Image Fusion Methodologies: A Survey of the State of the Art

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***Abstract*— Review of different image fusion methods for merging of complementary diagnostic content has been carried out in this paper. Image fusion methods enhance the quality of images quantitatively and qualitatively. The availability of a large number of techniques in feature processing, feature extraction and decision fusion makes the field of image fusion appealing to be Mused in many applications. The algorithms used for image fusion studies have resulted in the improved imaging quality and also have proved to be useful for many applications. The well-known approaches include PCA, wavelets transforms, neural networks, fuzzy logic, and classifiers such as support vector machines. This will benefit for researchers to carry out further work in this thrust area of research.**

***Keywords*—Image Fusion, Daubechies, Entropy, PCA, Wavelets, Laplacian pyramid**

I. INTRODUCTION

With the recent rapid developments in the field of digital image processing have become realities in a growing number of fields such as remote sensing, medical imaging, machine vision and the military applications. The result of the use of these techniques is a great increase of the amount of data available in a form of images. Image fusion provides an effective way of reducing this increasing volume of information while at the same time extracting all the useful information from the source images [1-2].

A process of combination of two or more images generated from multiple sensors or methods into a signal images is called image fusion. Image fusion merges the different information and obtains a new and improved image from several images of same object which provides different information based on different resolution and viewing angle [3]. There are several applications of image fusion, some of which are medical imaging, defense imaging, security systems, remote sensing, nighttime operations and multi-spectral and multi-focus imaging.

Image fusion is divided into two groups, first is multi-scale decomposition-based fusion methods, and second is non multi-scale decomposition based fusion methods [4].

A. Multi-scale decomposition-based fusion methods

Multi-scale transforms methods are decomposed source images into a set of spatial frequency sub-band images which is computed by convolving and sub-sampling operations. In recent years, many researchers have developed numerous multi-scale transforms methods for extraction of the information content of images for the purpose of image fusion [5]. Most commonly used multi-scale transform methods are pyramid transform, discrete wavelet transform, stationary wavelet transform, dual-tree complex wavelet transform and so on.

B. Non multi-scale decomposition based fusion methods

There are also many fusion methods which is not based on multi-scale decomposition and these method are classified into different classes. First class is Pixel level weighted average, in this each pixels of fused image are computed by weighted average of the pixel intensity of corresponding pixel of the input source images. This is also called linear method and mostly used linear methods are principal component analysis (PCA), Intensity Hue Saturation (IHS) etc. These techniques improve the spatial resolution while distorting the original chromaticity of the input images, which is a major drawback [6]. Adaptive transform based non-linear method is belongs to the second class. In this method first low pass component of each source image is adaptively modifies to enhance the local luminance mean, and the high pass component of each source image is adaptively modifies to enhance the local contrast, and then fusion is performed by nonlinear mapping [7]. Estimation theory is also used for image fusion method, in this method common estimation procedures are used which includes the maximum a posteriori estimate and the maximum likelihood estimate [8].

Artificial neural network are another class which is used for Image fusion process. They are sometimes physiologically motivated by the fusion of different sensor signals in biological systems. Multilayer perceptron neural networks and pulse-coupled neural networks are two types of neural networks that have been frequently utilized for image fusion [9].

II. LITERATURE REVIEW

As discussed in previous Section, image fusion process is widely used in many applications for reduction of increasing volume of information into single image and extraction of all the useful information from the source images. Several methods and approaches have been attempted earlier by many researchers for enhancement of source images using image

fusion methods. In this paper, these methods are studied for further improvements of the existing methods.

A. Pyramid transform based image fusion

A pyramid structure can be described as a collection of images at different scales which together represent the original image. One of the most frequently studied versions of the pyramid transform is the Laplacian pyramid (LPT). This technique is first used by Burt in binocular image fusion [10]. Burt used filters with increasing spatial extent to generate a sequence of images (pyramid) from each image, separating information observed at different resolutions. Then at each position in the transform image, the value in the pyramid showing the highest saliency was taken [11]. An inverse transform of the composite image was used to create the fused image. Later; Adelson disclosed the use of a Laplacian pyramid in construction of an image with an extended depth of field from a set of images taken with a fixed camera but with different focal lengths [12]. For fusion of visible and IR images in surveillance application Toet [13], Toet et al.[14] and Toet [15] developed a low-pass pyramid, contrast pyramid and morphological pyramidal methods in image fusion. Anderson was studied and design a decimate hierarchical pyramid for signal analyzing and synthesizing [16]. Pyramid based image fusion provide the sub-band images in spatial domain, while by increasing pyramid level, resolution of images reduces.

B. Wavelet transform based image fusion

Wavelet transform decomposes an image into four coefficients namely, low-low (LL), low-high (LH), high-low (HL) and high-high (HH) by separately filtering and down sampling using the low pass filter (L) and high pass filter (H) [17]. LL coefficient is a low frequency approximation (A) of image which contains less redundant information, while LH, HL and HH is high-frequency detail of image which represent horizontal (Hr),vertical (Vr) and diagonal (D) directional information due to the spatial resolution. The wavelet representation introduced by Mallat, in which Mallat tree are used for decomposition of the source images [18].

Later many researchers studied on different types of wavelet transform. Zhang et al. [19] and Ahmed et al. [20] studied on discrete wavelet transform for medical application and found 92% improvement over the mean rule fusion technique. They also used wavelet transform method for image denoising and to receive image edge. Tsai et. al. [21] and Mirajkar et al. [22] developed mask based image fusion method by using wavelet transform. In this method images are decomposed into many sub-band by adaptive decomposition method and found that adaptive decomposition improve the performance of the wavelet transform based fusion method. Ali et al. studied on additive wavelet transform and fuzzy logic method and estimate an intermediate high/low resolution multi-spectral image using component substitution, which is followed by additive wavelet based high frequency injection into low resolution multi-spectral bands. They found that the combination of wavelet and fuzzy logic enhance the performance of the fusion and also reveal that traditional additive wavelet fusion schemes reduce redundant high frequency information [23]. Medical image fusion for merging of complementary diagnostic content has been carried out by Abhinav et al [24] using Principal Component Analysis and Wavelets. They found that the time and frequency conservation property of wavelet and feature enhancement property of PCA makes this approach more suitable for medical image fusion.

C. Principal Component Analysis based image fusion

Fusion algorithm based on PCA, IHS are not belongs to the category of multi scale decomposition methods this algorithms are called Substitution methods, or linear transformation method. In PCA, principal components are linear combinations of optimally weighted observed variables and these components are computed by using the eigenvector and eigen values. In PCA, few principal components has largest variance, hence these components are used for subsequent analysis in image fusion [25].

Hamid et. al. [25] developed a new PCA method based on conventional standard PCA method. The spectral bands of multispectral images are used for study. PCA transform is applied on these images for generation of principal components images which contains the spatial information that is specific to each pixel. Abhinav et al.[26] studied the combination of PCA and wavelet transform method for image fusion. Abinav applied wavelet transformation method for conversion of images into wavelet coefficient and further PCA is used in fusion focuses the features of the decomposed images. They found that the time and frequency conservation property of wavelet and feature enhancement property of PCA makes this approach more suitable for medical image fusion. Jing et al. [27] proposed a novel PCA based Pixel-level multi-focus image fusion algorithm. For this new adaptive algorithm is used for generation of sample matrix of principal components. Jing are found that the proposed algorithm is more informative and also found that the method is less complex than the PCA method, which could save a lot of execution time in embedded system. Metwalli et al. [28] studied hybrid fusion method based on PCA and high pass filter for providing pan sharpened image with superior spatial resolution and less spectral distortion. This method is used in remote sensing data with different spatial and spectral properties. Metwalli is found that the developed method are significantly reduced the spectral distortion compared with the PCA, HPF, and GS fusion methods. Changtao et. al. [29] studied on multimodal medical image fusion based on IHS and PCA. Changtao used features of IHS and PCA methods and integrated the merits both preserving spatial information of the IHS transform and minimizing redundancy of PCA transform. Ming et al. [30] comparative studied on HIS, PCA, Brovey transform, wavelet transform method based image

fusion algorithm for remote sensing application and found that for color images IHS is capable for finding spot.

D. Artificial neural network based image fusion

Artificial neural networks (ANN) are enthused from the idea of biological neural network system to learn from inputs for processing features and for making global decisions. The neural network models have ability to predict, examine and understand information from a given set of input data without going through a exact mathematical solution is often seen as an advantage. The ANN models involve an input training set to identify the set of parameters of the network referred to as weights. This ability of ANN makes attractive for image fusion method due to the nature of variability between the images is subjected to change every time a new modality is used [31].

Szu et al. [32] developed Lagrange constraint neural network (LCNN) based fusion algorithm for sub-pixel multispectral remote sensing application and used for the early breast cancer detection using two-color mid and long infrared images of the breast. Li et al. [33] used a new multi-modality medical image fusion algorithm based on pulse-coupled neural networks (PCNN) and found that the new algorithm is very effective and provides a good performance in fusing multi-modality medical images. Xiaoqi et al. [34] proposed a new image fusion algorithm based on clustering neural network analysis based image fusion for clinical image processing. In this algorithm, pixels of origin images are classified into clustering feature pixels and secondary pixels base on clustering analysis and found that image fusion improves the quality of the origin image, fusion image also protects characters of the image and heightens the visual impact.

III. SUMMARY

The advancement of imaging technologies results in improved imaging accuracies. However, each methods of imaging have its own pros and cons The image fusion methods enhance the quality of images quantitatively and qualitatively. The availability of a large number of techniques in feature processing, feature extraction and decision fusion makes the field of image fusion appealing to be used in many applications. The algorithms used for image fusion studies have resulted in the improved imaging quality and also have proved to be useful for many applications. The well-known approaches include PCA, wavelets transforms, neural networks, fuzzy logic, and classifiers such as support vector machines.

PCA is reducing the number of dimensions, without much loss of information but also produce the spectral degradation. Pyramid based fusion not produces spectral degradation but its performance reduces with decomposition level. Wavelet transform based fusion method provides high SNR as well as no spectral degradation for fused images but suffers from directional selectivity during fusion. From the literature review it is also found that the use of these methods in integrated form is providing more superior results as compare to the individual form.

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