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Wavelet Transform based Image Informatics and applications: A Review

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Abstract- Information is the most important and unavoidable feature of a digital image. Wavelet transforms decomposes a signal into frequency bands, the width of which are determined by a dyadic scheme. This particular way of dividing frequency bands matches the statistical properties of most images very well. This useful property of wavelet transform applicable in image processing is the motivation for our research work, Wavelet transform based image informatics.

Keywords-- wavelet transform, image informatics, image fusion, image reconstruction

I. INTRODUCTION

The aim of our research work is to implement some wavelet transform based algorithms which can perform some operations on images by which it can be Compressed, Denoised, Contrast Enhanced, Segmented, Classified and Fused (to achieve maximum information from a group of images).We collectively call all these operations for images as "Image Informatics" as by this the information of image is maintained, enhanced, conserved and efficiently accessed. The parameters like Gradient ,Standard Deviation, Entropy and Cross-Entropy etc which are assessment parameters of information for an image has been calculated for a set of images and by using Lifting wavelet Transform we decomposed the images and further fuse the wavelet coefficients and achieved a more informative single Image with features extracted with improved assessment parameters. We implement this work through MATLAB Software on some medical images (Dentistry images) and find the desired result. The proposed scheme of image informatics has wide applications in image processing field especially in the area of Bio-Medical imaging, Microscopic Image Enhancement, Remote sensing , Pattern Recognition .

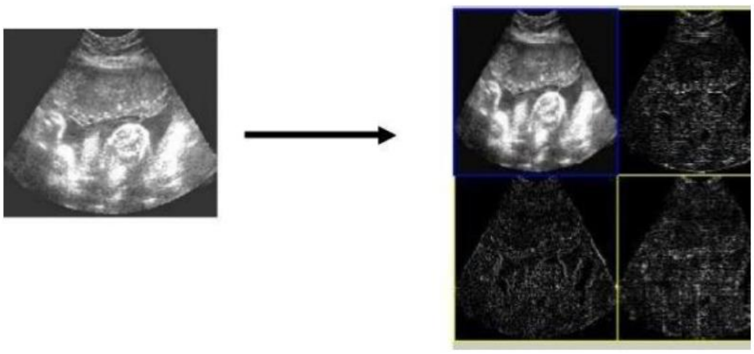

*Fig*1. Image decomposition in different frequency components by wavelet transform

The rest of the paper is organized as follows; Section 2 discusses related work, section 3 provides the understanding of Image Reconstruction, section 4 explains Image Fusion and Feature Extraction and in section 5 we have discussed applications of Wavelet Transforms followed by concluding the research paper.

II. RELATED WORK

Wavelet Transform has been proved an excellent signal processing tool in the area of image processing. This has been possible due to its unique properties like Multi resolution Analysis, perfect reconstruction and decomposition of image signal by its filter banks[5],[28],[29],[30],[31] .Wavelet can be used for classification of image disorders by various segmentation techniques and decomposition of images especially in medical images[2]. Many researchers has contributed a lot by their literatures on wavelet theory and its mathematical properties like orthogonality and sparse matrics behaviour [27],[28] .

In this literature survey we are focusing on those papers which are exploring some wavelet algorithms based strategies for conserving image information, image assessment Image Fusion, Compression, Image segmentation and classification which collectively called Image Informatics. The wavelet based decomposition of image can be reconstructed by many techniques like by Matched Wavelet estimation[5] and by wavelet based parallel filtered Back projection[8].The decomposition of image should be at multi-scale level for better feature extraction. And this can be achieved faithfully by Quaternion wavelet transform (QWT) [1].

Change detection is also an important practice in image processing specially for remote sensing images. A change detection method based on Gabor wavelet proved as an excellent method for enhancing image information [3]. Image fusion is also an excellent methodology used for Image informatics [1], [6].Many methods are there for image fusion like Feature residual and statistical matching and Perceptual image fusion by wavelet [6], [9]. The visual feature in an image must be measured accurately and related assessment parameters like gradient ,entropy ,standard deviation ,cross entropy must be maintained and improved in a computer –based approach for image informatics[6], [7], [10], [17].Wavelet has been proved an excellent tool for segmentation and classification of images .This can be based on statistical texture feature segmentation method and alpha-stable modelling of wavelet coefficients [13],[14].

III. IMAGE RECONSTRUCTION

Ansari and Gupta [5] propose a joint framework wherein lifting-based, separable, image-matched wavelets are estimated from compressively sensed images and are used for the reconstruction of the same. Matched wavelet can be easily designed if full image is available. Also compared to standard wavelets as sparsifying bases, matched wavelet may provide better reconstruction results in compressive sensing (CS) application. Since in CS application, we have compressively sensed images instead of full images, existing methods of designing matched wavelets cannot be used. Thus, they propose a joint framework that estimates matched wavelets from compressively sensed images and also reconstructs full images. This paper has three significant contributions. First, lifting-based, image-matched separable wavelet is designed from compressively sensed images and is also used to reconstruct the same. Second, a simple sensing matrix is employed to sample data at sub-Nyquist rate such that sensing and reconstruction time is reduced considerably. Third, a new multi-level L-Pyramid wavelet decomposition strategy is provided for separable wavelet implementation on images that leads to improved reconstruction performance. Compared to CS-based reconstruction using standard wavelets with Gaussian sensing matrix and with existing wavelet decomposition strategy, the proposed methodology provides faster and better image reconstruction in compressive sensing application [5]. An algorithm is also proposed by Escobedo and Ozanyan [8], relevant to tomography sensor systems, to obtain images from the parallel reconstruction of essentially localized elements at different scales. This is achieved by combining methodology to reconstruct images from limited or truncated data, with the time-frequency capabilities of the Wavelet Transform. Multi-scale, as well as time-frequency, localization properties of the separable two dimensional wavelet transform are exploited as an approach for faster reconstruction [8].

IV. IMAGE FUSION AND FEATURE EXTRACTION

Multi-sensor image fusion technologies, which convey image information from different sensor modalities to a single image, have been a growing interest in recent research.

Yang et al, proposes a novel multi-sensor image fusion method based on multiple visual features measurement with gradient domain guided filtering [4]. First, a Gaussian smoothing filter is employed to decompose each source image into two components: approximate component formed by homogeneous regions and detail component with sharp edges. Second, an effective decision map construction model is presented by measuring three key visual features of the input sensor image: contrast saliency, sharpness, and structure saliency. Third, a gradient domain guided filtering-based decision map optimization technique is proposed to make full use of spatial consistency and generate weight maps. Finally, the resultant image is fused with the weight maps and then is experimentally verified through multifocus image, multimodal medical image, and infrared-visible image fusion. The experimental results demonstrate that the proposed method can achieve better performance than state-of the- art methods in terms of subjective visual effect and objective evaluation [4].

Hill, Mualla and Bull [6] proposed a perceptual image fusion method that employs explicit luminance and contrast masking models. These models are combined to give the perceptual importance of each coefficient produced by the Dual-Tree Complex Wavelet Transform of each input image. This combined model of perceptual importance is used to select which coefficients are retained and furthermore to determine how to present the retained information in the most effective way. This work is the first to give a principled approach to image fusion from a perceptual perspective. Furthermore, the proposed method is shown to give improved quantitative and qualitative results compared to previously developed methods[6].Multi-scale based Image fusion is one of main fusion methods, in which multi-scale decomposition tool (MSD) and feature extraction play very important roles. The quaternion wavelet transform (QWT) is one of effective multi-scale decomposition tools. Therefore, this study proposes a novel multimodal image fusion method using QWT and multiple features. First, they perform QWT on each source images to obtain low frequency coefficients and high frequency coefficients. Second, a weighted average fusion rule based on the phase and magnitude of low frequency sub band and spatial variance is proposed to fuse the low frequency sub bands. Next, a choose-max fusion rule based on the contrast and energy of coefficient is proposed to integrate the high frequency sub bands. Finally, the final fused image is constructed by inverse QWT. The proposed method is conducted on multi-focus images, medical images, infrared-visible images and remote sensing images, respectively. This Multi scale decomposition of image and further fusion by using QWT is proposed by Pengfei and Zhang [1].In view of the shortcoming of traditional image fusion based on discrete wavelet transform (DWT) with unclear textural information, an effective visible light and infrared image fusion algorithm via feature residual and statistical matching is proposed by Wang ,Zhang and Bai[9].According to their work , first, the source images are decomposed into low-frequency coefficients and high-frequency coefficients by DWT. Second, two different fusion schemes are designed for the low-frequency coefficients and high frequency ones, respectively. The low-frequency coefficients are fused by a local feature residual-based scheme to achieve adaptive fusion; the high frequency coefficients are accomplished by a local statistical matching-based scheme to extract the edge information effectively. Finally, the fused image is obtained by inverse DWT. Experimental results demonstrate that the proposed method can produce a more accurate fused image, leading to an improved performance compared with existing methods [9].

A novel region-based image fusion framework based on multiscale image segmentation and statistical feature extraction is proposed by Canagarajah and Achim[14]. A Dual-Tree Complex Wavelet Transform (DT-CWT) and a statistical region merging algorithm are used to produce a region map of the source images. The input images are partitioned into meaningful regions containing salient information via symmetric alpha- stable distributions. The region features are then modelled using bi- variate alpha-stable distributions, and the statistical measure of similarity between corresponding regions of the source images is calculated. Finally, a segmentation- driven approach is used to fuse the images, region by region, in the Complex Wavelet domain. A novel decision method is introduced by considering the local statistical properties within the regions, which significantly improves the reliability of the feature selection and fusion processes [14]. An excellent work is done by Krishnan and Radhakrishnan[2] for image classification. They presented a computer-based approach to classify ten different kinds of focal and diffused liver disorders using ultrasound images. The diseased portion is isolated from the ultrasound image by applying active contour segmentation technique. The segmented region is further decomposed into horizontal, vertical and diagonal component images by applying bi orthogonal wavelet transform. From the above wavelet filtered component images, grey level run-length matrix features are extracted and classified using random forests by applying ten-fold cross-validation strategy. The results are compared with spatial feature extraction techniques such as intensity histogram, invariant moment features and spatial texture features such as grey-level co-occurrence matrices, grey-level run length matrices and fractal texture features. Their proposed technique, which is an application of texture feature extraction on transform domain images, gives an overall classification accuracy of 91% for a combination of ten classes of similar looking diseases which is appreciable than the spatial domain only techniques for liver disease classification from ultrasound images[2].Nanthagopal and Sukanesh[13] present a method to select both dominant run length and co-occurrence texture features of wavelet approximation tumour region of each tumour image slice to be segmented by a support vector machine (SVM). Two-dimensional discrete wavelet decomposition is performed on the tumour image to remove the noise. The images considered for this study belong to 208 tumour slices. Seventeen features are extracted and six features are selected using Student's t-test. This study constructed the SVM and probabilistic neural network (PNN) classifiers with the selected features. The classification accuracy of both classifiers is evaluated using the k fold cross validation method. The segmentation results are also compared with the experienced radiologist ground truth. Quantitative analysis between ground truth and the segmented tumour is presented in terms of segmentation accuracy and segmentation error. The proposed system provides some newly found texture features have an important contribution in classifying tumour slices efficiently and accurately [13].

Jian ,Daojing, Bianzhang and Junping [23] proposed an algorithm for segmenting and classifying document images. Feature used for classification is based on the histogram distribution pattern of different image classes. The important attribute of the algorithm is using wavelet correlation image to enhance raw image's pattern, so the classification accuracy is improved. In this paper document image is divided into four types: background, photo, text and graph. Firstly, the document image background has been distinguished easily by former normally method; secondly, three image types will be distinguished by their typical histograms, in order to make histograms feature clearer, each resolution' s H H wavelet subimage is used to add to the raw image at their resolution. At last, the photo, text and praph have been divided according to how the feature fit to the Laplacian distribution. Their simulation result shows that classification accuracy is significantly improved with lower classification error rates and better visual result [23] .Image compression is desirable for transmission and storage. We now survey the family of wavelet-based image compression algorithms. Image compression is a major application area for wavelets. Because the original image can be represented by a linear combination of the wavelet basis functions, similar to Fourier analysis, compression can be performed on the wavelet coefficients. The wavelet transform offers good time and frequency localization. Information stored in an image is decomposed into averages and differences of nearby pixels. For smooth areas, the difference elements are near zero. The wavelet approach is therefore a powerful tool for data compression, especially for functions with long-range slow variations and short-range sharp variations [30], [31]. The time and frequency localization of the basic functions are adjusted by both scale index j and position index k. We may decompose the image even further by applying a wavelet transform several times recursively [31].

Coefficients in a 1-level wavelet transform are organized into 4 bands, emphasizing low frequency trend information, vertical-directional fluctuations, horizontal-directional fluctuations, and diagonal-directional fluctuations, respectively. The low frequency band of coefficients can be further decomposed to form higher-level wavelet transforms. Most of the high frequency coefficients are of near-zero values. Note that information about the shape, intensity, and surface texture are well preserved and organized in different scales for analysis. Since wavelet transforms decompose images into several resolutions, the coefficients, in their own right, form a successive approximation of the original images. For this reason, wavelet transforms are naturally suited for progressive image compression algorithms. DeVore, Jawerth and Lucier [29] proposed an efficient image compression algorithm by preserving only the largest coefficients (which are scalar quantized) and their positions [15]. In the same year, Lewis and Knowles [30] published their image compression work using 2-D wavelet transform [29] and a tree-structured predictive algorithm to exploit the similarity across frequency bands of the same orientation[31].Many current progressive compression algorithms apply quantization on coefficients of wavelet transforms which became more widely used after invention of the zero-tree structure, a method to group wavelet coefficients across different scales to take advantage of the hidden correlation among coefficients [29] ,[30] ,[31].Image is often corrupted by noise in its acquisition or transmission. The goal of denoising is to remove the noise while retaining as much as possible the important signal features [24].

Zhu, Mai, and Shao [11] propose a simple but powerful color attenuation prior for haze removal from a single input hazy image. By creating a linear model for modeling the scene depth of the hazy image under this novel prior and learning the parameters of the model with a supervised learning method, the depth information can be well recovered [11]. Tang, Lu, Laude, Dhillon and Murray[12] proposes a simple yet effective method to reduce noise for ellipse fitting to scattered data on medical images. The method is developed specifically to address the challenge due to variation in the sharpness, magnitude and continuity of edges, when studying the medical images of a large population. The proposed method exploits prior knowledge to eliminate the inhomogeneity within the region of interest, and uses a k-means clustering technique to eliminate background noise[12].Few more algorithms for denoising of images are also proposed by which are based on scale mixtures of Gaussians in Wavelet domain[19] and in complex wavelet domain using mixture priors[16].

V. APPLICATIONS OF WAVELET TRANSFORMS

Wavelets transform have primary benefits in the field of modern medicine and image processing. In the medical field it has proven significantly useful in biomedical imaging but also for signal and image processing. Image Compression is a major application for wavelets. As the original image can be represented by a linear combination of the wavelet basis function, similar to Fourier analysis, comparison can be performed on the wavelet coefficients. In comparison to Fourier analysis, wavelet transforms provide better spatial domain localization property critical to many imaging applications. Wavelet transform provides good time and frequency localization. Image stored in an image is decomposed into averages and differences of nearby pixels. They are naturally suited for progressive image compressive algorithms because they form a successive approximation of original images. Wavelet based schemes perform better than standard schemes as they minimize the color distortion. The potential benefits also include applying wavelet transforms to fuse multispectral and panchromatic satellite imagery.

VI. CONCLUSION AND FUTURE SCOPE

In this paper we discussed about wavelet transforms with emphasis on their applications in imaging informatics. The application of wavelets to imaging informatics is only a decade old. Wavelets have demonstrated their importance in almost all areas of signal processing and image processing. In present scenarios, techniques based on wavelet transforms represent the best available solutions. In the coming years we expect to see the development of various hybrid schemes that focuses on incorporating wavelets and other statistical techniques to achieve greater success in the field of imaging informatics. Further exploration and research on these frontiers are likely to bring us more successful applications in imaging informatics.

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