International Journal of Engineering and Applied Sciences (IJEAS)
ISSN: 2394-3661, Volume-4, Issue-10, October 2017

Comparative study of Image Fusion Methods: A Review

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***Abstract*— As the size and cost of sensors decrease, sensor networks are increasingly becoming an attractive method to collect information in a given area. However, one single sensor is not capable of providing all the required information,either because of their design or because of observational constraints. One possible solution to get all the required information about a particular scene or subject is data fusion.. A small number of metrics proposed so far provide only a rough, numerical estimate of fusion performance with limited understanding of the relative merits of different fusion schemes. This paper proposes a method for comprehensive, objective, image fusion performance characterization using a fusion evaluation framework based on gradient information representation. We give the framework of the overall system and explain its usage method. The system has many functions: image denoising, image enhancement, image registration, image segmentation, image fusion, and fusion evaluation. This paper presents a literature review on some of the image fusion techniques for image fusion like, Laplace transform, Discrete Wavelet transform based fusion, Principal component analysis (PCA) based fusion etc. Comparison of all the techniques can be the better approach for future research.**

***Index Terms*— Laplace transform, Wavelet transform based fusion**

I. INTRODUCTION

Image Fusion is the formation of resultant image from a set of images into a single image, where the resultant fused image will be more informative and complete than any of the input images. This techniques can improve the quality and increase the application of these data. It fuses several images from different image sensors in order to obtain a new image that contains more information and has more positive image description to the same scene. Two images taken in different angles of scene sometimes cause distortion. Most of objects are the same but the shapes change a little. At the beginning of fusing images, we have to make sure that each pixel at correlated images has the connection between images in order to fix the problem of distortion; image registration can do this. Two images having same scene can register together using software to connect several control points. After registration, resampling is done to adjust each image that about to fuse to the same dimension. After resampling, each image will be of the same size. Several interpolation approaches can be used, to resample the image; the reason is that most approaches we use are all pixel-by-pixel fused It introduces pixel level fusion, feature level and decision leve techniques . Pixel level fusion gives detail information of image that cannot be brought by other level. It requires largest amount of information as shown in figure 1.

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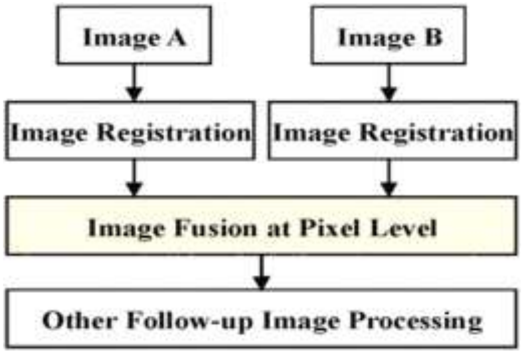

Figure 1. Structure of image fusion at pixel level

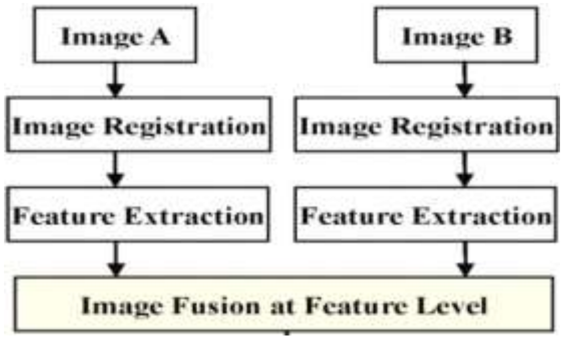

Figure 2. Structure of image fusion at feature level

Feature level is the middle level . It not only retain the sufficient important information but also compresses the information. So it is beneficial to real time processing. As shown in figure 2

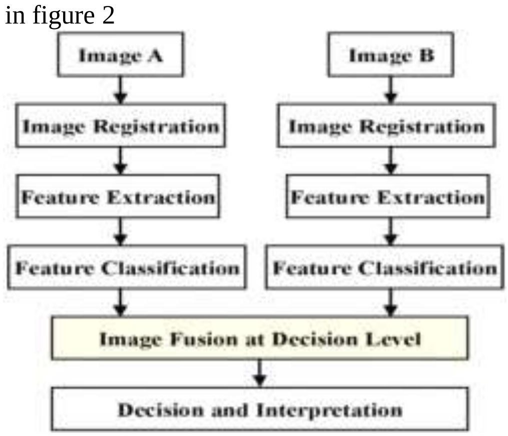

Figure 3. Structure of Decision-level image fusion

Decision level is the highest level fusion and the most complex. There is lower requirement of image registration in decision level fusion even without considering as shown in figure 3.

II. SINGLE-SENSOR IMAGE FUSION SYSTEM

A single sensor image fusion system is shown in Figure1. The sensor shown could be a visible-band sensor such as a digital camera. This sensor captures the real world as a sequence of images. The sequence is then fused in one single image and used either by a human operator or by a system to do some task. For example in object detection, a human operator searches the scene to detect objects such intruders in a security area maintaining the Integrity of the Specifications.

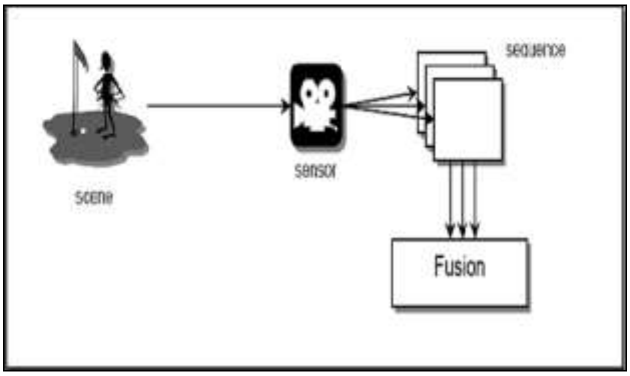

Figure 4: Single sensor image fusion system

This kind of systems has some limitations due to the capability of the imaging sensor that is being used. The conditions under which the system can operate, the dynamic range, resolution, etc. are all limited by the capability of the sensor. For example, a visible-band sensor such as the digital camera is appropriate for a brightly environment such as daylight scenes but is not suitable for poorly situations found during night, or under conditions such as in fog or rain.

III. MULTI- SENSOR IMAGE FUSION SYSTEM

A multi-sensor image fusion system overcomes the limitations of a single sensor fusion system by combining the images from these sensors to form a composite image. Figure 5 shows an illustration of a multi-sensor image fusion system. In this case, an infrared camera is being used the digital camera and their individual images are fused to obtain a fused image. This approach overcomes the problems referred to single sensor image fusion system, while the digital camera is appropriate for daylight scenes; the infrared camera is suitable in poorly illuminated ones

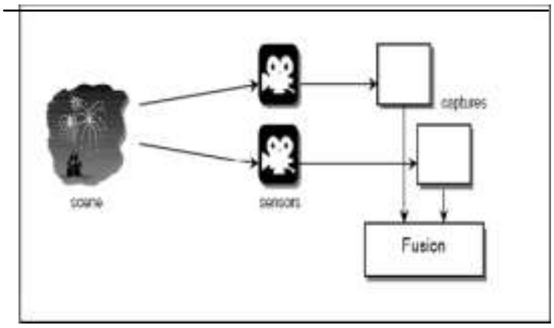

Figure 5: Multi -Sensor Image Fusion System

Multi sensor image fusion system has various advantages as:

- Extended range of operation.
- Extended spatial and temporal coverage
- Reduced uncertainty.
- Increased reliability.
- Robust system performance.
- Compact representation of information.

IV. FUSION TECHNIQUES

This section describes the methods that are use for image fusion also gives literature survey of these techniques.

1. Laplacian pyramid represents the edge of the image detail at every levels, so by comparing the corresponding Laplace-level pyramid of two images, it is possible to obtain the fused image which merge their respective outstanding detail, and makes the integration of the image retaining the amount of information as rich as possible. The source image is decomposed into a series of resolution spaces, and how to choose integration factor and fusion rule will directly affect the final quality of fused image [2,3]. Generally speaking, there are two fusion methods: the pixel-based and region-based. Though pixel-based method is simple and has less computation, the performance is poor. Because the local characters of an image are not dependent each other, there are more relationships among one pixel with its neighbors. So we designed the fusion operators based on the region method. The principle is as shown in Figure6.

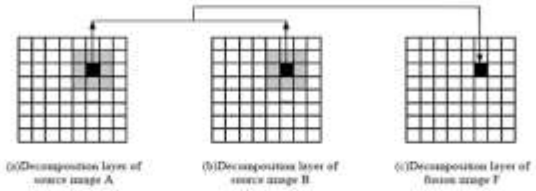

Figure 6: Fusion Strategy Based Region

The important issue for image fusion is to determine how to combine the sensor images. In recent years, several image fusion techniques have been proposed [1].The important fusion schemes perform the fusion right on the source images. One of the simplest of these image fusion methods just takes the pixel- by-pixel gray level average of the source images. This simplistic approach has disadvantage such as reducing the contrast. With the introduction of pyramid transform, it was found that better results were obtained if the fusion was performed in the transform domain. The pyramid transform appears to be very useful for this purpose. The basic idea is to perform a multi resolution decomposition on each source image, then integrate all these decompositions to form a composite representation, and finally reconstruct the fused image by performing an inverse multi-resolution transform Several types of pyramid decomposition or multi-scale transform are used or developed for image fusion such as Laplacian Pyramid, with the development of wavelet theory, the multi-scale wavelet decomposition has began to take the place of pyramid decomposition for image fusion. The wavelet transform can be considered to be one special type of pyramid decompositions. It retains most of the advantages for image fusion.

Tian Hui [11], introduces the three basic levels of image fusion which are pixel level, of feature level and decision level fusion, and then compares their properties and all other aspects. Later they describes the evaluation criteria of image fusion results from subjective evaluation and objective evaluation two aspects. According to the quantitative evaluation of the image fusion results and quality, this text uses and defines multiple evaluation parameters such as fusion image entropy, mutual information, the average gradient, standard deviation, cross-entropy, unite entropy, bias, relative bias, mean square error, root mean square error and peak SNR, and establishes the corresponding evaluation criteria. Further concludes that in the subjective evaluation of image fusion, visual characteristics, psychological status, and cultural background, environmental conditions all will have a significant impact on the evaluation results, so an objective evaluation criteria was established. They also established quantitative evaluation methods and criteria of the multi-sensor image fusion performance and quality are objective, reasonable and effective. The establishment of the evaluation methods and criteria has important meaning for the further in-depth expansion of the multi-sensor image fusion research

W. Wang [14], presents an algorithm for multi-focus image fusion, which uses a multi-resolution signal decomposition scheme called Laplacian pyramid method. They introduced the principle of Laplacian pyramid transform. The method mainly composed of three steps. Firstly, the Laplacian pyramids of each source image are deconstructed separately and then each level of new Laplacian pyramid is fused by adopting different fusion rules. To the top level, it adopts the maximum region information rule; and to the rest levels, it adopts the maximum region energy rule. Finally, the fused image is obtained by inverse Laplacian pyramid transform. Two sets of clock images are applied to verify the fusion approach which compares standard deviation, average gradient, entropy, with the various methods of fusion such as wavelet transform, average method and maximum method. Experimental results shows that Laplacian pyramid methods performs well as compared to above methods, as the indicator value.

M.Pradeep [7], presents an approach to implement image fusion algorithm using Laplacian Pyramid. This technique implements a pattern selective approach to image fusion. The basic idea is to perform pyramid decomposition on each source image and finally reconstruct the fused image by performing an inverse pyramid transform. . The aim of image fusion, apart from reducing the amount of data, is to create new images that are more suitable for the further image processing task such as segmentation object detection etc .This work offers like benefits like resolution S/N ratio, and pixel size. The result is shown by two clock images.

K.Wu et al.[17], introduces the concept of the image fusion using different levels of information abstraction can be divided into three levels: Pixel-level fusion, Feature-level fusion and Decision-level fusion. Pixel-level image fusion is the lowest level of image fusion, which feature-level image fusion and decision making level image fusion is based on and the highest level of accuracy of data fusion can be provided .At the level it have the details on the information which other levels do not have. Feature-level image fusion belongs to the middle level, which extractions the raw feature information from various sensors at the first, and then analysis and processes features information comprehensively. Decision-level image fusion is a high-level fusion, which provides the basis for the command and control decision-making with its results. It gives the concept and levels division of image fusion and introduces the commonly used pixel-level image fusion method and found that pixel level method is best for dependence of sensor, detection of performance ,information loss, and provides maximum amount of information than feature level and decision level.

S.Yun. et al., [8],proposes an image enhancement method base on laplacian pyramidal framework that decomposes an image into band pass to improve both global contrast and local information . this algorithm is compares with image enhancement using histogram algorithm, Contrast limited adaptive histogram algorithm, Bright preserving BI_histogram algorithm ,Recur sing mean Separate histogram, automatic and parameter free piecewise linear transformation, Gain controllable clip histogram equalization and found that laplacian method gives better results for images like airplane, lenna ,monkey.

N.INDHUMADHI, et al.[20], Presents Laplacian and Wavelet transform using spatial frequency and introduces the decomposition of image using 2D-DWT,the new sets of image are added to get new fused coefficient and finally inverse DWT with coefficient to construct the fuse image. Four parameter namely RMSE,PSNR, SPEED of fusion were used. Different images like Clock, Pepsi, Weapon Medical, Satellite, Navigation survelliance, are used. Later compares the laplacian pyramid and wavelet base fusion shows that Laplacian pyramid fusion with spatial frequency based wavelet produce quality image with good visual clarity.

2. Wavelets and Multi-resolution Processing:
The most common form of transform type image fusion algorithms is the wavelet fusion algorithm due to its simplicity and its ability to preserve the time and frequency details of the images to be fused.

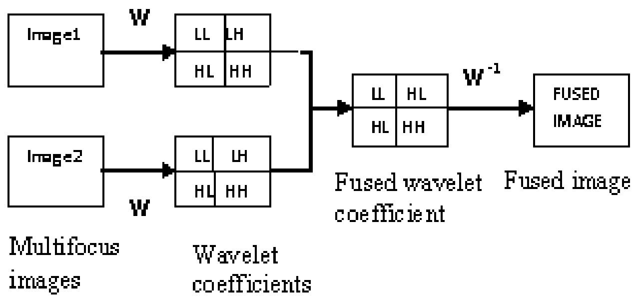

Figure 7: Block diagram of Wavelet Transform.

Wavelets are the foundation for representing images in various degrees of resolution. The wavelets were first shown to be the foundation of powerful new approach to signal processing and analysis called multi-resolution theory. Multi-resolution theory is concerned with the representation and analysis of images at more than one resolution.[12]

Z. Wang [13], introduced the principles of image fusion at the level of pixel, feature, and decision. They describes the design rules and steps of Graphical User Interface (GUI). Image fusion system based on GUI is then designed and the system has many functions: image denoising, image enhancement, image registration, image segmentation, image fusion and fusion evaluation. Match Measure rules are use for fusion, multi wavelet based algorithm gives superior performance for image fusion than traditional scalar wavelet.

D.Godse, et al [1],proposes wavelet base image fusion pixel base maximum selection rule algorithm. The two same source images are used at different angles to decompose in rows and columns by filtering and subsequent down sampling at each level. Pixel approximation algorithm on source image gives maximum value of binary decision map is formulated and concatenation of fuse approximation and gives new coefficient matrix. Then inverse wavelet transform is applied to reconstruct the resultant image. Wavelet provide a framework in which an image is decomposed, with each level corresponding to a coarser resolution band. The wavelet sharpened images have a very good spectral quality. Wavelet transform is preferred over Fourier transform and short time Fourier transforms since it provides multi- resolution. The spatial quality of the sharpened images varies based on the data used for sharpening. There is a need to investigate with different combination models in the wavelet domain to make the wavelet-based systems more robust spatial quality.

H.Gao, et al. [18],describes the algorithm of image fusion based on wavelet transform. Image fusion technology has started to become one of the focuses in the remote sensing image processing and analysis. Of remote sensing image fusion, the purpose is of sharpening the image, to improve the geometric correction and color correction, to improve the classification of features to make up lost in some kind of image data, and detection/observation earth environment changes. Fusion method adopted in this period includes HIS transform, average, weighted average, differential ratio, and Principal Component Analysis, high-pass filtering. These methods during the fusion process do not participate in the integration of image decomposition and transformation; fusion is only done at a lower level.

S. Huang.[3],proposes number of different fusion schemes of two fusion applications: the panchromatic (PAN) and multispectral (MS) image fusion and multi-focus image fusion. In the former application, the object of image fusion is generating a new image that enjoys the high-spatial resolution of the PAN images and the color information of the MS image. Schemes includes the intensity-hue-saturation (IHS) fusion scheme, principle component analysis (PCA) fusion scheme, discrete wavelet transform (DWT) fusion scheme and IHS-DWT hybrid scheme are introduced. We have concluded in experimental results that the PCA scheme outperforms the IHS scheme while IHS-DWT scheme has the best performance because its spectral distortion is minimal. In another application, the object of image fusion is collect the all the objects in focus from several CCD images of the same scene. Since the input image are gray-level, and thus only the DWT scheme is suitable. However, there are numerous fusion rules for merging the DWT coefficients of the input images. A fusion rules includes the choice of an activity-level measurement and the choice of a coefficient combing method. It has been shown in simulation results that CBA is the best activity-level measurements, and choose-max (CM) is the best method for combining approximation coefficients while weighted average (WA) and adaptive WA (AWA) are good for combing detail coefficients.

Dong-Chen He [9], presents a method of fusion, capable of combining a high resolution image with allow resolution image with or without any spectral relationship existing between two images. Preserving the spectral aspect of the low resolution image while integrating the spatial information of the high resolution image. The low resolution image is a color image, it can fuses individually each of the three components (red, green and blue) with the high resolution image and then obtain a new fused color image. In this fashion, all the images can be fuses to low resolution color image with a high resolution image. The new proposed method is an innovative and unique technique in its own right, because the most widely used methods in these areas are highly limited by two inconveniences such as three or more low-resolution images must be fused with a high spatial resolution image and the fused images do not preserve faithfully the colors of the original images.

Y.Zheng, et al. [4]presents a image fusion method, advanced DWT (aDWT), which incorporated PCA (principle component analysis) and morphological processing into a regular DWT fusion procedure. They compares the image fusion performance of six common methods (five pyramid methods and a regular DWT method) and our novel method based on four important quantitative measures − the root mean square error (RMSE), the entropy, the spatial frequency and the image quality index. Overall, across the four different kinds of imagery, the aDWT performed the best. Different image sources vary considerably in their intensities, contrast, noise, and intrinsic characteristics; therefore a big challenge for a fusion algorithm is to perform well across a variety of image sources, thus a DWT is a very promising method to meet this goal.

J. Gao,et al.[19],introduces the integration scheme base on image enhancement, and presents a fusion method with the wavelet image enhancement technology. they first enhances the source images according to wavelet image enhancement techniques, and then use the appropriate fusion rule to integrate the coefficients of the original images and the enhanced images. The proposed algorithm based on wavelet enhancement, has larger values of the fusion image entropy, standard deviation than the general method without using of wavelet enhancement. Entropy and standard deviation is increasing, indicating that the integration based on wavelet enhancement can broaden the image intensity distribution, increase the amount of information, and dig the hidden information into the fused image to the maximal extent. Although the clarity of the wavelet enhanced fusion image is less than the image obtained without using of wavelet enhancement, but the wavelet enhanced fusion image has better overall result. Whether from the aspect of objective criteria or visual effect, the proposed fusion algorithm based on wavelet enhancement is better than the algorithm without enhancing the original images.

S. Krishnamoorthy,et al. [5],presents eleven image fusion techniques implemented using Microsoft Visual C++ 6.0. The fusion was performed on twelve sets of input pair of medical images. The fused images were verified for their quality based on a perfect image in each of the sets. A set of nine image metrics were implemented to assess the fused image quality. The fused images of each set were also assessed based on their visual quality by ten respondents selected in random. The quality assessment based on the image metrics developed and visual perception was compared to assess the credibility of the image metrics. In the total of eleven image fusion techniques, three very basic fusion techniques were Averaging Method, Maximum Selection Method and Minimum Selection Method, five pyramidal methods were FSD Pyramid, Laplacian Pyramid, Gradient Pyramid, Ratio Pyramid and Morphological Pyramid Methods and two of basic wavelet methods were Haar Wavelet and DBSS(2,2) Wavelet Methods. The readings produced by the 9 image metrics developed - MSE, PSNR, SC, NCC, AD, MD, NAE, LMSE and SSIM, were used to assess the best fusion algorithm (in terms of the quality of the fused images) using Pareto optimality method. DWT with Haar based fusion method was assessed best. The assessment saw that the fused images produced by Morphological Pyramid Method were the rated most inferior in quality.

The algorithms were also assessed based on the visual quality of the fused images. Ten people were selected, in random, to visually assess the fused images produced in each of the 3 sets and were asked to pick out the best and worst image they found in each image set. The results here validated the results produced based on image metric readings. DWT with Haar was rated 63.33% times, much higher that the rating given to the other algorithms. Similarly the results also matched as Morphological pyramid rated inferior in visual quality.

B. Y. Shutao Li [16] proposes methods base on some mathematical transforms, e.g. discrete cosine, Wavelet, Curvelet. When an image is subjected to any transform, it is decomposed into its sub-band components which may be regarded as frequency domain or wavelet domain. So this type of technique is also termed as ‘Multi-resolution analyses’. All transform domain techniques can be realized by a generic scheme given in figure. The outcome of transformation is the coefficients which are to be used for fusion. For the fusion some criteria is fixed which may be regarded as ‘fusion rule’ e.g. maximum, minimum, mean, rand. These block compares the coefficients and based upon fusion method it yields fused coefficients. Inverse transformation is applied to get synthetic, fused image in spatial domain. Image fusion in transform domain needs nearly perfect reconstruction of the spatial domain information.

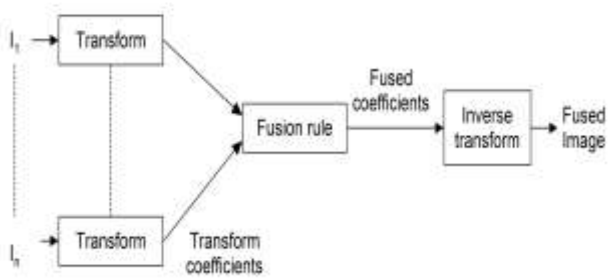

Figure 8.Generic scheme of Image fusion using Transform

Later conclude transform domain methods prove to be efficient over the spatial domain methods. Less value of RMS for the transform domain methods clearly indicates that the fused image is void of art facts. Higher value of PSNR shows that image is less prone to noise compared to spatial domain methods. Entropy is approximately same for all the methods. Cross correlation coefficient value approximates to 1, which represents the degree of similarity to that of original image. When the standard deviation value of images of curvelet and wavelet are compared, it is higher for the wavelet transform. These indicates that wavelet transforms efficient in representing the contrast information. The same can be confirmed by using visual inspection of the fused images. The edges are more sharp for curvelet based image than wavelet based image while contrast for wavelet is better than curvelet based method. This proves that curvelet transform can represent the curves efficiently than wavelet transform and wavelet has better capability to represent texture, contrast information than curve let.

F.Sadjadi. [10], describes a method for evaluating the performance of image fusion algorithms. They describes set of measures of effectiveness for comparative performance analysis and then used them on the output of a number of using algorithms that have been applied to a set of real passive infrared (IR) and visible band imagery. Further concludes that the comparative merit of each fusion method is very much dependent on the measures of effectiveness being used. However, many of the fusion methods produced results that has lower measures of effectiveness than their input imagery.

S.Udomhusakal [22], proposes multi-focus image fusion using spatial frequency measurement and wavelet packets. The two set of images were transform and decompose into sixteen sub band using wavelet packets. later each sub-band is partition into sub band block and each sub-band is identified using SFM. Then find the inverse wavelet transform to reconstruct the image. The objective performance is measure using PSNR and Edge measurement to evaluate the quality of fuse fuse image. The propose method has an advantages over SFM base method smaller the value of edge measurement better the image quality. In future , the effect of color information or chrominance component to fuse image will be studied in order to get best quality for color image fusion.

C.lacewells. et al. [23], presents a technique for an accurate fuse image using discrete wavelet transform (DWT) for feature extraction and using generic algorithm to get optimize image. The propose fusion is evaluated with mutual information (MI), RMSE. The three methods pixel level genetic algorithm (PLGA), DWT image fusion and DWT_GA image fusion are compares according to M.I and RMSE. The three sets of weather forecasting images are used to take results The results seems to best for DWT_GA image fusion than above methods. DWT_GA gives more accurate and improves the drawbacks of information loss.

Z.Wu.et al. [24], presents image fusion on wavelet transform for remote sensing images base on intensity (I),Hue(H), saturation(S),transformation. To improve the performance of image fusion multispectral images are user to get I,H,S. The combination of HIS and wavelet method has better reserve the spectral features.

S.Vekkot, et al. [2], proposes pixel based maximum selection rule to low frequency approximations and filter mask base fusion to high frequency wavelet decomposition. Advantages of pixel and region based fusion in a single image which can help the development of sophisticated algorithms enhancing the edges and structural details. A Graphical User Interface is developed for image fusion to make the research outcomes available to the end user. The variations in performance of fusion rules for different test images show that the choice of an optimum fusion rule depends mainly on the type of images to be used, degradation models used to introduce noise in source images and the application. The filter mask hybrid fusion removes noise and other artifact of image and shows better results than pixel fusion.

Cui Li, et al. [25], presents method based on multi-scale wavelet decomposition of image fusion algorithm and selective analysis the multi-scale image fusion method based on wavelet-domain.. The fusion method of maximum operation factor was adopted for the sub-images with low-frequency band. In the corresponding high-frequency coefficient, the whole fused image can be obtained by inverse wavelet transform of the low-frequency and the high-frequency sub-images which were processed by the multi-scale image fusion. For this four methods are compares. The six set of digital clocks are use to get entropy, correlation coefficient, RMSE. The fusion result is more improved compared Wavelet Modulus Maxima algorithm base on region of energy and shows improvement in both visual and quantitative indices in multi-scale wavelet decomposition and regional energy image fusion.

Mirajkar, et al. [26], propose wavelet transform algorithm to prove geometric resolution of image. They describes different wavelet base method such as Hybrid architecture base on wavelet transform in which both pixel and region base rules are integrate. Stationary wavelet transform (SWT) and discrete wavelet transform. These two methods are similar but in SWT process of down sampling is suppressed. Total four images are use with size of 256*256 to compares the objective evaluation on the basis of mean square error, signal to noise ratio, and n peak signal to noise ratio. By comparing the results of images SWT based image fusion level 2 method shows good result.

S.Bedi,etal,[15] describers thatwavelets are finite duration oscillatory functions with zero average value. They have finite energy. They are suited for analysis of transient signal. The irregularity and good localization properties make them better basis for analysis of signals with discontinuities.

Literature review on image fusion techniques and image qualityassessment par ameters such as Structural similarity index measure, laplacian mean squared error, mean squared error, Peak signal to noise ratio, entropy, structural content, Normalized cross correlation, Maximum difference, normalized absolute error. Comparison and effective use of all the techniques in image quality assessment is also determined.

Proper fusion technique depends on the specific application. Spatial domain provides high spatial resolution But in spatial domain spectral distortion is the main drawback therefore transform domain image fusion is done. Based on the analysis done on various transform domain techniques such as, wavelet transform, discrete wavelet transform, curvelet transform. It has been concludes that each technique it meant for specific application and one technique has an edge over the other in terms of particular application.

The image quality assessment parameters have been reviewed and determine the role of individual image quality assessment parameter to determine the quality of the fused image.

V. CONCLUSION

This paper presents, the survey of laplacian and wavelet transform method are describe. Analysis done on various transform domain techniques such as wavelet transform, PCA base transform, discrete wavelet transform. It has been conclude one techniques has an edge over the other in terms of particular applications.

The image quality assessment parameters have been reviwed and determine the role of individual image quality assessment parameter to determine the quality of fused image.

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