Image Denoising Based on Particle Filtering: A Literature Review

EKTA KESHARWANI
Department of Electronics and Communication Engineering
Jabalpur Engineering College Jabalpur (M.P.), India
E-mail: ektakwani09@gmail.com

AGYA MISHRA
Department of Electronics and Communication Engineering
Jabalpur Engineering College Jabalpur (M.P.), India
E-mail: agyamishra@gmail.com

Abstract

Image denoising plays an important role in many applications such as image restoration, visual tracking, image segmentation, image classification etc., where obtaining the original image content is crucial task for high performance. Image denoising is one of the fundamental challenges in the field of image processing and computer vision applications. This paper reviews different algorithms mainly focused on application of particle filtering along with other frequency domain filters for image denoising application. Particle filter alone is capable to suppress outlier rich components of noise but when used in combined form it can provide new dimensions of flexibility for addressing noise components. The main contribution of this paper is to find a unified framework to denoise any image using particle filtering.

Keywords: Image denoising; Particle filter; Peak signal to noise ratio; Mean square error; improved signal to noise ratio.

1. Introduction

Image denoising is an important image processing task, both as a process itself, as a component in other processes. There exists number of techniques to denoise an image or a set of data exist. The main properties of a good image denoising model is that it will remove noise while preserving important details [8]. In this paper we have compared number of denoising techniques which involves different algorithms for different types of image noises. There are two kinds of typical noises, one is salt and pepper noise also termed as impulse noise which have the same amplitude but random position, the other is the random noise that distribute randomly and each pixel has amplitude. Thought of particle filter into weighting filter which is based on similarity choosing put forward a new denoising method by improving gray information and image edge structure information [1]. Rao-Blackwellized Particle filtering method involves a combination of particle filter and a kalman filter along with MLE (maximum likelihood estimation) which can easily calculate posterior distribution with a recursive, stochastic mixture of Gaussians [2]. In image restoration process calibration measurement helps us to get the system matrix which gives relation between particle position and induced voltage signal in the receive coil, and denoising the system matrix using frequency domain filters(by DFT or DCT) results in better resolution and better signal to noise ratio[3]. Recursive 2D particle filter and particle filter along with DWT (discrete wavelet transform) can be used to improve different types of degradation such as linear/nonlinear sensor model and space-invariant/space invariant blur [4] [5]. Particle filters are proven best application in tracking problems so in robot localization particle filter has been used to calculate the best possible disparity value of each pixel in a stereo pair [6]. All these papers are compared with respect to some parameters like PSNR, MSE, ISNR and variance of noise and discussed along with their advantages and limitations.

2. Performance Analysis

This papers reviews various algorithms based on different types of particle filtering techniques to denoise any image and mostly includes particle filters for their major application and their performance analysis are discussed separately for each paper.

2.1 *Gaussian filter along with weighted particle filter-*

In this paper [1] both grey information and edge structure information is considered compared to traditional Gaussian filter which only considers grey information of the image. This is possible only because of combination of Gaussian filter and weighted particle filter. Result in terms of PSNR and different four types of

parameters has been shown in the Fig. 1 below which shows that this hybrid combination of filter works better than any gaussian filter or NL-means filter.

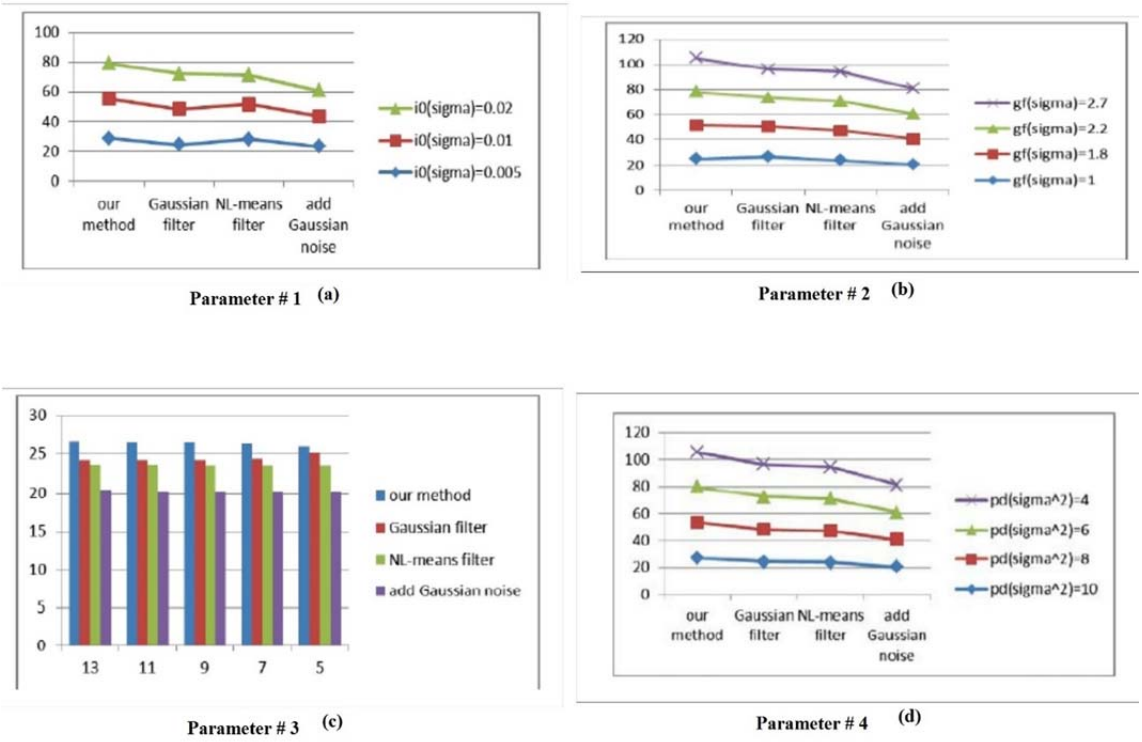

Fig. 1 The PSNR value under different parameters; (a) i0 (sigma), (b) gf (sigma), (c) k size, (d) pd (sigma) [1]

This method selects pixels that are similar to the current pixel to do weighted average within a fixed small window but not range in the whole image and weight not only relates to images grey value, but also uses variance of its edge structure. So this paper concludes that it can easily remove image noises and maintain well texture structure. It reflects good denoising effect for normally distributed noise.

2.2 RBPF with MLE algorithm-

In this paper [2] RBPF with MLE is Rao-Blackwellized particle filter with maximum likelihood estimation. Rao-Blackwellization is done by combining particle filter with a bank of kalman filters. Maximum likelihood estimation finds the distribution of noise by evaluating likelihood around a particle dependent.

Algorithm for proposed method is given below-

- Input real noisy image and Estimate noise level using fast estimation.
- Apply RBPF with MLE to real noisy image.
- Reduce dimension of noisy image.
- Compute variables that are to be sampled using sequential importance sampling.
- Multiply/discard samples with respect to high/low importance weight by selection step.
- Compute marginal posterior distribution of discrete states.
- For each sample, update the mean and covariance of continuous state using kalman filters.
- Calculate weights and noise reduced image at output will be received.

TABLE I. PSNR VALUES FOR DENOISED MEDICAL IMAGES OF DIFFERENT ESTIMATED GAUSSIAN NOISE LEVELS

Images	Noise Level	PF	MRF	RBPF	RBPF +MLE
image1	1.6015	37.9994	41.1826	44.1102	47.2995
image2	1.4591	38.1975	41.4005	44.0645	47.5081
image3	1.4170	38.4394	41.5705	43.6580	47.5820
image4	1.3997	38.1817	41.3929	42.8167	47.4977
image5	1.4918	38.2677	41.4375	43.6565	47.5020

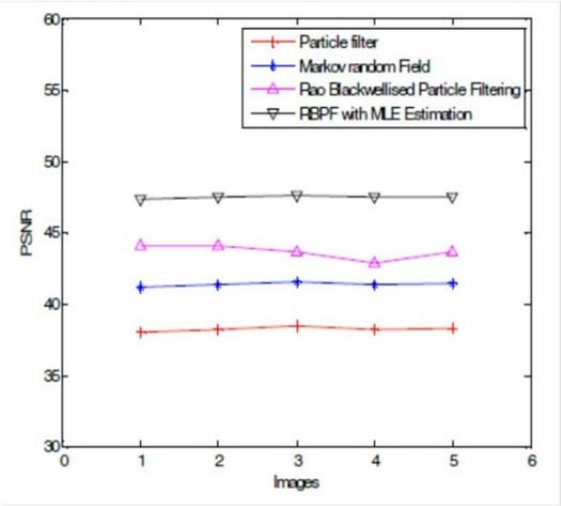

TABLE II. MSE VALUES FOR DENOISED MEDICAL IMAGES OF DIFFERENT ESTIMATED GAUSSIAN NOISE LEVELS

Images	PF	MRF	RBPF	RBPF+MLE
image1	1.0665	0.7641	0.5532	0.3813
image2	1.0334	0.7368	0.5584	0.3659
image3	1.0188	0.7355	0.5775	0.3691
image4	1.0632	0.7566	0.5874	0.3768
image5	1.0455	0.7518	0.5906	0.3775

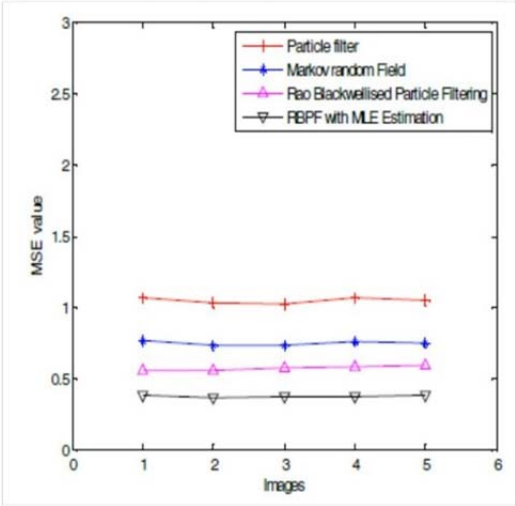

Fig. 2 PSNR & MSE values with plot for RBPF with MLE [2]

This algorithm was tested for many standard grey scale images. Dataset images have taken from a medical center through internet. These noisy images are denoised by four algorithms particle filter, MRF particle filter, RBPF and RBPF with MLE. Tested results are shown in the Fig. 2 above. Hence this paper concludes that RBPF with MLE gives better results compared to other three algorithms mentioned in [2] by providing better Gaussian noise corrupted digital images.

2.3 Magnetic particle imaging using frequency domain filtering-

In this paper [4] standard approach employs reconstruction of system matrix. Magnetic particle imaging is new modality, which allows the determination of the spatial distribution of magnetic nanoparticles in-vivo. As an effect of measurement based calibration and because measurement based acquisition system matrix contains noise and this limits the quality of reconstruction result. To denoise the system matrix we use DFT and DCT transform along with hard and soft thresholding because system functions are well compressible with certain basis transformation this results in decreasing the regularization parameter and increasing the no. of iterations. Thereby, a higher resolution and lower noise floor of the reconstructed particle map. Reconstruction result of this algorithm has been shown in Fig. 3

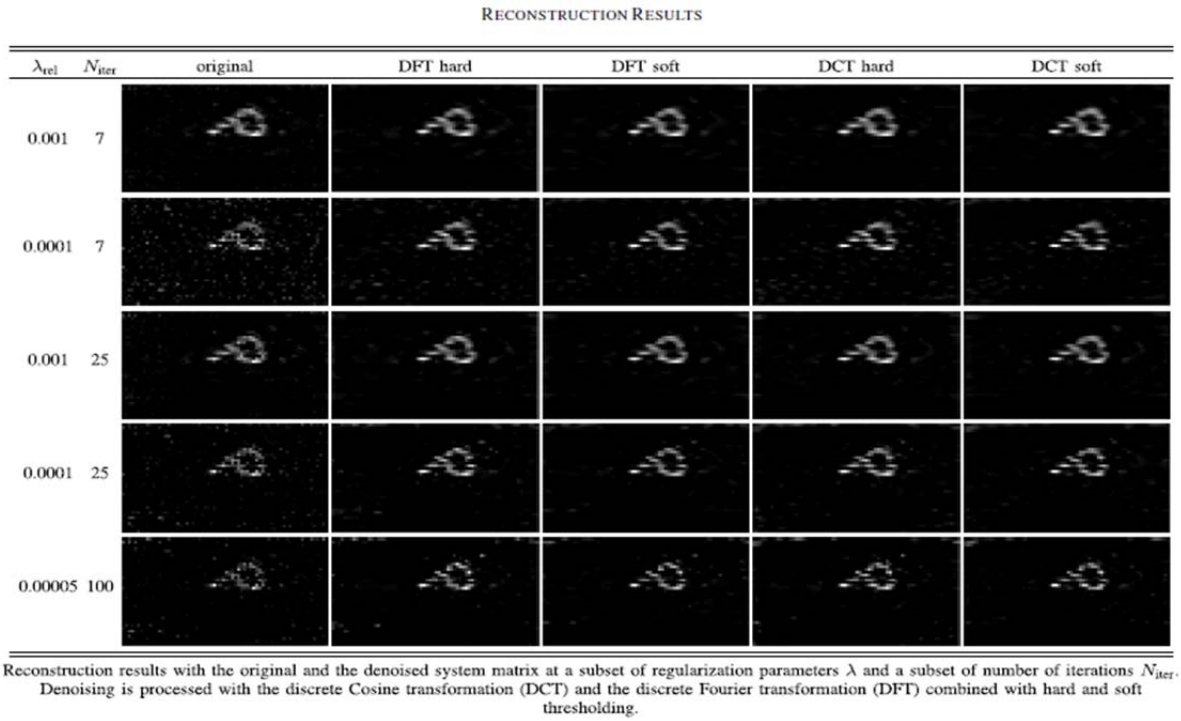

Fig. 3 MPI with DFT and DCT results [3]

This paper concludes that resolution of the reconstructed particle distribution is enhanced. Furthermore, a higher SNR of the reconstructed particle map is achieved using a denoised version of system matrix.

2.4 Algorithm using hybrid combination of particle filter and wavelet-

In [4] [5], particle filter along with wavelet transform for image denoising of a standard grey scale image. Particle filter effectively restores image suffering from space variant blur, nongaussian noise and nonlinearity due to sensor but is less efficient in suppressing Gaussian noise component. This limitation is overcome by using combination of particle filter along with DWT Shown in Fig. 4

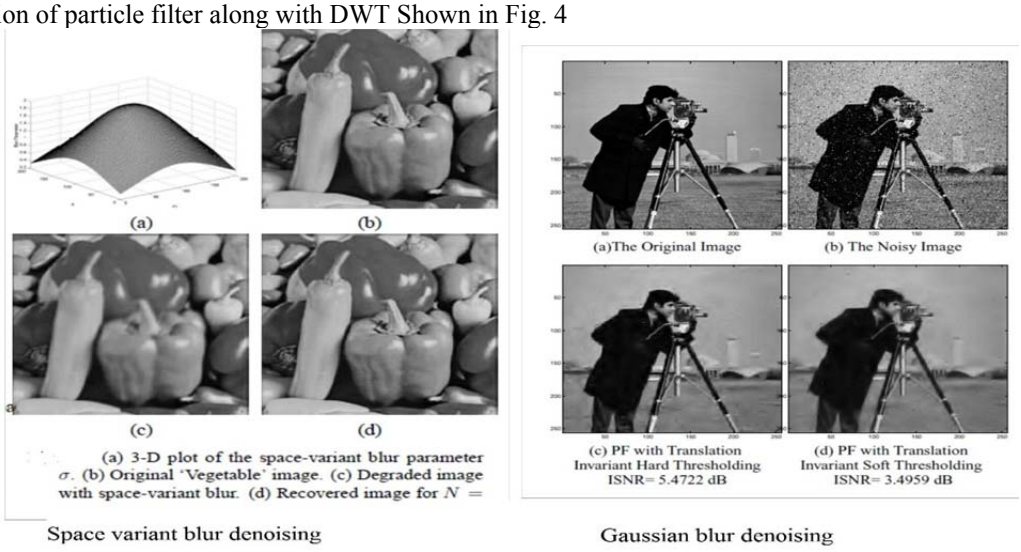

Fig.4 Space variant blur and Gaussian blur denoising [4], [5]

2.5 Scan line weighted Particle filter algorithm to calculate disparity map –

In this paper [6] particle filter is used to determine position of robot in a known environment, this is done via particle filtering for accurate stereo matching. In this paper using three steps disparity maps are calculated which further results in calculating depth value from different view of image to get position of the robot in known environment. These three steps are

- Utilize multiple disparity maps in order to acquire a very distinctive set of features called landmarks and use segmentation as a grouping technique.

- Apply scan line particle filtering using corresponding landmarks as virtual sensor data to estimate the best disparity value.
- Do weighing in particle filtering algorithm along with histogram technique and optimize result using plane fitting algorithm to improve performance of particle filter

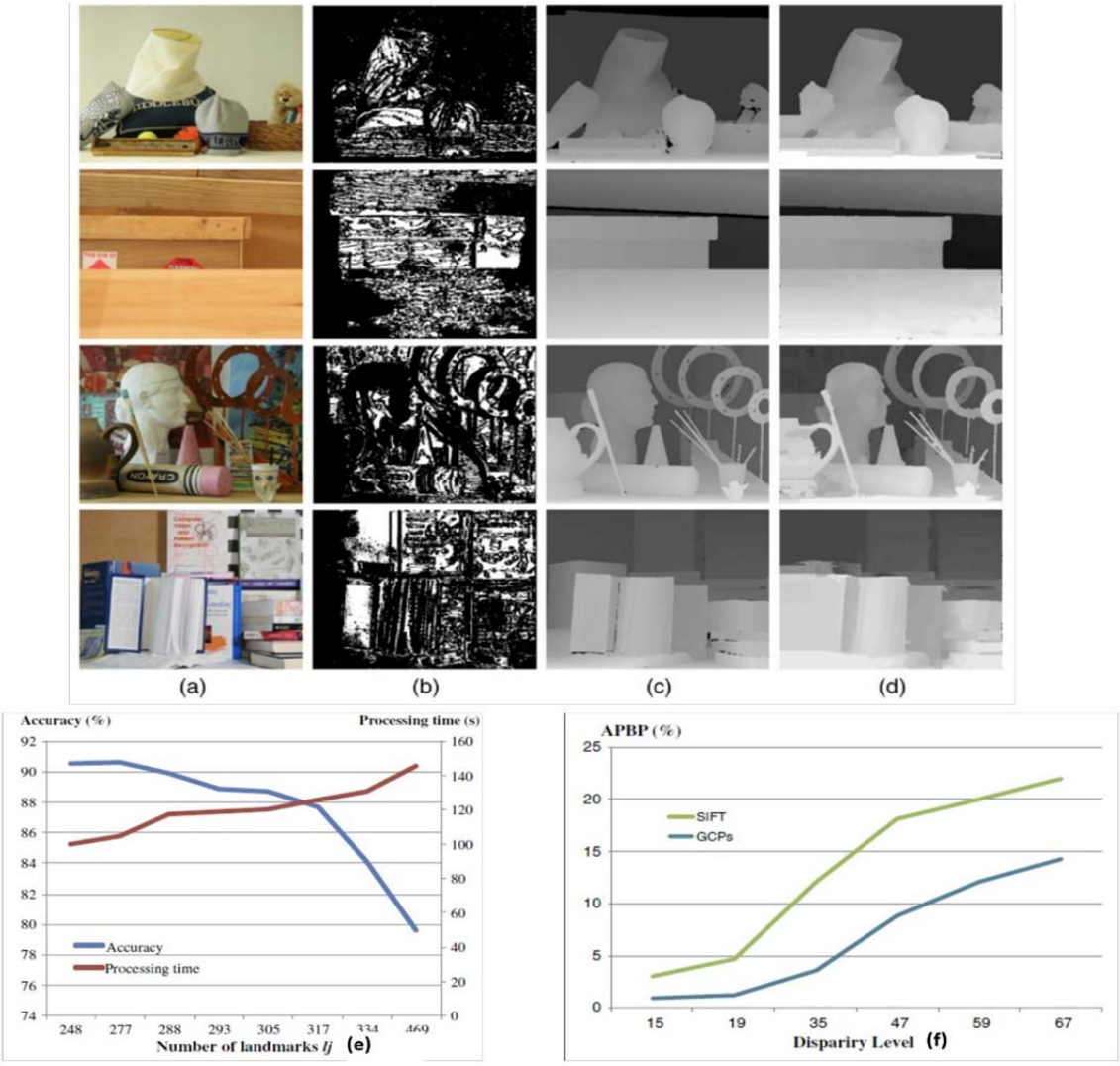

Fig. 5 Result of particle filter when used for robot localization stereo image pair result (a) original left image of stereo pairs, (b) GCP's shown in white color, (c) ground truth maps, (d) result of proposed method, (e) the accuracy and the processing time of our method compared to SIFT algorithm, (f) the average percentage of bad pixel compared to the number of disparity levels for the associated methods utilized for the acquirement of landmarks. [6]

3. Comparison of existing Particle filter based image denoising algorithm –

SN	Reference papers	Algorithms with filter	Measurment parameter	Advantages	Limitation	Experiment performed on
1	A new image denoising method based on Gaussian filter [1]	Gaussian filter+ weighted PF	Variance of image noise, PSNR=28.19 dB	Removes normally distributed noise	not that good for other types of noise	256*256 standard grey image
2	A new implementation of particle filter for digital noisy image [2]	RBPF with MLE RBPF=PF+ KF	PSNR=47.29dB, MSE=.3768, at noise level of 1.3997	Effective for Gaussian noise corrupted image	Complexity given in terms of particles to be denoised	256*256 8bit/pixel standard grey scale image
3	Reconstruction enhancement by denoising the Magnetic particle imaging system matrix using frequency domain filter [3]	Frequency domain filtering with DFT & DCT along with thresholding	Variance of noise for each particle, FOV= 20.4*12 mm^2	Resolution of reconstructed particle was improved resulting in better SNR of 2D signal	Calibration process is tedious	matrix obtained on regular spatial grid of 68*40 size covers
4	Image restoration using hybrid combination of particle filter and wavelet denoising [4]	Hybrid combination of particle filter with DWT	ISNR=6.712 dB	Heavily tailed, Gaussian like noise is removed	Limited for noise and blur removal	256*256 grey scale test image
5	Particle Filter for image restoration[5]	2D-Recursive particle filter	For N=100 ISNR=9.88 dB	Works good over Gaussian blur	works only on current pixel	grey scale vegetable image
6	A stereo matching approach based on particle filters and scattered controlled landmarks[6]	RANSAC+ Histrogram (PF used for robot localization)	APBP= 7.80%	Computation-al cost and processing time improved	If no. of landmarks increases accuracy affected	Stereo pair of middle bury 4 greyscale image

Above table and this performance analysis study concludes that Particle filter is a very good approach to denoise any color or grey scale image. But study of [1], [2], and [4] provides the idea of combining particle filter along with another techniques such as with gaussiam filter, bank of kalman filter, haar wavelet transform[7], histogram technic etc. result in very good performance. In [6] we see that particle filter is used to find position of robot using an image date so it may also be useful to predict direction of noise in any image. Therefore particle filter proven to be an excellent approach for denoising any grey or color image

4. Conclusion

This performance analysis and comparison table concludes that particle filter holds good promise for denoising any grey or color image and when combined to other algorithms it provides tremendously good results. Although particle selection is a tedious procedure.so in future work there is scope of combining particle filter with other existing algorithm for further denoising of any image

References

[1] Manyu wang, Sheng Zheng, Xiaolong Li, Xiongjie Qin (2014): A new image denoising method based on Gaussian filter, IEEE International, pp 163-167.

[2] Dr. Anna Saro Vijendran, Bobby Lukose (2014): A new implementation of particle filter for digital noisy image, 2014 International Conference on Intelligent Computing Application, pp 198-202.

[3] Alexander Weber, Jurgen Weizenecker. Ulrich Heinen, Michale Heidenereich, Thorsten M. Buzug (2015): Reconstruction enhancement by denoising the magnetic partical imaging system matrix using frequency domain filter, IEEE Transactions on Magnetics, vol. 51, no. 2.

[4] Yan Zhai, Mark Yeary, Victor DeBrunner, Joseph P. Havlicek, Osama Alkhouli (2005): Image restoration Using using a hybrid combination of particle filtering and wavelet denoising, IEEE

[5] S. Ibrahim Sadhar, P.Y. Praveen Kumar, A.N. Rajgopalan (2004): particle filters for image restoration, National Conference on Communication (NCC04) Banglore.

[6] Stylianos Ploumpis, Angelos Amanatiadis, Antonios gasteratos (2015): A stereo matching approach based on particle filters and scattered control landmarks, Image and Vision Computing, vol. 38, pp 13-23
[7] Aarti Pareyani, Dr. Agya Mishra (2015): Low contrast image enhancement using adaptive filter and DWT: a literature review, Indian Journal of Computer Science and Engineering (IJCSE) , vol. 6 pp 91-97
[8] William k. Pratt, "Digital Image Processing", John Wiley and Sons, Inc. 2001