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Wavelet-Based Denoising Of Images

Abstract- Wavelet-analysis has become a powerful tool for denoising images. It represents a new way to achieve better noise reduction and increased contrast. Here, experimentally demonstrate abilities of discrete wavelet transform with Daubechies basis functions for improving the quality of noisy images. In this research two methods has been compaired for modify the coefficients using soft and hard threshold to improv the visual fineness of noisy image depend on Root-Mean-Square error (RMS). The low RMS value and better noise reduction find in soft threshold method which is based on Daubechies wavelet (db8) for first example image RMS=0.101 and second example RMS= .109.

Keywords- image processing, wavelet-analysis, noise , Root-Mean-Square error

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1.Introduction

Images are often contaminated due to the many noise types during their acquisition and transmission. Aiming to get the high quality of images, different denoising procedures can be applied. Among widely used techniques for noise reduction, wavelet-based approaches are related to the most powerful ones [1,2,3,4]. These approaches assume a transition from the original image to the wavelet space and further correction of wavelet-coefficients at small scales. Typically, approaches based on the discrete wavelet-transform are used for this purpose. They decompose the image to horizontal, vertical and diagonal elements at different levels of resolution: from large to small scales. While large scales mainly contain information about important image features, small scales characterized by littel wavelet-coefficients are more probably influenced by noise [5]. These littel coefficients can be thresholded without affecting the fluent lineament of the image: if the coefficient is smaller than the threshold, it is adjusted to "zero"; do it another way it remains unchanged. The inverse wavelet signal transform on the budding image provides reconstruction of an signal or image with actual characteristics [6]. Here, consider the case of additive Gaussian noise [7] and experimentally demonstrate abilities of the discrete wavelet transform for improving the quality of noisy images. Denoising an image

or signals can be provided by the correction the Wavelet-Coefficients with hard or soft thresholding approaches. To reach better filtering technique most important select the best analysis method because the large Decomposition-coefficients are mainly associated with a signal. Denoising is achieved by selecting the discrete wavelet transform function 2D-DWT to find the best construction.

2.Related literature

A. D. Salman presented a technique based on wavelet transform or wavelet pasket , then using thresholding methods or "shrinkage" for denoising the images by set all high-frequency sub-band coefficients that are less than particular threshold to (0) . Several grayscale images examples used like Barbara , wbarb , sinsin at different noise levels are 10 , 20 , 30 , with Daubechies wavelet function 10-cofficeint least asymmetric to explore many characteristics of image de-noising algorithm and comparison between wavelet pasket and wavelet transform through RMS and PSNR (Peak-Signal-to-Noise-Ratio). Auther conclude that wavelet pasket transform removes noise better than other technique[8].

F. Xiaoa et al presented method wavelet-based image de-noising through thresholding parameters. To find properties of different threshold techniques are used grayscale test

images (lina, Barbara) of size 512x512 and add various noise (10 , 20 , 30 , 35) with soft-thresholding and semi-soft-thresholding applied to discrete Mayer-filter at the fourth level analyze , then comparison the results through (MSE) and (PSNR). Depend on their results the best method was Feature-Adaptiv shrink and Bayes-shrink with low error[9].

Z. Weipeng et al. presented a technique based on combining 2D-Discrete wavelet transform and using Bilateral-filtering for denoising two images of Coal-Mine of different scenes in refuge chamber with sizes of (352x288) pixels. First the wavelet transform is embraced to separate the image of wellbeing enclosure and low-frequency component of subject image leave unchanged. Second, three high-frequency elements are running by Bilateral-filter for best image reconstructed. While providing better optical effects and at last end incorporating wavelet transforms and Bilateral-Filtering, can as a result destruct image noises of refuge chamber. Depending on information entropy, standard deviation and mean gradient results was compared and reflect this method more effectively eliminate noises[10].

Y. P. chaudhari et al proposed a method based on Discrete wavelet transform and apply Haar, db4, Sym4 wavelet transforms to decomposes (lina , Barbara , cameraman , runner , handshake) grayscale images and study the analysis of the image to more one level (first and second level) on the basis of increased level of analysis the coefficients of sub-band becomes smoother. Soft and hard thresholding performed at each decomposition level of an signal (Harr, db4, Sym4) after adding Guassian noise at the variance intensity (0.01) or salt pepper noise at the variance intensity (0.1). Two parameters (PSNR , MSE) were used for comparison. Wavelet transform Sym4 gives low error values[11].

Previous literature say, image or signal processing method is required to reduction unwanted noise so the quality of processed signal does not deteriorate. In addition, minor reduction of figure size has an adverse effect on the quality of the original size of the figure.

Large figures may span both columns and positioned at the top or the bottom of the page. Borders around outside figure should be avoided. In figure axes labels, use words rather than symbols.

3. Proposed denoising method

Wavelet analysis uses little solution-like functions known as “wavelets”. In technical applications including noise filtering, the discrete form of the

wavelet-transform is typically considered. Functions used within the discrete wavelet-transform do not have analytic expression (except for the simplest, the Haar-wavelet); they are obtained as solutions for some algebraic equations and represented by series of filter coefficients (the filter banks). Among different wavelet-functions, the Daubechies family of orthonormal wavelets is related to the most popular. The request of the Daubechies function means the quantity of vanishing moments, or the quantity of zero moment of the wavelet. The bigger number of vanishing minutes is related with the better localization in the frequency domain. The Daubechies wavelets are indicated as "dbN", where N is the request of the wavelet[12].

In order to apply the wavelet transformation for processing an picture or image we should execute a two dimensional form of the analysis and composing filter banks. In the two dimensional case, the one dimension analysis channel bank is first connected to the columns of the picture and after that connected to the rows . In the event that the picture has N1 rows and N2 columns, at that point in the wake of applying the one dimension analysis channel bank to every column have two sub-band pictures, each having N1/2 lines and N2/2 columns; subsequent to applying the one dimension analysis channel bank to each line of both of the two sub-band pictures, have four sub-band pictures, each having N1/2 lines and N2/2 columns.

When performing denoising based on the soft-thresholding method [13]. Consider a image $f_{i,j}$ of the size (M,N) . Accept that is contaminated by Gaussian noise $Z_{i,j}$ with the standard deviation σ . The damage image, indicated by $y_{i,j}$ is given as in this equation:

$$y_{i,j} = f_{i,j} + Z_{i,j} \quad (1)$$

Based on this noisy image $y_{i,j}$ can find an estimate $\hat{f}_{i,j}$ of the pure-original image $f_{i,j}$.

Can be referred to the 2D discrete and inverse discrete wavelet transforms by W and W^{-1} , respectively. After using the discrete wavelet transform (DWT) W to the image (1), then obtain

$$\begin{aligned} d_{i,j} &= c_{i,j} + \varepsilon_{i,j} , \\ d_{i,j} &= W(y_{i,j}) , \\ c_{i,j} &= W(f_{i,j}) , \\ \varepsilon_{i,j} &= W(z_{i,j}) , \end{aligned} \quad (2)$$

Where $i, j = 1, 2, \dots, M$.

The wavelet thresholding function (T) . The approximation $\hat{f}_{i,j}$ of the pure-original image $f_{i,j}$ after using the wavelet thresholding $y_{i,j}$ is given as in this equation:

$$\hat{f}_{i,j} = W^{-1}(T(W(y_{i,j}))) \quad (3)$$

Here, $\hat{f}_{i,j}$ is obtained from noisy image $y_{i,j}$ by first using the discrete wavelet transform on it for analysis, after that thresholding method used, and then performing the inverse wavelet transform, the soft thresholding function is defined as follows[14]:

$$\hat{f}_{i,j} = \begin{cases} f_{i,j} - T, & f_{i,j} \geq T, \\ f_{i,j} + T, & f_{i,j} \leq -T, \\ 0, & |f_{i,j}| < T \end{cases} \quad (4)$$

When the threshold function is selected as $\hat{f}_{i,j} = f_{i,j}$ and chooses all wavelet coefficients that are greater than T (the given threshold) and set the others to (0). The thresholding approach consider that only low-valued coefficients are changed by (0) is called (hard threshold) and described as [15]:

$$\hat{f}_{i,j} = \begin{cases} f_{i,j}, & |f_{i,j}| \geq T, \\ 0, & |f_{i,j}| < T \end{cases} \quad (5)$$

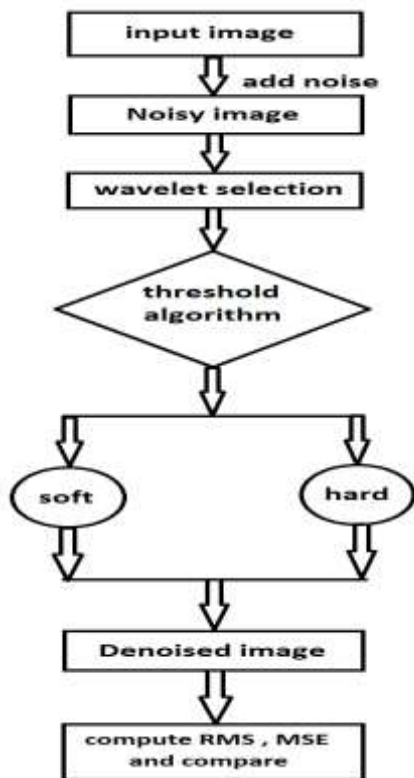


Fig. 1: Denoising procedure schema

The denoising procedure is explained in Fig.1 . Grayscale image are used as original image from MATLAB database as shown in Fig.2 and Fig.3 , then Gaussian noise is added to the original image .Next step Wavelet selected from db1 to db20 to decomposed these Noisy images and compare the quality of filtering, this important step to reduce the lost information after splits the approximation coefficients in the orthogonal wavelet decomposition , the third level decompose is applied to these noisy image , in order to split the sub band of low frequency components as a result the resolution will be much larger. Next step have performed soft and hard threshold and applied to the transformed signal bands, when attenuation the higher-frequency bands, the high-frequency noise is reduced. For many threshold levels can see the effects of attenuation on the denoising characteristics of the image system. The inverse of wavelet transforms has been performed to reaches the best reconstruction and get the denoising image. Final step performed various wavelet transforms and thresholding method with help some parameters such as Root-Mean-Square error (RMS) and Absolute error (MSE) between the original and de-noising images was estimated [16].

4.Parameters selection and Evaluation criteria

In our suggested method, we calculate threshold estimation by using:

$$T = \delta \sqrt{2 \log N} \quad (6)$$

Where δ is the additive noise and N is the number of the coefficients , The threshold is proportional to the size logarithm square root of the image (Donohos threshold) .For better performance to reduction the noise which distributed over all wavelet coefficients ,then used the Bayes threshold rule

$$\lambda_s = \frac{\delta^2_D}{\delta} \quad (7)$$

λ_s are several thresholds in several subbands , δ_D is the noise level estimation is given as in this equation:

$$\delta_D = \frac{1}{0.6745} (\text{median}(|W|)) \quad (8)$$

W are the wavelet coefficients for high level frequency diagonal [17].

The absolute error between the original image and de-noising image is very important to know the noise reduction level, so the term the mean squared error that is defined:

$$MSE = \frac{\sum_{i,j=1}^M (z(i,j) - s(i,j))^2}{M \times N} \quad (9)$$

$s(i, j)$ is the original image without noise and $z(i, j)$ is the appreciation image and $M \times N$ is the image size [18].

The other important parameter is called Root Mean Square error (RMS), It is often used to measure the difference between previously predicted values and the estimated values that actually observed from the image or signal which modeled or estimated, the root-mean-square error between two image is given as:

$$RMS = \sqrt{\frac{\sum_{j=1}^m \sum_{i=1}^n (z(i,j) - s(i,j))^2}{M \times N}} \quad (10)$$

Where the $M \times N$ the size of the image and can see from the above equation that the root mean square error results are monitored relatively for large errors, this means that RMS very good tool and more useful when the big error is particularly undesirable [19].

5. Results and discussion

Thus, by performing soft thresholding and applying Daubechies wavelets we will attempt to remove noise and improve image quality. In this work study how selection of the wavelet transform effects of the image size, and performed its change by using the standard Matlab influences the quality of denoising, and how the results depend on the image size. Aiming to function "imresize".

The procedure of image denoising included several steps: (i) to select the wavelet (dbN, with $N \in [1, 20]$) for direct wavelet transform; (ii) to set the wavelet thresholding function T ; and (iii) to perform the inverse wavelet transform for image reconstruction. For each wavelet and image size calculated the absolute error between the denoised image and the original image.

In results and experiments, have taken a grayscale image (Fig. 2a) of the size 560x800. Standard deviation of the added Gaussian noise was selected as 0.1, 0.2, 0.3, 0.4 and 0.5. For each noise level performed the discret wavelet transform with Daubechies wavelets (dbN, $N \in [1, 20]$) and estimated error of image

reconstruction after the described denoising procedure. According to the obtained results, for all noise levels the best reconstruction (the minimal error) was obtained for db8. Absolute error (MSE) varied from 0.53 ($\sigma=0.1$) to 0.74 ($\sigma=0.5$). The considered image after adding noise and the reconstructed image are shown in Fig. 1b,c.

Further, analyzed how the results depend on the image size. then performed image resizing with different scale factor (from 0.5 to 1.5) and repeated the procedure of image denoising. For 3 values of the scale factor (0.5, 0.6 and 1.1) the minimal error was reached for db14, however, the results were comparable with db8, for other 7 values of the scale factor, the wavelet db8 provided the best reconstruction. Dependencies of the reconstruction error versus the number of wavelet for two scaling factors are shown in Fig. 2d,e.

In order to check how the results depend on the selected image, performed analogous study for another image (Fig. 3). Although best reconstruction can be achieved for different wavelet functions dbN (see, e.g., Fig. 2d), the wavelet db8 allowed to reach minimal reconstruction error in the most selections of noise intensities and image sizes.

Now, by performing soft and hard thresholding and applying Daubechies wavelets will attempt to remove noise and calculate the RMS for each threshold point to find the best soft and hard threshold point which reflect the low RMS error, This means have got a better threshold and better performance to reduce the noise, (Fig. 4) showed the comparison between soft and hard threshold for two image example. According to the obtained results, demonstrates the performance of the two proposed methods by using the Matlab 2-D denosing function which is based on daubechies wavelet (db8) for the first image-example (a) when the noise standard deviation ($\sigma = 0.1$). It is observed that Root-Mean-Square error ($RMS=0.101$) for soft thresholding value (0.198) has much lower error compared with the hard threshold value (0.395) and ($RMS=0.1022$) Second example (b) confirms these results to a noise contaminated image ($\sigma = 0.1$) with soft threshold value (0.139) selected from different threshold levels, an optimal threshold associated with minimal RMS can be selected ($RMS=0.109$) and the hard threshold value (0.303), then the ($RMS=0.112$). Performed the different images allowed us to reach better noise reduction with soft thresholding.

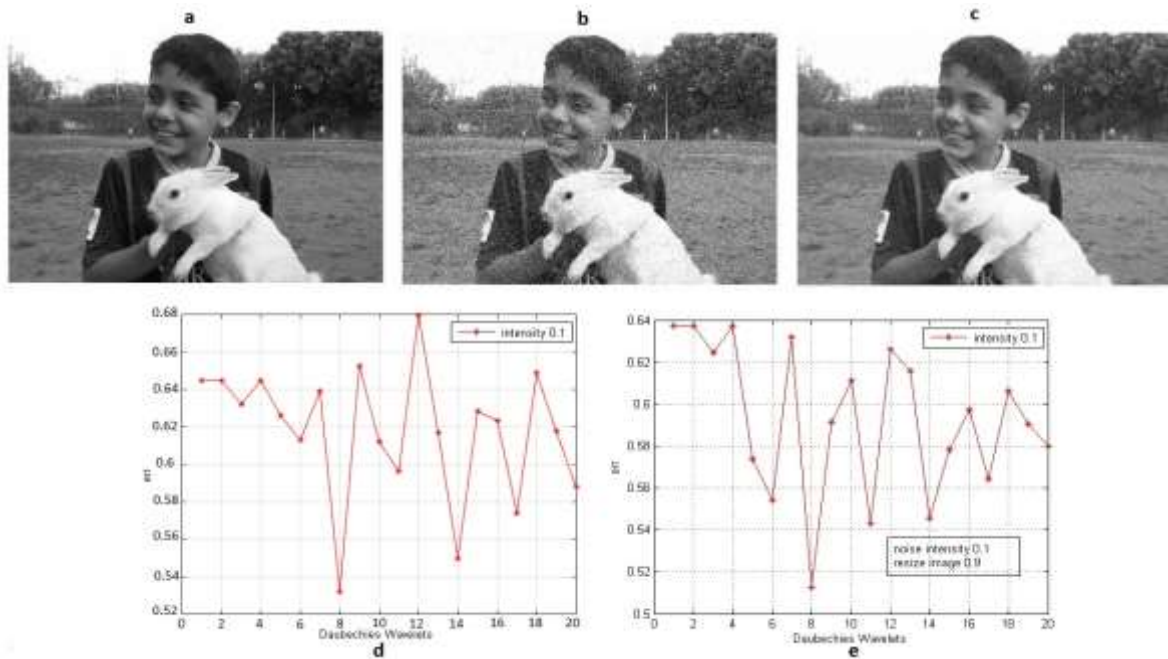


Fig. 2. First image-example of the wavelet(Daubechies function)based denoising: a) original image, b) image with noise ($\sigma= 0.1$), c) image after denoising procedure with the wavelet db8, d) and e) dependencies of the reconstruction error (*MSE*) versus the number of wavelet for scaling factors 1.0 and 0.9, respectively.

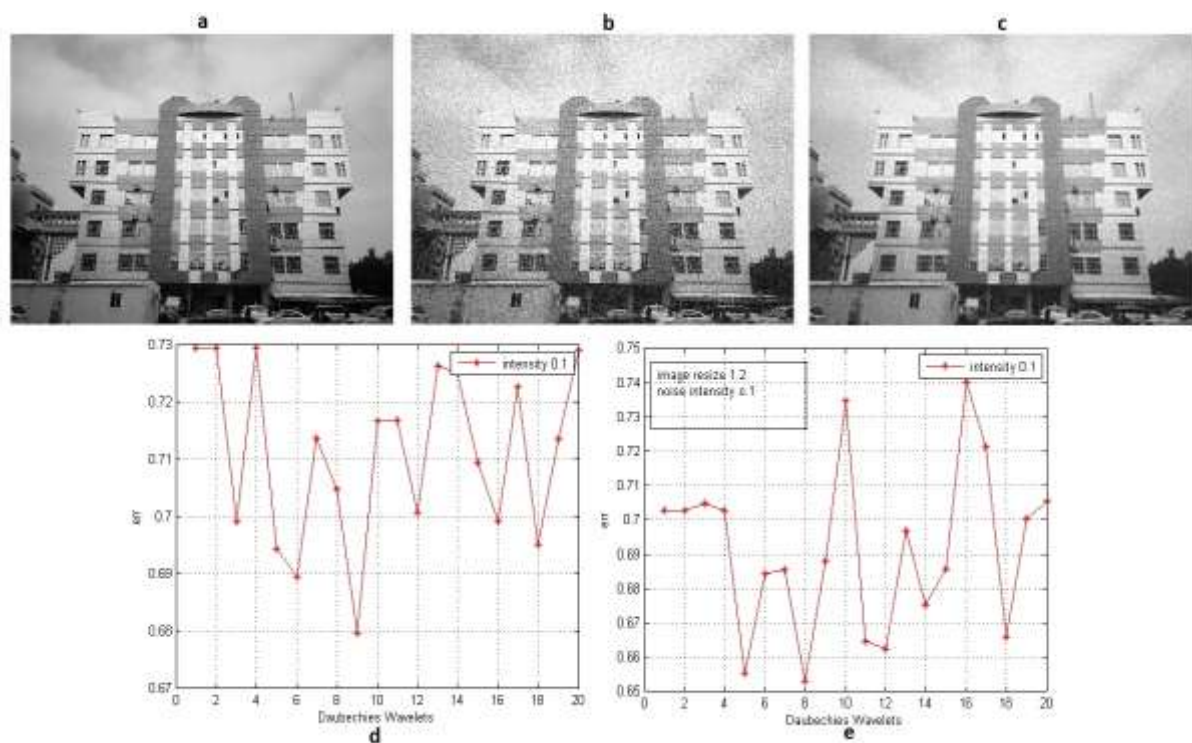


Fig. 3. Second example of the wavelet-based denoising. All denotations are the same as in Fig. 1.

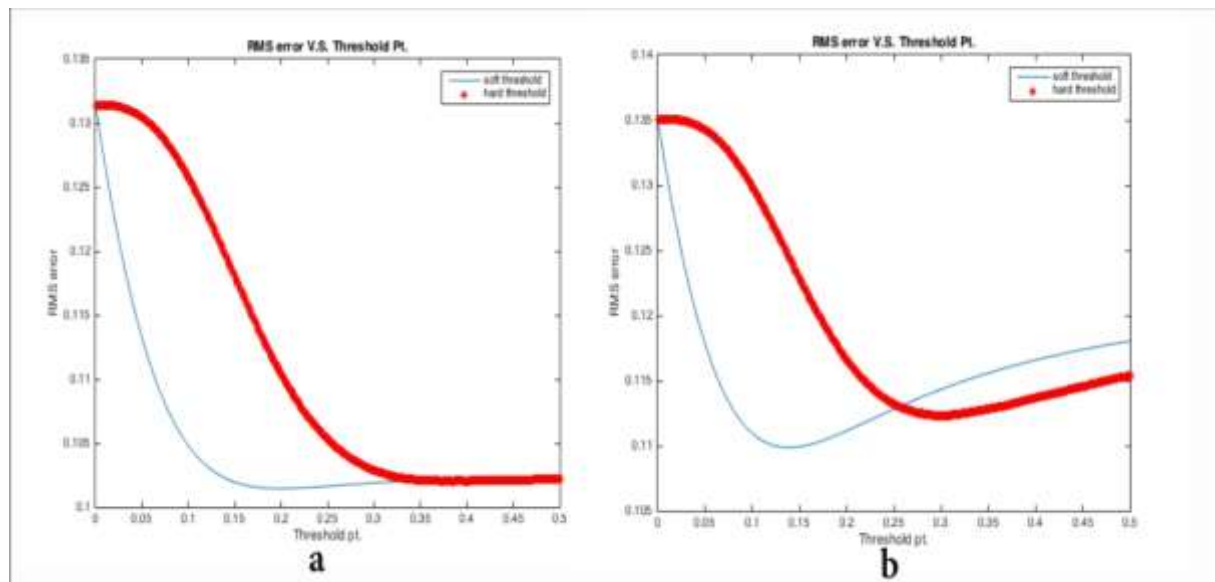


Fig. 4.a.first image example *RMS* error Vs. soft and hard threshold ($\sigma=0.1$) b. second image example *RMS* error Vs. soft and hard threshold ($\sigma=0.1$)

5. Conclusion

Thus, we used in this work the Daubechies wavelets (db1, ..., db20) for improving the quality of noisy images considering the case of additive Gaussian noise. Has been used analyzed how the quality of image reconstruction depends on the noise intensity and image size. According to the obtained results, the best image denoising is obtained by the wavelet db8 that provided the minimal reconstruction error. Daubechies wavelet with soft and hard threshold was shown that soft threshold increases denoising performances of two dimensions DWT compared with hard thresholding because all coefficients for a noisy image are corrected to keep signal regularity after reconstruction, the soft threshold is a better approach for wavelet denoising.

References

- [1] C.S. Burrus, R.A. Gopinath, H. Guo, "Introduction to wavelet and wavelet transforms," New Jersey: Prentice Hall, 1 st ed ,P. 268,1998.
- [2] S. Gupta and L. Kaur, " Wavelet Based Image Compression Using Daubechies Filters,"proceeding of the 8th national conference on communications, Bombay , 2002.
- [3] W. A. Mahmoud , M. S. Abdul-wahab , A. A. sabri , " A New Algorithm For Reconstruction of Lost Blocks Using Discrete Wavelet Transform, " Engineering and technology journal , Vol.24 , No. 10 . 2005
- [4] D. B. H. Tay , "Daubechies Wavelets as Approximate Hilbert-Pairs? , " IEEE signal processing letters , Vol.15,pp.57-60, 2008.
- [5] M. Jansen, "Noise reduction by wavelet thresholding," New York: Springer-Verlag, Vol 161, p. 196, 2001.
- [6] D.L.Donoho, I.M. Johnstone, "Ideal spatial adaptation via wavelet shrinkage,"Biometrika. 1994. Vol. 81, No. 3, P. 425 – 455.
- [7] P. Patidar, M. Gupta, S. Srivastava, A.K. Nagawat, "Image denoising by various filters for different noise," International Journal of Computer Applications. Vol. 9. No. 4. P.45-50, 2010.
- [8] A. D. Salman , " Wavelet and Wavelet Packet Analysis For Image Denoising, " Engineering and technology journal , Vol. 27. No 9 , 2009
- [9] F. Xiaoa and Y. Zhanga, " A Comparative study on Thresholding Methods in Waveletbased Image Denoising," Advanced in control Engineering and information Science, procedia Engineering 15 , p.3998 – 4003 , 2011
- [10] Z. Weipeng,"image denoising algorithm of refuge chamber by combining wavelet transform and bilateral filtering," International Journal of Mining Science and Technology 23, science Direct, p. 221 – 225 , 2013.
- [11] Y. P. Chaudhari , P. M. Mahajan ," Image Denoising of Various Images using Wavelet Transform and Thresholding Techniques," International Research Journal of Engineering and Technology , Vol 4 . Issue 02 , 2017
- [12] D. Abhinav, M. Swatilekha, " comparative analysis of coiflet and daubechies wavelets using global threshold for image denoising, " International journal of advances in engineering and technology. vol. 6 p. 2247-2252, 2013.

- [13] H. Om, M. Biswas, “ A new image denoising scheme using soft thresholding,” *Journal of Signal and Information Processing*. Vol. 3. P. 360 – 363. 2012.
- [14] D. L. Donoho, “De-Noising by Soft Thresholding,” *IEEE Transactions on Information Theory*, Vol. 41, No. 3, pp. 613-627, 1995.
- [15] P. Hedao and S. S. Godbole , “ Wavelet Thresholding Approach For Image Denoising, ” *International journal of network security and its application* ,” Vol.3 , No.4, 2011.
- [16] A. S. yaseen , O. N. pavlova , A. N. Pavlov , “ Wavelet Filtration of Noisy Images ,” *Technical physics letters* , Vol 42, issue 1 , p. 82-84 , 2016
- [17] A. Bijalwan , A. Goyal and N. Sethi , “ Wavelet Transform Based Image Denoise Using Threshold Approaches,”*Vol.1 Issue-5* , 2012.
- [18] H. Om, M. Biswas, “ An Improved Image Denoising Method Based on Wavelet Thresholding , ” *Journal of signal and information processing* , Vol. 3 pp. 109-116 , 2012.
- [19] P. Ndajah, H. Kikuchi, M. Yukawa, H. Watanabe , S. Muramatsu, “ An Investigation on The Quality of Denoised Images, ”*international journal of circuits , systems and signal processing* , Vol.5, Issue 4 , 2011.