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Image Denoising Using Spectral Clustering By Empirical Wavelet Transform and Householder Transform

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Abstract- **Image denoising remains as one of the challenging problem for researches. There have been several ample denoising techniques introduced but each approach has its own advantages and limitations. This paper presents a novel approach of adaptive decomposition known as Empirical Wavelet Transform; the purpose is to decompose the signal depending upon the contained information. The Householder orthogonalization approach introduced makes the IMF obtained as a result of EWT decomposition orthogonal and thus increases the PSNR value. Besides the SSIM and IQI is also computed.**

Index Terms- **Denoising, Empirical Mode Decomposition, Empirical Wavelet Transform, Householder Transform.**

I.INTRODUCTION

An image is an important source for accessing of information ,transmission and acquisition. It has a wide area of application in weather, military, remote sensing and so on .There are different methods adopted for the removal of the noise in the image, but still it remains as a great challenge for researches. The noise removal introduces artifacts and blurring of images [2].

Many researches are undergoing still on image denoising. There are different methods such as Spatial Filters and wavelet domain, but the drawback is that they follow a prescribed subdivision scheme. The purpose of image denoising is to obtain a noise removal image from the degraded image and thus restore the original image. This paper proposes an image denoising technique based on Empirical Wavelet Transform.

In this paper a new approach to build adaptive wavelets that are capable to extract the AM-FM components of a signal is introduced. The main idea behind this is that it has a compact support Fourier spectrum. The different modes is separated by segmenting the fourier spectrum and applying the filtering action corresponding to each detected support. In this case the orthonormal basis are developed by considering distinct fourier supports. Based on this construction, an Empirical Wavelet Transform is introduced to analyze the signal it is used [1].

The remainder of the paper is organized as follows. Section II describes the Related Work. Section III describes about different noises in the image. Section IV describes about Empirical Wavelet Transform. Section V Results and Discussion. Section VI draws some of the Conclusion and in Section VII future scopes are discussed.

II. RELATED WORK

Several investigations were carried out based on denoising approaches. The DWT of the image provides the best spatial and spectral localization of the image formation compared with other multiscale representations. Signal is passed via two complementary filters to provide both approximate and detail coefficients. The method is known as decomposition or analysis. The method of reconstructing back the original signal is called as reconstruction or synthesis. The combination of analysis and synthesis together constitute the DWT and IDWT [4].

In case of 2D image, N level decomposition is carried out performing frequency bands namely LL,LH,HL,HH .Here decomposition is carried out in case of both rows and columns. The main drawback is that it follows a prescribed subdivision scheme [4] .

After in the year 1998 Huang developed a method called as EMD to decompose a signal into specific modes is introduced. The method does not use any prescribed function basis but it is adapted according to the information in the signal. The method does not use any prescribed function basis but it is adapted according to the information present in the signal. The interesting fact is that it follows an algorithmic approach; it is highly adaptable and able to extract both stationary and non stationary part of the signal. That is it can be expressed as AM–FM components. The IMF’s are extracted first computing the upper and lower envelope via cubic spline interpolation and the average of it provides the mean. The algorithm is adaptable but based on ad-hoc process it is mathematically difficult to model [1] .

There were different other adaptive approaches which uses adaptive decompositions such as Malvar – Wilson wavelets and brushlets. In case of Malvar Wilson wavelets it builds an daptive representation .Here the temporal signal is segmented itself. But the temporal segmentation is a difficult task to be carried out. The next method called is brushlets which aims to build an adaptive filter bank in the Fourier domain. But he scheme is based on a prescribed subdivision [3] -[5].

III. DIFFERENT NOISES IN THE IMAGE

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Noise is generally defined as an undesirable effect produced in the image. While undergoing image acquisition or transmission, it causes several factors to introduce noise in the image. Depending on the type, the noise can affect the image in various manners. Generally the main aim is to remove all these kinds of noise which cause disturbances. The noises are identified and different algorithms are applied to remove the noise content. .There are different kinds of noise which affect the images such as Impulse noise (Salt-and-pepper noise), Amplifier noise (Gaussian noise), Shot noise, Quantization noise (uniform noise), Film grain, Multiplicative noise (Speckle noise) and Periodic noise .

Impulse noise is as a result of black and white dots that is found in the image and it is also caused due to the sharp and sudden changes of the image signal. But the image gets corrupted only to a small extent. Another type of noise is the Gaussian noise which follows the Gaussian distribution and is additive in nature. The noise is completely independent of the pixel value at each point. Poisson noise, it is caused when the photons sensed by the sensor cannot provide much statistical information regarding it and other type of noise is the speckle noise which is modelled by the random value multiplication with the pixel value of the image.

IV EMPIRICAL WAVELETS

In this paper a method to built family of wavelets adapted to the processed signal is introduced. Where the basis function is constructed depending upon the information contained in the signal. Major advantage of adaptive wavelets is they are capable of extracting the AM–FM components of the signal. It combine's both the strength of wavelet formalism and EMD's adaptability. In EWT the signal is segmented based on information content within the signal .The EWT consists of major steps it first detects the Fourier support and built the corresponding wavelet accordingly to those supports. Filter the input signal with the obtained filter bank to get the different components [1] .

A. Segmentation of the Fourier Spectrum

Segmentation is the basic thing which provides adaptability with respect to the analyzed signal .Main aim is to separate different portions of the spectrum. Assume that there is a need of N+ 1 boundary but 0 and π is always used so need to determine N-1 extra boundaries .For this at first find the local maxima in the spectrum and sort in the decreasing order. The Fig.1 depicts the fourier spectrum of the signal.Fig.2.describes the fourier spectrum segmented and in Fig.3.desribes different segments of the fourier spectrum

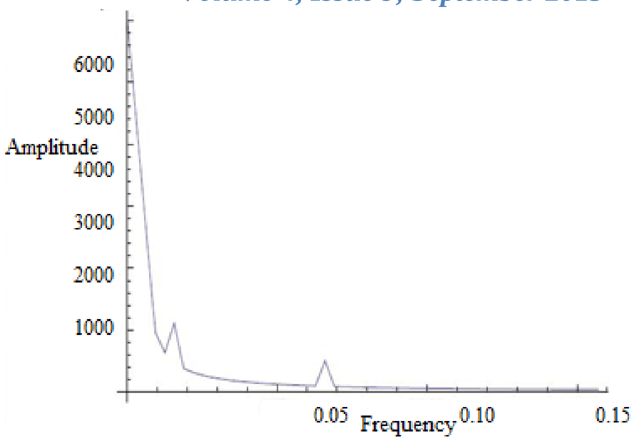

Fig.1.Fourier Spectrum of the signal

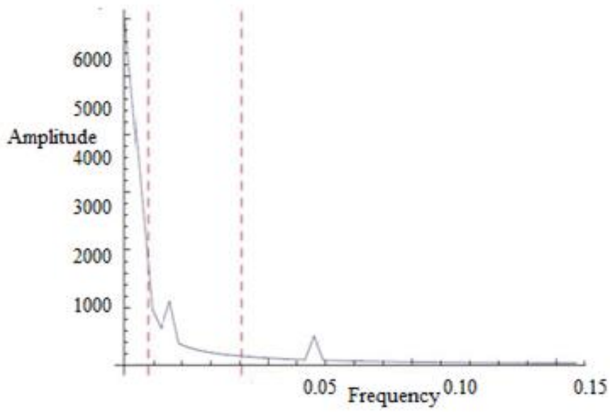

Fig.2. Fourier spectrum segmented

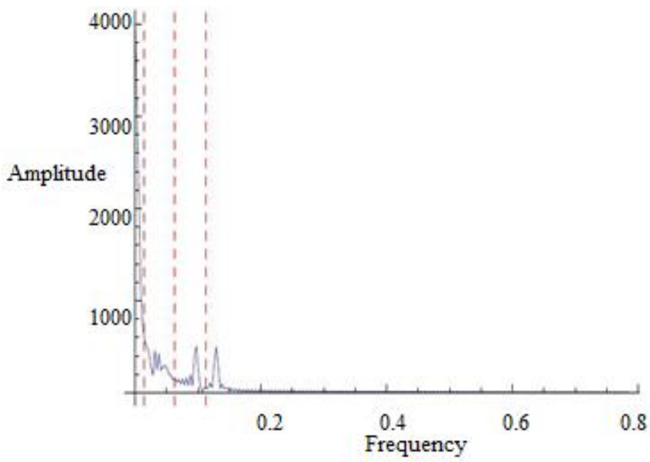

Fig.3. Segmentation of Fourier spectrum into two or three

B. Frame

To obtain a tight frame framing is done. There shouldn't be any loss of information within the signal. The below condition should be satisfied to obtain a tight frame [8] .

$$\gamma < \min_n \left(\frac{w_{n+1}-w_n}{w_{n+1}+w_n}\right) \qquad (1)$$

then the set $\{\emptyset_1(t), \{\psi\_n\ (t)\}_{n=1}^{N}\}$ is a tight frame of $L^2(R)$.The parameter γ allows to ensure that two consecutive transition areas should not be overlapped.

C. Empirical Wavelet Transform

The Empirical Wavelet Transform in the same manner as the classic wavelet transform. The detail coefficients are given by the inner products with the empirical wavelets [1] :

$$W_f^{\epsilon}(n,t) = \langle f, \psi_n \rangle \int f(\tau)\, \overline{\psi_n(\tau - t)}\, d\tau \qquad (2)$$

and the approximation coefficients is obtained by the inner product with the scaling function

$$W_f^{\epsilon}(0,t) = \langle f, \emptyset_1 \rangle = \int f(\tau)\overline{\emptyset_1(\tau - t)}\, d\tau \qquad (3)$$

the signal is reconstructed by the below equation,

$$f(t) = W_f^{\epsilon}(0,t) * \emptyset_1(t) + \sum_{n=1}^{N} W_f^{\epsilon}(n,t) * \psi_n(t) \qquad (4)$$

D. Image Denoising Using EWT

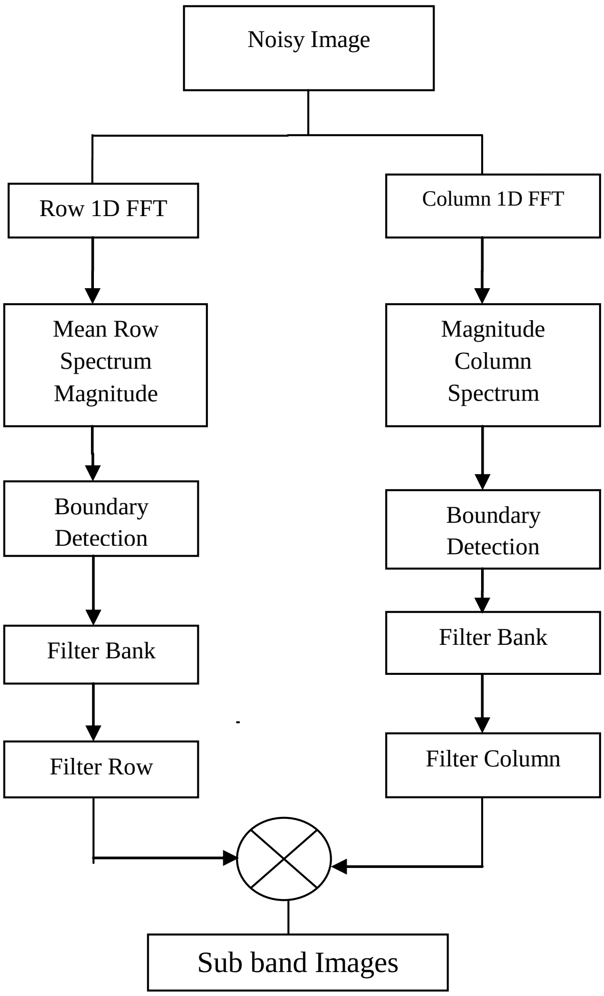

Fig.4. Image Denoising Using EWT

In this paper, it addresses the opportunity to apply the EWT to 2D signals (images). The basic idea of 2D-EWT to construct, is to adopt a tensor product as for classic wavelets, which means process the rows and then the columns of the input image by using the 1D-EWT.But mainly the problem arises is that : there is no guarantee that two different rows and columns will have the same number of fourier supports. The consequence is that in the output image corresponding to a specific band, different frequency modes are mixed which leads to a strange representation. To overcome these issues, a solution is to adopt the same filter for each rows and columns. An easy way is to consider a mean spectrum for the rows and the columns, then perform the detection of the Fourier supports based on this mean spectrum and finally apply the same filters for all rows and columns. The block diagram of Fig. 4. depicts that the 2D Empirical Wavelet Transform algorithm and it is performed in case of rows and columns.

- Perform the 1D FFT of each row i of f ; $f^{\wedge}(i,w)$ and compute the mean row spectrum magnitude.

$$F_{row}^{\sim} = \frac{1}{N_{row}\sum_{i=0}^{N_{row}} f^{\wedge}(i,w)} \qquad (5)$$

- Perform the 1D FFT of each column j of f; $f^{\wedge}(w,j)$ and compute the mean column spectrum magnitude.

$$F_{columns}^{\sim} = \frac{1}{N_{columns}\sum_{j=0}^{N_{columns}} f^{\wedge}(w,j)} \qquad (6)$$

- Boundary detection is performed on F_{row} and the corresponding filter bank is constructed .
- Boundary detection is performed on $F_{columns}$ and the corresponding filter bank is constructed .
- Filter f along the rows which provides N_{R+1} output images.
- Filter along the columns which provides at the end (N_{R+1}) (N_{C+1}) sub band images.

E. Householder Transform

Householder transformations are orthogonal transformations that have a major application in linear algebra, a Householder transformation also known as Householder reflection is a linear transformation that describes a reflection about a plane.

The Householder transformation is given by a vector u with unit length, the matrix [7] .

$$H = I - 2uu^{T} \qquad (7)$$

In this paper the application of Householder Transform in EWT helps to increase the PSNR value. In case of EWT the IMF's obtained are not orthogonal. Since the IMF's are not orthogonal the projection of the IMF 1 on IMF 2 will not be zero and hence sharing of the information content takes place. To achieve orthogonalization Householder Transform is applied. So the noise content in one IMF does not depend on other IMF's and hence the noise in the IMF's can be removed this leads to increase the PSNR.

V RESULTS AND DISCUSSIONS

The simulation tool used over here is MATLAB R2012a. It is defined as a high performance language for technical computing. For image denoising the database obtained is from the Microsoft windows.

A .Peak Signal To Noise Ratio

It is a mathematical measure of image quality based on the pixel difference between two images. SNR measure is defined as an estimate of quality of reconstructed image compared with original image. PSNR is defined as [6]

$$PSNR = 10\log_{10}\frac{s^2}{MSE} \qquad (8)$$

B. Image Quality Index

It depicts the comparison between original and distorted image based on luminance, contrast, and structural comparisons the below equations illustrates that [6].

$$l(x,y) = 2\,\frac{\mu_x \mu_y}{\mu_x^2+\mu_y^2} \quad (9)$$

$$c(x,y) = 2\,\frac{\sigma_x \sigma_y}{\sigma_x^2+\sigma_y^2} \quad (10)$$

$$s(x,y) = 2\,\frac{\sigma_{xy}}{\sigma_x+\sigma_y} \quad (11)$$

C. Structural Similarity Index

Wang developed Structural Similarity Index as an improvement for UIQI, the original and distorted images are divided into blocks of size 8 x 8 and then the blocks are converted into vectors. Two means, two standard derivations and one covariance value are computed from the images [6].

$$\text{SSIM}\,(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)} \quad (12)$$

Fig.5.Noisy input for performing the EWT denoising

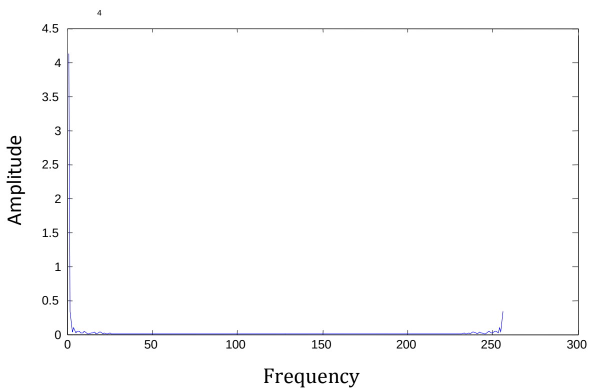

Fig.6.Fourier Spectrum of the signal

In this paper a family of wavelets adapted to the processed signal is used. Here the Fourier spectrum is considered to provide adaptability based on the information present in the signal. The Fig.6. Explains the Fourier spectrum of the signal

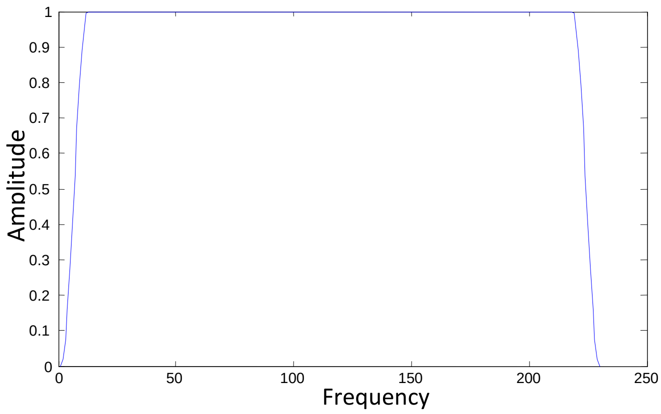

Fig.7. Cosine Tapped Filter

One way to reach adaptability is to consider that the filters supports depend on where the information in the spectrum of analyzed signal is located. After determining the Fourier spectrum of the signal in Fig. 7. the output has been filtered to get the IMF components

Fig.8.Red component of the image

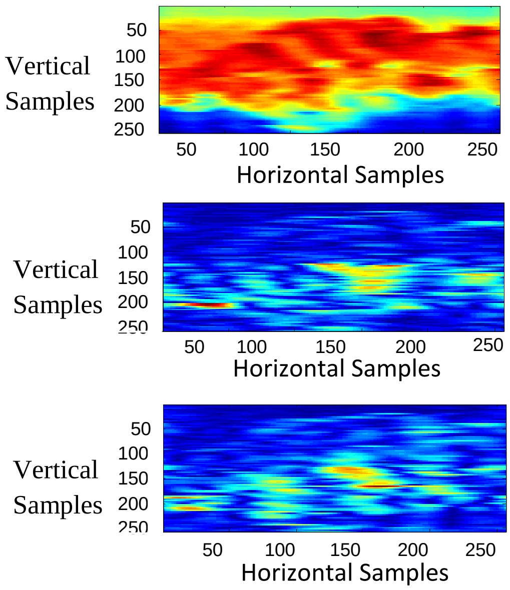

Fig.9. IMF of the Red component

IMF's of different components namely red green and blue component are determined. The IMF's of these components are found.IMF properties are equivalent to say that the spectrum of an IMF is of compact support and centred around a specific frequency.

Fig.10.Green Component of the image

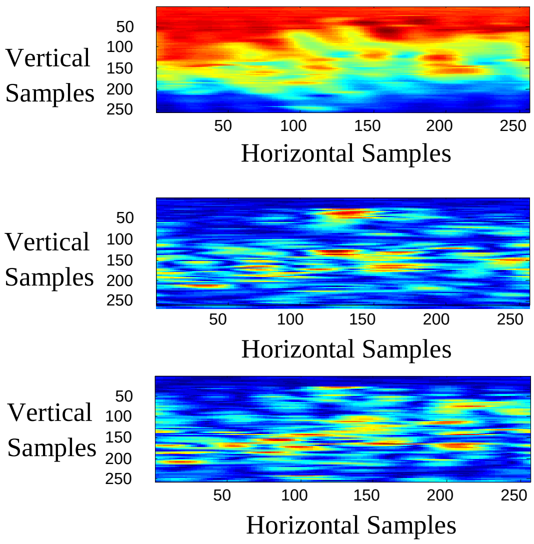

Fig. 11.IMF of the Green Component

Fig. 12.Blue Component of the image

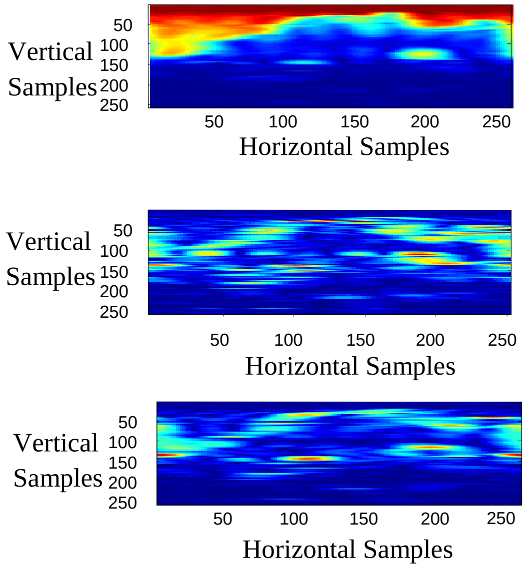

Fig. 13.IMF of the Blue Component

Denoising using EWT to be performed, the red green and blue component of the image should be separately determined it's IMF and the noise in the IMF should be removed to get the denoised image as the output.

Fig. 14.Denoised Image using EWT

By finding the separate components for red green and blue the noisy components in the IMF's has been denoised to get the denoised output using EWT is shown in Fig.14.

Fig. 15.Triangular Matrix; Output Of Householder Transform

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The output of the Householder Transform is the triangular matrix it is shown in Fig.15. In this paper the IMF's produced by performing EWT are not orthogonal and hence sharing of the information content takes place. By the application of Householder Transform the IMF's are made orthogonal and thus more PSNR can be obtained.

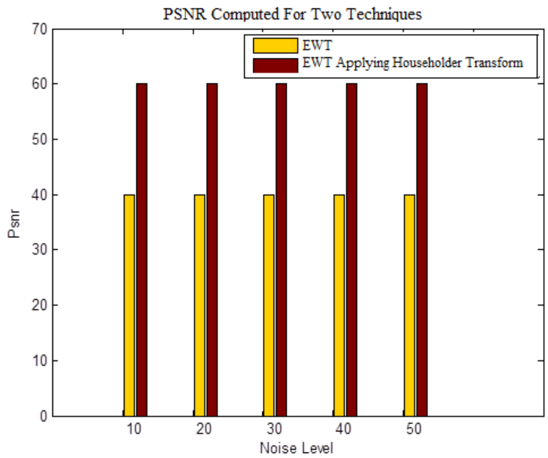

Fig. 16.PSNR Computed For Two Techniques

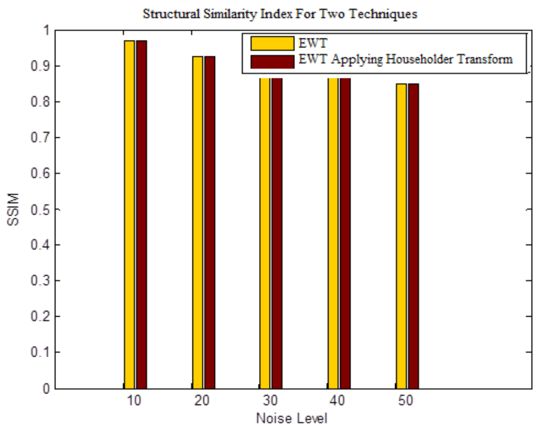

Fig. 17.SSIM Computed For Two Techniques

Fig. 18.IQI Computed For Two Techniques

The performance is evaluated in terms of PSNR, SSIM and IQI is shown in the bar plot in theFig.16, Fig.17, Fig.18. For different noise levels the denoising is performed with different techniques such as EWT and HT. From the bar plot it is clearly illustrated that with the application of Householder Transform in the EWT the PSNR can be increased up to a value of about 60% when the noise level is 10.This clearly gives an idea that the Householder Transform provides that the IMF's obtained as a result of EWT are orthogonal and hence there is no overlapping of IMF components and due to orthogonalization, the PSNR can be increased with the application of house holder transform in the EWT. Similarly the SSIM and IQI is also computed for different noise levels. When the noise level is 10 the SSIM calculated for the EWT is 0.9685 and the same value is obtained while denoising using Householder Transform. In case of IQI , the application of Householder Transform in Empirical Wavelet Transform produces a value of about 0.9298.

VI CONCLUSION

Efficient denoising techniques for images are a valid challenge for researches. Because of the sophistication of the methods, many algorithms are not yet attained a desirable level of applicability. The 2D-EWT is performed to process images. The difference with the processing of 1D EWT is that in case of 2D it process both the rows and columns. Performance of denoising algorithms is measured using PSNR, SSIM and IQI .In case of EWT the IMF's obtained as a result of EWT are not orthogonal. The projection of IMF 1 on IMF 2 will not be zero. Hence to achieve Orthogonalization the Householder Transform is applied, this will cause an increase in the PSNR value. The Householder transform makes the IMF orthogonal and hence the projection of IMF 1 on IMF 2 will be zero and there is no sharing of information takes place which makes the noisy IMF's separate leading to an increase in the PSNR value.

VII FUTURE SCOPES

As an extension work the Empirical Wavelet Transform can be explored in case of deconvolution. For segmenting the Fourier spectrum also different methods can be adopted.

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