based filtering approach. The second stage consists of image fusion using DWT and fDCT based methods. A comparative analysis is performed of the two methods. Image quality assessment concerning measures such as PSNR, SNR, SSIM, MAE, Gradient and standard deviation were performed. It was observed that the fDCT based image fusion method performed with comparatively higher measures than the DWT given the similar initial conditions. Experimental results show that the coefficients considering the scale and orientation of fDCT provides a higher accuracy than compared to coefficients obtained from DWT method.*

***Key Words*: Gamma correction, DWT, fDCT, Median Filtering, Gaussian noise,static filtering, fDCT wrapping.**

1. INTRODUCTION

Image fusion plays a significant role in many of pre-sent's day's applications ranging from military applica-tions, healthcare industries, satellite imagery and wireless systems. The requirement of effective and robust techniques for the process of fusion of image is more than necessary in present day's scenario. Some of the applications in medical image fusion include detection and diagnosis of modular related disorders and conditions. In military applications, image fusion helps in identifying enemy intrusion through advanced surveillance system.

However, a major limitation observed in the process of image fusion is that of practicality in real time applications. In the context of wireless systems, the data undergoes transmission stage, channel and receiver stages where it encounters many types of noise and its effects. For example, in the transmission stage, during the sampling and quantization, the image is affected by what is known as aliasing and quantization noise which is caused due to sampling errors. When it sent for the encoding process, the image is affected by certain noise. When the data is transmitted through a channel, the image is affected what is known as Additive White Gaussian Noise (AWGN) which alters the characteristics of the image significantly.

Another major limitation is that of the illumination is caused due to short dynamic range that results from the type of image acquisition device. Many methods for im-age enhancement considering the spatial domain is pro-posed, however, in the context of image fusion, the scope of image enhancement remains to be dealt with. Image fusion methods considering the noise factor and the illumination conditions are limited which otherwise has a greater scope of applications and significance.

Methods of image fusion mainly involve temporal based methods which applies imaging techniques on a time se-ries domain. The implication of transformation function such as Discrete Wavelet Transformation (DWT), Curve let transformation, etc are yet to be explored in the context of image fusion.

It is observed that, though there are many methods which are available in the context of image fusion, the practicality associated with these techniques are very li-mited. Hence in the proposed work, image fusion tech-niques are implemented considering the aspects of image illumination and noise factors of the image. A comparative analysis is performed based on the two methods proposed in the previous section.

The paper is structured as follows; the first section deals with the introduction which signifies the importance and the limitations pertaining to image fusion methods. The second section deals with the literature survey, the third section deals with the proposed system and implementation. The fourth section deals with the results and discussions followed by conclusion.

1.1 LITERUTURE SURVEY

Image fusion is a process of combining relevant informa-tion of images into single image information in view to enhance the image quality assessment. Deepak Kumar et. al [1] proposes a generalized techniques that are involved in image fusion process. Some of the methods mentioned in this paper are averaging method, principal component analysis and discrete wavelet transformation (DWT) to name a few. A comparative analysis is also performed re-garding the significance and limitations of each method in view of the image quality.

Y. Zhang et. al [2] performed a study in understanding the process of image fusion along with its significance and limitations. Among the various image fusion techniques, the significant techniques involve HIS (Intensity, Hue and Saturation) based image fusion, PCA (Principal Component Analysis) based image fusion arithmetic combinations and wavelet fusion. Major limitations in these methods involved variations in parameters concerning spherical distribution, band combination and colour distortion problems. Hence, there is a requirement to enhancement the quality of the image.

Harry N Gross et. al [3] proposed an application involving the improvement of image enhancement by considering a spectral mixture analysis and image fusion techniques. The spectral mixture analysis is performed to obtain higher spatial accuracy which is implemented through conventional unmixing to generate fraction images. Further fusion methods are implemented to combine the spectral and spatial images to form a single image which provides more information to the user.

Methods of evaluation for to assess the performance of image fusion techniques was proposed by Alparone et. al [4] concerning the multispectral high resolution pan chromatic images, The radiometric and distortion measurements which are observed in the pan images are encapsulated in a specific measurement which accounts for factors such as variation in contrast, mean bias and spectral distortion. Comparitive analysis is performed among different image fusion methods using this quality assessment metrics.

M. Gonzalez et. al [5] proposed a new method involving fusion of multispectral and panchromatic images using IHS and PCA based methods which is performed on a wavelet based decomposition technique. The image is first decomposed using the wavelet transformation to extract the detail coefficients which is then processed using IHS and PCA methods which consecutively merges both spectral and spatial aspects of the image leading to higher resolution of the image. Experimental results showed that when using undecimated algorithm is used in wavelet transformation, improved performance in the methods was observed.

Myungjin Choi [6] proposed a new method involving IHS based image fusion, the significance of this method was to fuse massive amount of images which are obtained from the satellite images, further a trade-off is performed between the spectral and spatial aspects of the image to improve the image quality assessments. The significance of this approach is easy and fast implementation of the image fusion process.

C. Pohl and J. L Van Genderen [7] performed an evaluation on the different methods involving image fusion along with its possible applications. The methods of image fusion in this works mainly involve pixel based image fusion. The geometric correction of the image data concerns factors such as geometric model, ground control points, digital evaluation model and resampling methods. The objectives of image fusion involves sharpening of images, improving the geometric corrections and enhancing features not visible in a single data alone. Another aspect observed in this work is the significance of band selection and its role in the image fusion process.

Yoonsuk Choi and Shahram Latifi [8] performed a review on the different image fusion techniques for satellite im-ages. The main focus of the work is the reviewing of the background of the transformation theory, analysis of standard colours and contour-let based schemes, hybrid schemes and wavelet transformation based schemes. Of these methods, the wavelet transformation based image fusion produced improved results in context of standardization and minimization of colour distortion. This inturn has better performance as compared to IHS and PCA based methods. This is further signified in the following work.

Krista Amolins et. al [9] performed a study of applications of image fusion considering the wavelet based transformations. It was observed that the standard image fusion methods such as IHS and PCA based methods that though the spatial information is improved in the image information, the colour distortion was produced which significantly deteriorates the quality of the image data. Various methods of wavelet based transformation was applied for image fusion process and it was observed that even the simplest of wavelet based image fusion produced improved quality of performance in the context of image quality assessment as compared to the standard methods of fusion techniques such as IHS and PCA. This is especially prevalent in panchromatic satellite imagery.

Myungjin Choi et. al [10] emphasied the use of curvelet transformation for image fusion. A comparative analysis was compared to other standard methods such as IHS, PCA and wavelet based methods. The main objective of image fusion was to obtain good details of the spectral and spatial information of the image data. However, the DWT method produced better accuracy in the context of spatial information by representing the edges. The proposed curvelet transformation resulted in better accuracy in terms of representing the edges in the image which further improved the accuracy of the image spatial information.

Filippo Nencini et. al [11] proposed an image fusion me-thod using curvelet based transformation considering the panchromatic images. First, the directional detail edge coefficients were derived which further soft thresholded to reduce the noise. It was observed that the noise reduction was better when compared to Discrete Wavelet Transformation (DWT). Experimental results showed an improved result in image quality such as image sharpening and reduction in local inaccuracies.

1.2 PROPOSED SYSTEM

The proposed system is basically divided into three modules involving pre-processing, image fusion using Discrete Wavelet Transformation and image fusion using Discrete Curvelet Transformation. The pre-processing stage consists of addition of noise and noise removal me-thod. The fusion method concerning the DWT considers the image fusion method based on the haar wavelet and the daubechies basis function, and finally the curvelet based method considers the wrapping and usage of 2nd order static filter for fusion of image.

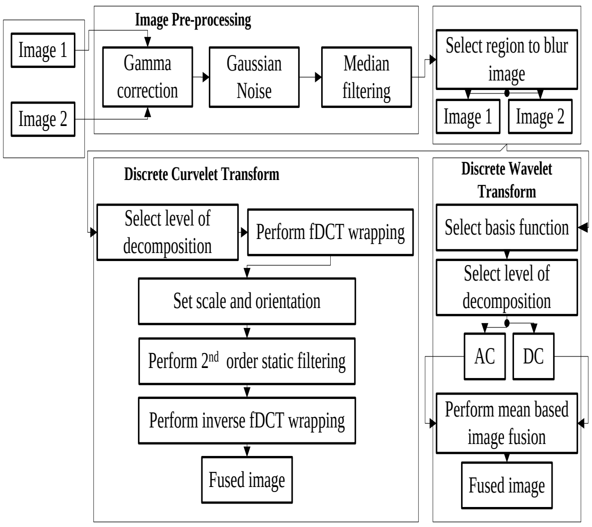

Fig 1: block diagram of proposed System Architecture

The functionalities mentioned above will have an in depth analysis with respect to its working. This is given as follows.

a. *Pre-processing*

As mentioned in the previous section, the pre-processing stage consists of two stages involving image enhancement and noise removal process. The image enhancement is performed using gamma correction method which is based on spatial based image enhancement having an adjusting parameter of gamma factor that depends on the image considered. The gamma correction method is given as follows,

$$I\ (x, y) = T\ [f(x, y)] \quad (1)$$

Where, I (x, y) → input image,
T(x, y) → transformed image

The gamma correction method considering the transformed image is given as,

$$f(x, y) = (f(x, y))^{\gamma} \quad (2)$$

Where, γ → gamma factor

Once, the image is enhanced, it is further processed considering the noise removal process, the noise considered in this context is the Gaussian noise, which reflects the channel noise (Additive white Gaussian Noise: AWGN) that is prevalent in the wireless communication system. The characteristic observed in the Gaussian noise is an implicit random distribution of high intensity values (1's and 0's) which makes distorts the respective histogram of the image. The Gaussian noise distribution considered is given in eq. X as follows,

$$I_{GN}(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad (3)$$

Where,
z→ gray level of the image
μ → Mean value
σ → Standard deviation

The filtering method considered in this context is the median filter (also known as the averaging filter). The significance of median filtering is its ability to preserve the edges in an image while maintaining minimum system and computational complexity. The median filter calculates the median which is obtained from the defined pattern from the adjacent pixels in numerical order, consequently the computed median value is replaced with the middle pixel value. The size of mask considered in this filter is of order 3 X 3 which is given as follows,

$$mask = \begin{bmatrix} 0.11 & 0.11 & 0.11 \\ 0.11 & 0.11 & 0.11 \\ 0.11 & 0.11 & 0.11 \end{bmatrix}$$

b. *Discrete Wavelet Decomposition*

In the decomposition stage, a preferable technique used in decomposition stage is the Discrete Wavelet Transformation (DWT), the selection criteria for DWT was based on its computational efficiency, practicality and simplicity.

The pre-processed image data is further multiplied with the basis function considering the 'haar' and the 'db4'. This results in two types coefficients mainly derived from low pass filter and the high pass filter known as Approximation Coefficients (AC) and the Detail Coefficients (DC) respectively. The decomposition is performed up to 3 level, however, this parameter could be adjusted considering the nature of image. The image fusion method considered in this context is the mean based image fusion. In this method, the mean of AC components of two images is performed, along with computing the mean of DC components of two images, upon reconstruction of the image (considering the updated AC and DC components) using the inverse DWT, the fused image is obtained.

c. Fast Discrete Curvelet Transformation (fDCT)

The pre-processed image is first transformed into real valued curvelet components, the probabilities for the curvelet at the finest level is type wavelet. The number of scales considering the coarsest wavelet level is given in eq. X as shown below,

$$nb = \log_2(\min(m, n)) - 3$$

The number of angles st the 2nd coarsest level considering a minimum of 8 must be a multiple of 4. The obtained curvelet coefficients consists of two types mainly 'sine' and 'cosine' components in the case of real valued curvelet components which is present in the first two quadrants and the last two quadrants respectively. The scaling is performed on the integer varying from finest to coarsest scale, and the orientation (angle) varies from top-lest corner and increases clockwise.

At level 3 decomposition the scaled and oriented curvelet components are sent to the 2nd order static filtering which controls the way the matrix boundaries are added, This method is considered equivalent to the structuring element used in the morphological operations. The number of 1's (considering the pixel intensities) in the image is considered for which zeros and ones are padded considering symmetry. Finally an inverse fDCT wrapping is performed to reconstruct the fused image using the curvelet components post filtering process.

2. RESULTS AND DISCUSSIONS

This section deals with the obtained simulation results along with its description and significance with respect to the project. The parametric evaluations along with its description are also mentioned in this section.

The pre-processing stage in the proposed system consists of image enhancement using gamma correction and noise removal process using the median based filtering method. The pre-processed image is measured by two measures namely Peak Signal to noise Ratio (PSNR) and Signal to Noise Ratio (SNR).

***Peak signal to noise ratio (PSNR)**:* Peak signal-to-noise ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale.

Signal to Noise Ratio (SNR): Signal-to-noise ratio is defined as the ratio of the power of a signal (meaningful information) and the power of background noise (unwanted signal)

$$SNR = \frac{P_{signal}}{P_{noise}}$$

Where, P is average power. Both signal and noise power must be measured at the same and within the same system bandwidth.

Structural Similarity Index (SSIM)

The structural similarity (SSIM) index is a method for predicting the perceived quality of digital television and cinematic pictures, as well as other kinds of digital images and videos. SSIM is used for measuring the similarity between two images. The SSIM index is a full reference metric; in other words, the measurement or prediction of image quality is based on an initial uncompressed or distortion-free image as reference.

$$SSIM(x, y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

Where, μ_x → average of x

μ_y → Average of y

σ_x^2 → Variance of x

σ_y^2 → Variance of y

σ_{xy} → Covariance of x and y

c_1, c_2 → stabilization of division with weak denominator

Mean Absolute Error (MAE): It is defined as the measure of two continuous variables which is given as follows,

$$MAE = \frac{\sum_{i=1}^{n}|y_i - x_i|}{n}$$

It is also measured as the average vertical and horizontal distance between each point Y-X.

Measures of analysis for image fusion method,

1. Standard deviation: The standard deviation is used to measure the amount of variation which gives an estimate of the range of values that is prevalent in the image data. It also gives an estimate of the validity of the population which is used to derive statistical conclusions.

The overall observations for the images considered are given in the following table X as shown below for controlling parameter as given in table 1

Table -1: controlling parameter

sl.no	parameter	value
1.	Gamma factor	0.71
2.	Noise scaling	2
3.	compression scaling	0.62
4.	image size	245 X 428

Table 2: Observations for DWT based image fusion

sl.no	Image	PSNR	SNR	SSIM	MAE	Std. Dev.
1.	Image_1	30.33	25.40	1.4	0.95	58.12
2.	Image_2	27.20	17.92	7.3	0.86	63.15
3.	Image_3	35.85	31.35	0.46	0.989	46.10
4.	Image_4	30.56	24.14	2.95	0.899	65.82
5.	Image_5	34.84	28.94	0.65	0.98	48.56
6.	Image_6	36.24	32.20	0.518	0.98	51.45
7.	Image_7	36.30	31.76	0.53	0.98	73.53
8.	Image_8	37.8	32.28	0.294	0.992	65.82
9.	Image_9	34.06	29.17	0.782	0.97	54.48
10.	Image_10	36.25	32.78	0.429	0.990	67.80

Table 3: observations for fDCT based image fusion

sl.no	Image	PSNR	SNR	SSIM	MAE	Std. Dev.
1.	Image_1	32.66	27.68	1.25	0.97	58.15
2.	Image_2	25.63	16.35	7.9	0.83	63.15
3.	Image_3	37.25	32.74	0.368	0.993	43.03
4.	Image_4	25.91	19.49	4.925	0.754	63.17
5.	Image_5	36.05	30.15	0.56	0.98	47.92
6.	Image_6	37.30	33.27	0.32	0.99	51.42
7.	Image_7	39.05	34.50	0.24	0.99	73.53
8.	Image_8	39.71	34.17	0.226	0.994	63.17
9.	Image_9	36.90	32.01	0.474	0.99	54.45
10.	Image_10	35.10	31.63	0.380	0.991	66.80

3. CONCLUSIONS

The overall proposed method for image fusion method involves mainly pre-processing, image fusion using DWT and fDCT methods and a comparative analysis of the two methods. Image quality assessment concerning measures such as PSNR, SNR, SSIM, MAE, Gradient and standard deviation were performed. It was observed that the fDCT based image fusion method performed with comparatively higher measures than the DWT given the similar initial conditions. Therefore, the inference can be made that the coefficients considering the scale and orientation of from fDCT provides a higher accuracy than compared to coefficients obtained from DWT method.

In future works, more image fusion techniques could be considered for a variety of applications ranging from medical diagnostics to satellite imagery. Practicality of the techniques could be tested on real time imaging data to test the feasibility, performance and robustness of the image fusion techniques, finally different methods of obtaining the coefficients for image fusion could be identified which leads to more effective methods of image fusion given for a particular type of image.

ACKNOWLEDGEMENT

I am highly obliged to Department of Electronics and communication Engineering, SDM College of Engineer-ing and Technology.

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BIOGRAPHIES

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