Comparative Analysis of Image Denoising

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***Abstract*— In day today life we come across many visual scenes everyday such as images, audio, video frames and this visual information can be stored, processed, transmitted, recognized and interpreted in different ways. Several image processing techniques like pattern recognition, binarization, image denoising, segmentation, etc., are used in different applications to enhance the quality of the image and each technique has its own merits and demerits. This article examines the various image denoising methods used for image processing in order to achieve a high quality image as well fast retrieval.**

Keywords*— Pattern recognition; binarization; image denoising; segmentation;

I. INTRODUCTION

Digital images plays a vital role in many applications like satellite television, MRI (magnetic resonance imaging),GIS (geographical information systems),astronomy, Remote Sensing, Medical Imaging, Non-destructive Evaluation, Forensic Studies, Textiles, Material Science, Military, Film industry, Document processing, Graphic arts, Printing Industry, etc. In practical the data sets collected by image sensors are usually contaminated by various types of noises. Imperfect instruments, problems with the data acquisition process, and interfering natural phenomena can all degrade the data of interest [12]. Generally noise can be introduced by channel interferences, transmission errors and compression etc., in which it degrades the image quality by changing its pixel value. Most of the natural images are assumed to have additive random noise referred as Gaussian noise with or without coherence, speckle noises are found in ultrasound images, MRI images are affected by rician noise .Other common noises are salt-and-pepper noise, shot noise, quantization noise, film grain, anisotropic noise, etc.,

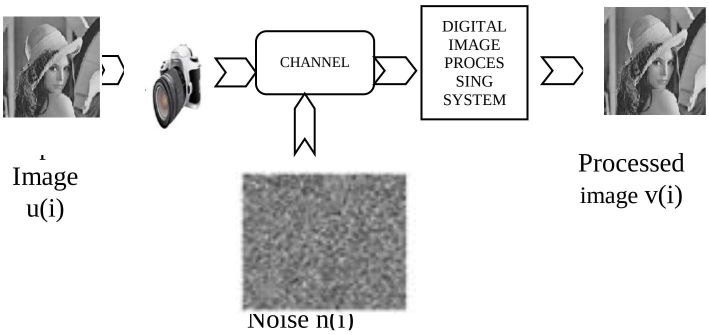

Fig 1: Block Diagram

Here the received image can be represented as, **v(i)=u(i)+n(i).**Where, v(i) is the observed value, u(i) is the true value and n(i) is the noise value at the pixel i. Hence remove or suppress the noise in the image is a necessary step in many image processing application. Several techniques are used to remove the noise in the image. Among the various methodologies image denoising is one of the active research area.

II. TYPES OF IMAGE NOISE

Noise can be either additive or in multiplicative form. Noises of additive nature, gets added to the original signal to corrupt signal/image is called additive noise while those noises which gets multiplied to the original signal are called multiplicative noise model. Pattern of various noises such as Gaussian, uniform, salt-and-pepper, speckle and their probabilistic characteristics are discussed below.

A. Gaussian Noise

Gaussian noise is a statistical noise whose probability density function is equal to that of normal distribution. Gaussian noise is caused by random fluctuations in the signal (Johnson-Nyquist noise). In additive white Gaussian noise each component of pixel is distributed identically independent at each pixel. It is uncorrelated since it is independent of signal intensity. Digital images can be degraded by Gaussian noise during acquisition of the image. Gaussian smoothing involving Gaussian Blur and edge detection is an important process used by denoising algorithms to denoise the image.

B. Uniform Noise

It is a quantization noise caused when the pixels of the scanned or sensed image is quantized into a number of discrete levels. The probability density function of this noise is approximately equal to that of uniform distribution. In this type of noise, a specified range in the image is uniformly distributed by grey values. It may either be signal dependent or signal independent according to dithering techniques.

C. Salt and Pepper Noise

It is also known as spike or shot noise. This type of noise is caused by sharp and sudden disturbances in the image signal. The image with salt-and-pepper noise has dark pixels in bright regions and bright pixels in dark regions that white and black pixels are randomly distributed over the noisy image. The probability mass function of shot noise is equal to that of Poisson distribution. Since it is discrete in nature, there is only two possible values of 'a' and 'b' such that 0 (for black called pepper noise) and 255(for white called salt noise). It is caused by malfunctions in camera sensor cells, transmission errors, etc.

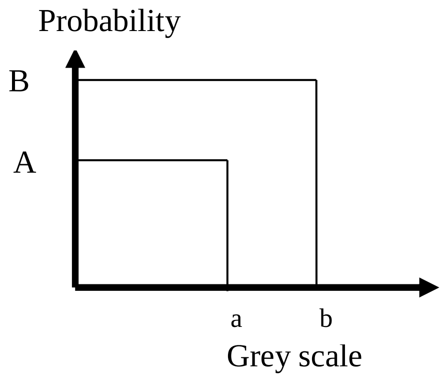

Fig 2: Salt-and-Pepper noise

D. Speckle Noise

Speckle noise is generally found during image acquisition and transmission process in Synthetic Aperture Radar (SAR) images, satellite images and medical images. Speckled noise can be modeled by random values multiplied by pixel values of an image. Speckle noise occurs due to the interference caused to the image during transmission and reception. It results in bright and dark spots in the image due to constructive and destructive interference.

III. IMAGE DENOISING

Denoising aims at attenuating the noise while retaining the contents of the image such as edges, corners and texture details with high precision as that of original image. Image denoising is one of the important steps in image preprocessing for performing high level task such as image recognition and interpretation of scenes in the image. Denoising, apart from technical difficulties they may also result in destruction of image if applied non-effectively and inadequately. It is very important to apply an efficient denoising technique to the images to retain its original precision. To achieve good performance, the denoising algorithm should adapt to image discontinuities. At First a spatial domain approach has been implemented. This filter domain approach is a speedy method but it is unable to preserve edges, which are identified as discontinuities in the image. This problem is overcome by wavelet domain approach in which it has a great advantage of preserving edges.

A. Classification of denoising algorithm

Filtering is a fundamental pre-processing operation performed in image processing. The technique used for enhancing or modifying an image is called filtering. In filtering the value of any given pixel in the image is determined by applying some algorithms to the values of the pixel in the neighborhood of the corresponding input level. Spatial domain filtering and transform domain filtering are the two fundamental approaches for image denoising. Various spatial and temporal domain filtering methods are shown in Fig 3.

Spatial domain filtering is the traditional way to remove noise from the image which is further classified into linear and non-linear filtering. In transform domain filtering, the denoising algorithm is chosen according to the basis function. These basis functions are again classified into data adaptive and non-adaptive transforms.

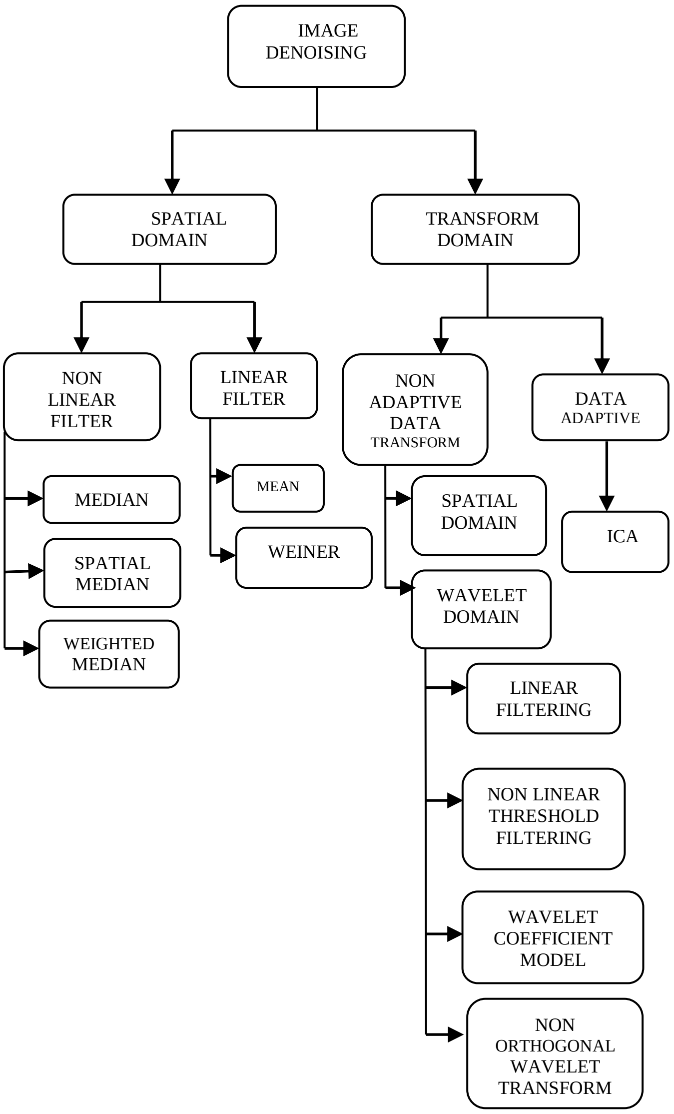

Fig 3: Classification of Image Denoising

A. Mean Filter:

Mean filter also known as average filter is an example of linear filtering under spatial domain. The process of reducing the amount of intensity variation between one pixel to the next corresponding pixel is called smoothing. Smoothing plays a vital role in image denoising. Mean filtering is a simple and easy method for smoothing the images. In mean filtering, masking is done on each pixel in the signal. Then the average of the mask containing each component of the pixel is taken to form a single pixel. Mean filtering is useful in the case of removing grain noise and Gaussian noise. They suffer from a major drawback that they tend to blur the sharp

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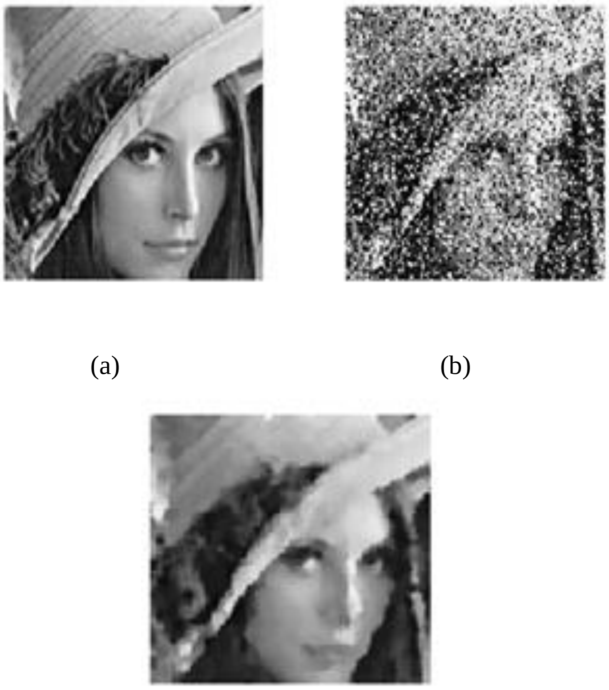
edges in the image, destroying lines and other fine structures present in the image.

B. Median Filters

Median filter is a type of non-linear filter. It follows the sliding window principle. By taking median value within a user defined window for each data point. The pixels are scanned over pixel matrix of the entire image. The median of the surrounding pixel values in the window, the center pixel of the resultant is calculated and replaced with the computed median. There are various median filters like standard median filter (SMF), central weighted median filter (CWMF) adaptive weighted median filter(AWMF),recursive median filter, iterative median filter, directional median filter, switching median filter, adaptive median filter, etc. It preserves the sharpness in the image but there is no error propagation.

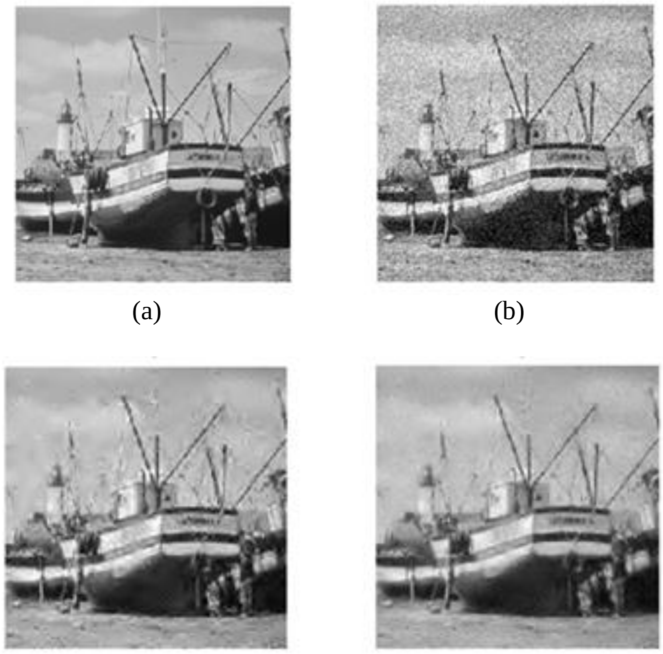


(a) (b) (c)

Fig 4: (a) Input image (b) Noise image (c) Output image after applying median filter.

C. Discrete Wavelet Transforms

Wavelet transform decomposes a signal into a set of basic functions called wavelets. Discrete wavelet transform transforms a discrete time signal to a discrete wavelet representation. Denoising is carried out by choosing a wavelet and a level N, decomposition of the signal at level N is computed. The soft thresholding method is used to compute the threshold of the detail coefficient. Then reconstruct the signal using the approximation coefficients and the modified detail coefficients. It has better performance due its properties like sparsity, multiresolution and multiscale nature, etc. This method has low computational complexity when used with wavelet filter banks. However, good denoising is possible with clarity at lower level decomposition, there is lack of directionality of decomposition functions. Also it suffers ringing near discontinuities.



(a) (b) (c) (d)

Fig 5: (a) Original image (b) Noisy image (c) Hard Denoising (d) Soft Denoising

D. Independent Component Anaysis

Independent Component Analysis is an example of Data-Adaptive Transform under Transform domain filtering. ICA is a well-suited denoising technique for non-Gaussian data. Demerits of using ICA based methods over other wavelet based method are the Computational cost. The computational cost of ICA algorithm is high because it uses sliding window and also it requires sample of noise free data or it requires at least two frames of the same data.

E. Two-Stage Image Denoising By Principal Component Analysis With Local Pixel Grouping

PCA is a method of identifying the patterns in data and expressing them with similarities and differences. It is a de-correlation technique used for dimensionality reduction, data compression and random noise reduction. In PCA it is easy to compress the data without much loss of information. In this technique, the image subjected to noise is passed on through two stages of denoising process. The first stage involves the initial estimation of the image by removing much of the noise. The blur image is given as the input and local pixel grouping and principal component analysis is performed. Then thresholding value is set and then inverse PCA is performed depend on the above value to reconstruct the quality of the image. The same process is iterated for the second stage to adjust the noise level and to improve denoising performance. This method has better image structure preservation near discontinuities such as edges, corners, etc.

F. *Total Variation Model*

It is observed that noise will be at high frequencies. The signal and images with excessive and spurious detail will have the high total variance that is the integral of the absolute gradient of those signals and the image is high. The key idea behind image denoising using total variance is based on the above observation to reduce the total variance of the signal or image subject to it for getting a close match to the original signal. The TV-L1 model is not strictly convex. This means that in general, there is no unique global minimizer.

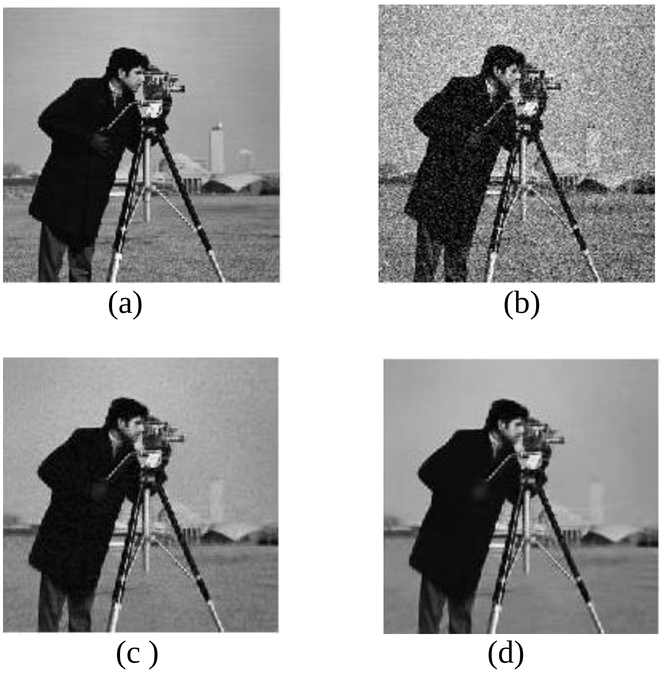
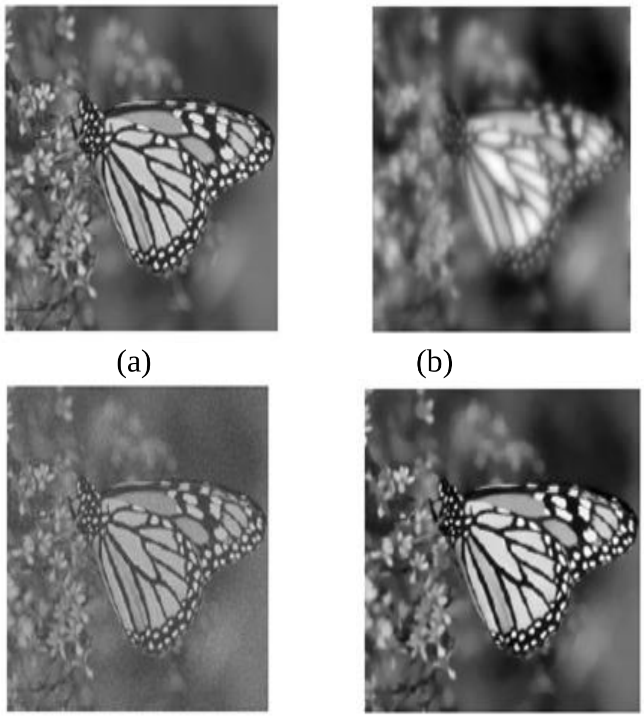


Fig 6: (a) Original image (b) Noisy image (c) Denoised image after the first stage of LPG-PCA Denoising. (d) Denoised image after the second stage of LPG-PCA Denoising.

This is one of the best edge preserving regularization method. The TV-L1 model also offers some desirable improvements. First, it turns out that the TV-L1 model is more effective than the ROF model in removing impulse noise (e.g. salt and pepper noise) Second, the TV-L1 model is contrast invariant. Therefore the TV-L1 model has a strong geometrical meaning which makes it useful for scale-driven feature selection and denoising of shapes. This method is very useful when the pixels are located at the edges since, it can preserve the edges. It retains sharp intensity boundaries of the denoised image. Yet it suffers a major drawback that absolute intensity levels are altered during denoising. And also shapes in images are altered by high boundary curvature, reducing object perimeter.



(c) (d)

Fig 7: (a) Original image (b) Noisy image (c) Output image denoised by Tikhonov model (d) Output image denoised by TV-L1 model.

IV. IMAGE QUALITY METRICS

The various image quality metrics which is used to discover the quality of the output image are discussed below.

A. *Peak Signal to Noise Ratio (PSNR)*

A.

$$PSNR = 10\log_{10}\left(\frac{Peak^2}{MSE}\right)$$

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right)$$

PSNR is commonly expressed in terms of the logarithmic decibel scale. Higher PSNR value offers a good image quality.

B. *Structural Similarity Index Metrics (SSIM)*

$$SSIM = \frac{\left(2\sigma_{xy} + C_2\right)\left(2\times\bar{x}\times\bar{y} + C_1\right)}{\left(\sigma_x^2 + \sigma_y^2 + C_2\right)\left(\left(\bar{x}\right)^2 + \left(\bar{y}\right)^2 + C_1\right)}$$

Where C_1 and C_2 are constants.

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \quad \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$$

The SSIM index is in the range between [0, 1]. A value 0 indicates no correlation between the images. A value is close to one indicates that the denoised image is as close as to original image.

C.Mean Squared Error

$$MSE = \frac{1}{MN}\sum_{ij}\left(A_{ij} - B_{ij}\right)^2.$$

Where A_{ij} is the original image, B_{ij} is the denoised image. Larger the MSE value, image quality is poor.

D.Laplacian Mean Squared Error (LMSE)

$$LMSE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\nabla^2 A - \nabla^2 B\right)^2}{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\nabla^2 A\right)^2}$$

Smaller value of laplacian mean squared error provides good denoised image

E. Normalized Absolute Error (NAE)

$$NAE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left|\nabla^2 A - \nabla^2 B\right|}{\sum_{i=1}^{m}\sum_{j=1}^{n}\left|\nabla^2 A\right|}$$

Smaller value of Normalized Absolute Error (NAE) provides good denoised image.

V. CONCLUSIONS

Noises in the image can be removed by using various denoising methodologies. Mean filter (Linear filter) and median filter (Nonlinear filter) both are performing well for removing impulsive type of noises. Wavelets play a very important role, especially when the noise is a Gaussian type. ICA is a well-suited denoising technique for non-Gaussian data. Two-Stage Image Denoising by Principal Component Analysis with Local Pixel Grouping is a best method, in which it has a better image structure preservation near discontinuities such as edges, corners, etc. In Total Variation Denoising Model well suited when the pixels are located at the edges since, it can preserve the edges. It retains sharp intensity boundaries of the denoised image.

VI. REFERENCES

[1] Lei Zhang, Weisheng Dong, David Zhang, and Guangming Shi, “Two-stage image denoising by principal component analysis with local pixel grouping”, Elsevier, Pattern Recognition 43 (2010), 1531–1549.

[2] Jansirani S, Karthikeyan S, Kiruba Priyadharsihni V, “Combined Method of Two Stage LPG-PCA Denoising with Impact on Preprocessing Step for Noisy Images” , International Journal of Computer Applications (0975 – 8887) Volume 83 – No 11, December 2013.

[3] Ioana Adam, ”Complex Wavelet Transform: application to denoising”, Politehnica University Of Timisoa,

[4] Torsten Seemann, “Digital Image Processing using Local Segmentation”, Monash University, Australia, April 2002.

[5] Sukadev Meher,” Development of Some Novel Nonlinear and Adaptive Digital Image Filters for Efficient Noise Suppress”, National Institute of Technology, Rourkela, Orissa, December 2004.

[6] Mr. Salem Saleh Al-amri , Dr. N.V. Kalyankar and Dr. Khamitkar S.D, “A Comparative Study of Removal Noise from Remote Sensing Image”, IJCSI International Journal of Computer Science Issues, Vol. 7, Issue. 1, No. 1, January 2010.

[7] Rajat Singh, D.S. Meena, “Study Of Image Denoising Using Curvelet Transform”, National Institute of Technology, Rourkela, 2013.

[8] Anutam, Rajni, ”performance analysis of image denoising with wavelet thresholding methods for different levels of decomposition”, International Journal of Computer applications(0975-8887),Vol-86,No 16,January 2014.

[9] Vikas D Patil, Sachin D.Ruikar,”PCA based image- enhancement in wavelet domain” ,International Journal of Engineering Trends and Technology”,vol-3,issue 1,2012.

[10] Prateek Kumar Garg, Puspneel Verma, Ankur Bhardwaz, ”A survey paper on various median filtering techniques for noise removal from digital images”, American International Journal of Research in Formal, Applied &Natural Sciences.

[11] V N Prudhvi Raj, T Venkateswarlu,”Denoising of medical images using total variational method”, Signal &Image Processing: International Journal (SIPIJ), vol-3, no-2, April 2012.

[12] Y.Murali Mohan Babu, M.V.Subramanyam, M.N.Giri Prasad, “PCA based image denoising”, Signal &Image Processing: International Journal (SIPIJ) Vol.3, No.2, April 2012.

[13] Rupinderpal Kaur,Rajneet Kaur,”Survey of De-noising Uing Filters and Fast Wavelet Transform”, International Journal of Advanced Research in Computer Science and Software Engineering,Vol.3,Issue 2,February 2013.

[14] Toran Lal Sahu,Deepty Dubey,”A Survey on Image Noises and Denoise Tachniques”, International Journal of Advanced Research in Computer Engineering &Technology”,Vol.1,Issue 9,November 2012.

[15] C.Liu,W.T.Freeman,R.Szeliski and S.B.Kang,”Noise Estimation from a Single Image,”Proc.IEEE Conf. Computer Vision and Pattern Recognition,pp.901-908,June 2006.

[16] D.L.Donoho,”De-noising by soft-thresholding”,IEEE Trans. Information Theory,Vol.41,No.3,pp.613-627,May 1995.

[17] Shawetangi kala Raj Kumar Sahu, “Comparative analysis between PCA and Fast ICA based Denoising of CFA Images for SingleSensor Digital Cameras”, International Journal of Advanced Research in Computer Engineering & Technology Vol. 1, Issue 5, July 2012