International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-4 Issue-1, October 2014

Recent Image Enhancement Techniques: A Review

Akanksha Singh, Sini Shibu, Shatendra Dubey

Abstract- This paper reviews various image enhancement techniques both in spatial and frequency domains and compared them to suggest a method for a high SNR, enhanced and perceptually clearer images while preserving the image`s original colour. Histogram equalisation, low pass filter, fuzzy based image enhancement, Stochastic Resonance in different domains and colour enhancement techniques are being discussed and their effectiveness is gauged and to compare them with various available image enhancement techniques using well defined performance matrices and performance parameters.

Index Terms- Image enhancement, DCT, DWT, Noise, Stochastic Resonance

I. Introduction

In recent years, the need of digital image processing for military, medical and industrial purposes is growing. Extensive researches are being done in this area. Digital image processing has been changed from a specialized subject to a new research tool. The image is often interfered by noise while the image is digitized, transported and recorded. Noise is considered to be a nuisance which decreases an image quality. Image enhancement and denoising techniques are employed to improve luminance, contrast, colour and signal-to-noise ratio (SNR) of the image while preserving the image details. Of course, the techniques to be used also depend on the type of application we are interested in. For example, in military, sometimes an image with good perceptual quality and originality may not be required rather some important details are necessary to be extracted. The image enhancement and denoising methods can mainly classified as the spatial domain method, frequency domain method, the partial differential equations method and MRF denoising. The traditional noise reduction methods includes the spatial domain method and the frequency domain method. The spatial domain method works on the two-dimensional space where an image`s pixels gray values are altered, for example, by using methods like neighbourhood average, median filtering, geometric filtering etc. The frequency domain methods turn the image from spatial domain to frequency domain as per the used transformation model(such as the Fourier transform) ,different frequency components of the image are processed, and then the inverse transform is performed to bring the image back to spatial domain for the processing of results further. One of the major challenges while processing an image in frequency domain is that the signal and noise spectrum in an image overlaps.

Manuscript published on 30 October 2014.
***** Correspondence Author (s)
Akanksha Singh*, M.Tech Scholar, Department of Computer Engineering, NRIIST College, Bhopal, India.
Sini Shibu, Asst. Prof., Department of Computer Engineering, NRIIST College, Bhopal, India.
Shatendra Dubey, Asst. Prof., Department of Computer Engineering, NRIIST College, Bhopal, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license http://creativecommons.org/licenses/by-nc-nd/4.0/

The image details are contained in high-frequency spectrum whereas the noise is uniformly distributed in the whole frequency band (such as a Gaussian noise). Reducing noise, therefore, may result in the loss of image details. Hence, a trade-off between noise reduction and the preservation of image details is necessary. The traditional Low-pass filtering method is to filter the high frequency components of the image, although this technique is effective in noise reduction, but it also destroys the image details. Low-pass filter may be simple averaging filer where intensity value of each pixel is replaced by the average over its neighbourhood [1]. Gaussian averaging filer has better results as for each pixel it performs the weighted average over the neighbourhood of the pixel having the more weight given to the pixels closer to the pixel, maximum weight for the pixel itself and minimum weight for the farthest pixels. Effect of LPF is to smoothen out the noise by distributing the noise throughout the image space. Therefore, for a high noise levels, LPF blurs the image. Markov random field (MRF) is another powerful tool used in image enhancement and denoising. First study of MRF models was carried out by Abend Et al in 1965 [2]. Extensive work on the simulation of images, especially the texture image, using MRF was carried out by Hassner et al [3]. Introduction of new techniques like Gibbs distribution and simulated annealing [4] for image denoising carries forward the MRF technique and the topic was extensively studied and developed. Since then MRF is used in image signal restoration, texture analysis, edge detection and other areas of image processing. Fuzzy logic is yet another powerful tool for image processing. Introduced by Prewitt [5] to the area of image processing, currently, the fuzzy methods have been used to the image segmentation [6,7] and the binary image restoration [8,9] extensively. This paper discusses some of the important techniques used in image enhancement and then compares them with the other existing techniques in terms of the performance matrices and performance parameters.

II. Histogram Equalization Technique

Histogram equalization is a simple but effective technique for the enhancement of low contrast images. Histogram equalization is a technique for adjusting image intensities to enhance the image contrast [10]. Consider an image f represented by $r \times c$ matrix. Elements of these matrices are integers which represents pixel intensities ranging from 0 to $L-1$ where L is the number of possible intensity values which is usually 256. For a normalised histogram p with a bin for each possible pixel intensity

$$p = \frac{\text{number of pixels with intensity n}}{\text{total number of pixels}}$$

$n = 1,2,3, \ldots\ldots, L-1$

The histogram equalized image is then defined as

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

$$g_{i,j} = \text{floor}((L-1)\sum_{n=0}^{f_{i,j}} p_n$$

In other words if the pixel intensities of image f is denoted by k, then

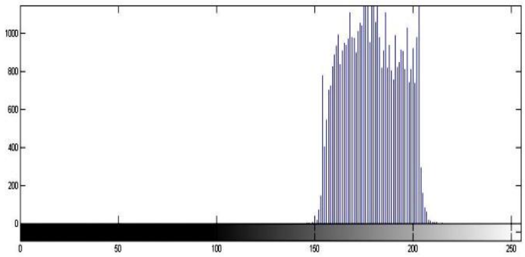
$$T(k) = \text{floor}((L-1)\sum_{n=0}^{k} p_n$$

If X and Y are continuous random variables in the region $[0, L-1]$ denoting the pixel intensities of input image f and enhanced image g respectively, then

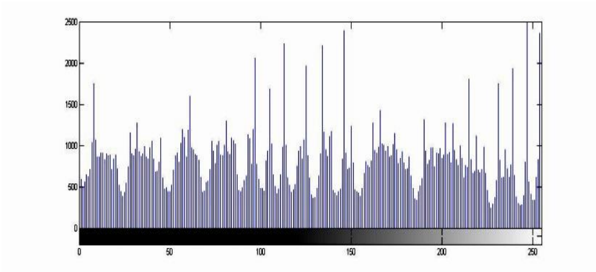
$$Y = T(X) = (L-1)\int_0^X p_x(x)dx$$

Where p_x is the probability density function of f. T is cumulative distribution function of X multiplied by (L-1). Y is also uniformly distributed on$[0, L-1]$.

Fig. 1(a) Original Image 1(b) Output Image



2 (a) Histogram of the Low Contrast Image as shown in Fig 1(a)



2 (b) Histogram of the Enhanced Image as shown in Fig 1(b)

A disadvantage of the method is that it is indiscriminate. It may increase the contrast of background noise, while decreasing the usable signal. Also histogram equalization can produce undesirable effects such as visible image gradient for the images of low colour by decreasing its colour depth further. Hence this method is suitable only for the images with much higher colour depth than pallete size [11]. Another approach of noise reduction and image enhancement is based on the work carried out in literature in the field of stochastic resonance [12], [13], [14]. A psychophysics experiment [15] revealed that human brain can intercept an image added with time varying noise and the perceived quality of the intercepted image depends upon the intensity of contamination and the temporal characteristics of the contamination. Stochastic resonance (SR) is an interesting technique where the noise in the image itself is utilized to enhance the image is terms of contrast, brightness, minimal signal-to-noise ratio and preservation of chromatic consistency. Noise may be externally added noise or it may be the internal noise of the image for example internal noise of a low contrast image due to insufficient illumination. These techniques are applied both in spatial and frequency domain. Some of the work carried out in Stochastic Resonance for image enhancement is discussed below:

III. NONLINEAR NON-DYNAMIC STOCHASTIC RESONANCE

R. K. Jha, R. Chouhan, P. K. Biswas [16] proposed a Non-linear, Non-dynamic Stochastic resonance for the contrast enhancement of low contrast images for both gray scale and colored images. As discussed before, noise can play a constructive role in enhancing weak signals. Stochastic Resonance occurs if the signal-to-noise, input/output correlation reaches its maximum value at a certain noise level. For a stochastic resonance to occur, the following three properties must be possessed by a system.

1. Non-linearity in terms of threshold
2. A small amplitude sub-threshold.
3. A noise source.

A weak signal (low contrast image) with very low noise will never cross the threshold thereby having low SNR. A signal with high noise level has the noise as the dominating entity and therefore SNR is again low. At an intermediate noise level, however, the weak signal is able to cross the threshold, and giving maximum SNR at some optimum moderate noise intensity.

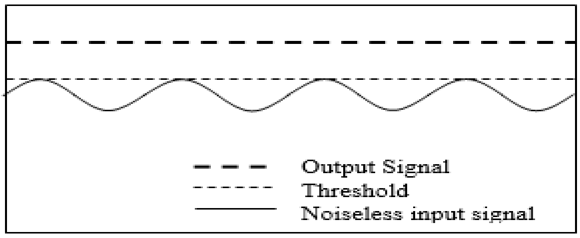


Fig. 1(a)

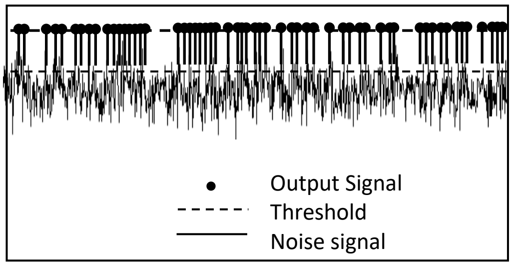


Fig. 1(b)

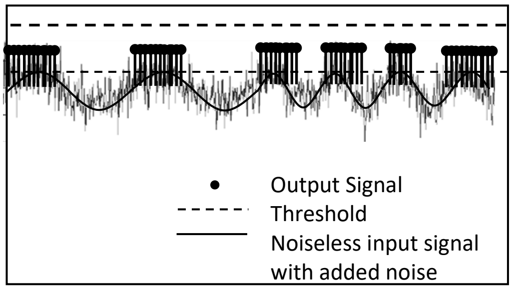


Fig. 1(c)

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

Figure 1(a) shows a noiseless input signal or sub-threshold signal which does not cross the threshold. Figure 1(b) is a random noise signal which randomly crosses the threshold and figure 1(c) shows the input signal with added noise.

To gauge the system performance, contrast, perceptual quality, and preservance of degree of colour enhancement are taken into account and for this purpose three performance metrics F, PQM and CEF respectively are used, to characterize each of them. Metric of contrast enhancement (F) is based on global variance and mean of original and enhanced images [16].

Image quality index Q is given by:

$$Q = \frac{\sigma_2}{\mu}$$

Where σ and μ are respectively the standard deviation and mean of the image.

Relative contrast enhancement factor

$$F = \frac{\text{Quality index postenhancement } (Q_B)}{\text{pre} - \text{enhancement } (Q_A)}$$

For good colour and contrast F and CEF should be greater than 1. Perceptual quality metric (PQM) is used to judge the image perceptual quality as was proposed by Wang et al. [17]. For good perceptual quality, PQM should be close to 10. The colour enhancement factor (CEF) is used to judge colour quality [18] as ratio of colourfulness of output to input image. For good colour and contrast enhancement, respective values CEF and F should be greater than 1.

The steps in this technique may be summarised as:

STEP 1: Produce N frames of random noise, ξ(x, y), of mean zero and standard deviationσ_0. Each of the noise frames is added to the low contrast image generating N different noisy low contrast images

STEP 2: Each noisy image is thresholded using a predetermined threshold (taken as the standard deviation of noise itself). All the thresholded frames (binary images) are averaged to produce an enhanced image of good contrast.

STEP 3: Calculate performance metrics F, CEF and PQM for this output. STEP 4: Increase standard deviation of noise by a unit. Repeat the steps above and analyze values of performance metrics. The process is stopped when CEF+F becomes maximum within the constraint that PQM is close to 10. Moreover, performance of the algorithm highly depends on the type of the noise signal used with Gaussian noise showed best results as compared to uniform, gamma and poisson distributions [16].

IV. COLOUR ENHANCEMENT TECHNIQUES – DCT AND DWT

The CES technique is used for image enhancement by treating the chromatic components unlike other techniques which treats the luminance components of an image. These methods work in frequency domain and utilize the wavelet transform coefficient scaling (CES-DWT) and compressed image scaling (CES-DCT) techniques to improve both global and local contrasts while preserving good colour consistency [18]. In the Y-Cb-Cr colour space, the chrominance components are decorrelated better than that in the R - G – B colour space. If Y component in Y-Cb-Cr colour space is increased the image colours are de-saturated. With G > R and G > B, if Y component is increased, keeping both Cb and Cr constant it is seen that both the (R/G) and (B/G) factors decreases [19], [20]. The image colour enhancement (or preservation) thus includes the processing of chromatic components by performing a scaling operation using the scale factors of Y component. Advantage of DWT compression over DCT compression is that the high and low frequency components can be altered independently. The resulting sub-bands in a DWT compression can be represented as a small number of significant coefficients and a large number of trivial coefficients. Significant coefficient represents the edge structure of the image where as trivial coefficients represents noise or texture. Thus preservation of the important edges and suppression of noise is easier and better. Image colour preservation using CES-DWT is carried out by estimating scale factors for scaling coefficients and wavelet coefficients of luminance component and applying them to the chrominance colour components thereby alleviating the de-saturation effect in the luminance enhancement process. The technique proposed in [18] also addresses the issue of blocking artifacts that may arise after a DCT compression. The blocking artifacts occur in the region where brightness values vary significantly such as at the edges of the abrupt luminance variations. An outline of the algorithm for CES-DCT and CES-DWT colour enhancement technique is presented as under along with the algorithm and flowcharts:

V. CES-DCT PROCEDURE

- Resize the image for applying DCT Compression.
- Convert into YCbCr colour space.
- Convert luminance part of the input image into a vector.
- Calculate the scaling coefficient from this image.
- Apply DCT for all three colour spaces and obtain Y, U, V (i.e. Y-Cb-Cr)
- Decompose into N X N blocks
- If, $\sigma > \sigma_{threshold}$ then decompose into $N/2 \times N/2$ blocks.
- Convert image into vector for this compressed image block.
- Apply the scaling coefficient (κ into compressed image in all the three colour spaces.
- Convert vector into image and combine the smaller blocks.
- Apply inverse DCT.
- Convert into RGB colour space

VI. SCALING CRITERIA

I. For brightness: Scale Only DC Coefficients. Scaling coefficient is given as

$$\kappa = \frac{f\left(\frac{Y(0,0)}{NI_{max}}\right)}{\frac{Y(0,0)}{NI_{max}}}$$

II. For contrast: Scale DC and AC Coefficients. Scaling coefficient is given as:

$$\kappa = \min\left(\kappa, \frac{B_{max}}{\mu} + \kappa\sigma\right)$$

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

III. For colour: Scale DC and AC Coefficients using function.

$$\kappa = \max(\kappa, 1)$$

Where

I_{max} is maximum brightness of image

N is the size

σ is the standard deviation

μ is the mean.

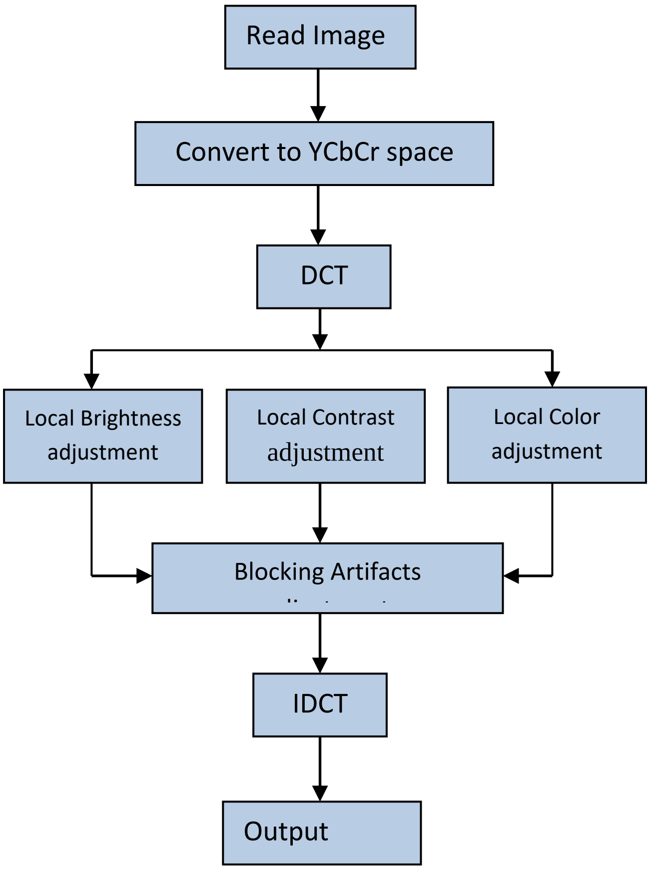


Fig: CES-DCT based Enhancement Process [18]

VII. CES-DWT PROCEDURE

This method is computationally effective since linear scale factors are directly applied to both scaling and wavelet coefficients in compressed domain. Wavelet shrinkage terms are also included resulting in a high PSNR. A. Enhanced Scaling Coefficients Estimation Scaling coefficients do not have exactly the same properties as the intensity values in the spatial domain. A mapping function is hence required to adjust local image brightness. The contrast enhancement criterion is:

$$\hat{s} = 2^L I_{max} f(s/2^L I_{max}) \quad (4)$$

Where

k_s is scale factor for the scaling coefficients. if $g(.)$ represents the scaled mapping function obtained by dividing $f(.)$ by the normalized scaling coefficient s. The mapping function used, $g(x)$, is given as:

$$g(x) = \begin{cases} 1 + c_1(m - x)\exp\left(\frac{-|x-m|^2}{{\sigma_1}^2}\right), 0 \le x \le m \\ 1 + c_2(m - x)\exp\left(\frac{-|x-m|^2}{{\sigma_2}^2}\right), \text{otherwise} \end{cases} \quad (5)$$

Where

m is balance control parameter.

σ_1 and σ_2 are shaping parameters.

c_1 and c_2 are amplitude constants.

Coefficient of x will scale-up if g(x) is greater than 1 and vice versa. Enhanced scaling coefficient ($\hat{s}$) is thus obtained as:

$$\hat{s} = k_s s = g(s/2^L I_{max})s \quad (6)$$

In order to reduce discontinuity, smoothing convolution filter $h(s)$ is used:

$$\hat{s} = g(h(s)/2^L I_{max})s \quad (7)$$

B. Estimation of Enhanced Wavelet coefficients

Enhanced wavelet coefficients are estimated in order to improve clarity of details such as edges and textures. This will result in better local contrast and sharpness of image. Since, number of scales factors for scaling coefficients is much less than the wavelet coefficients, scale factor for each wavelet coefficient is considered independently. The scale factor k_w for wavelet coefficient is given as:

$$\hat{\omega} = k_\omega \omega = g_\omega \gamma_\omega \lambda_\omega \omega \quad (8)$$

Where g_ω is scale factor for scaling coefficient as computed below in (6)

γ_ω is locality factor.

λ_ω is shrinkage factor.

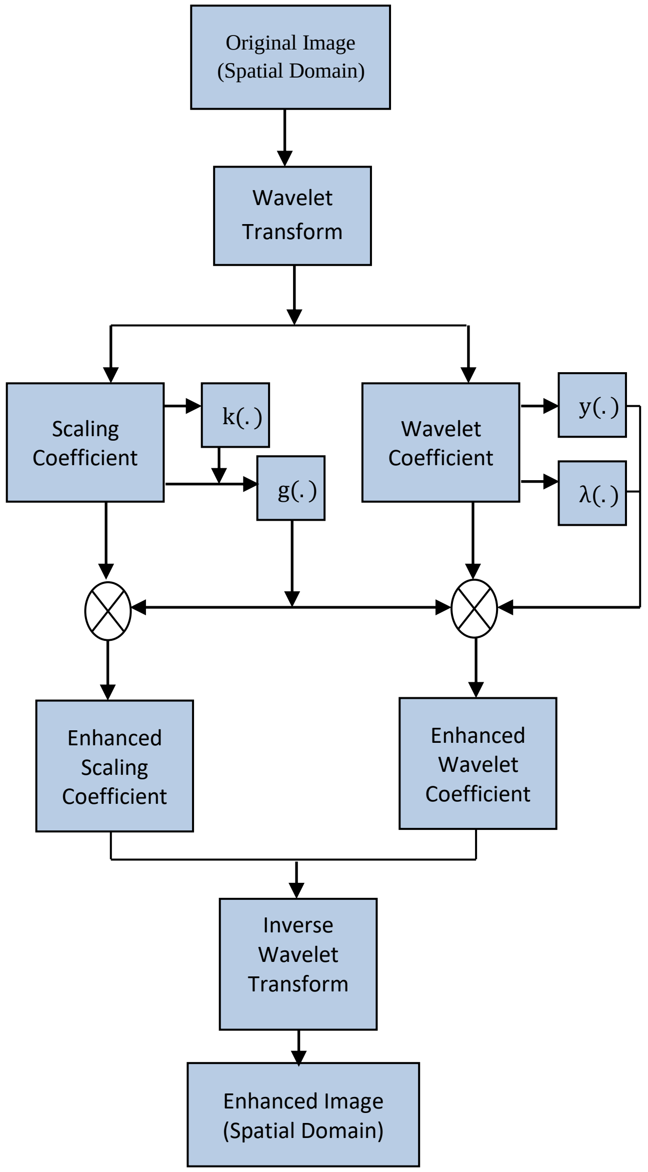


Fig: CES-DWT based Enhancement Process [18]

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

VIII. Comparison and Discussions

Table I shows values of performance metrics using Stochastic Resonance technique against some existing spatial domain contrast enhancement techniques.

Table I - Comparative performance of the proposed technique (using Gaussian noise) with various existing techniques using three performance metrics F, PQM and CEF as given in.

Methods	F	PQM	CEF
SR	**2.35**	**9.74**	**6.6**
Photoshop	2.05	11.01	1.25
CLAHE	2.18	10.39	1.26
Gamma	1.22	10.95	1.48
Retines	0.09	12.37	0.27
MSR	0.37	11.67	0.72
MHPF	0.60	11.55	0.84

The Stochastic Resonance based technique is compared against Contrast Limited Adaptive Histogram equalization (CLAHE), Gamma correction, Retines, MSR and MHPF techniques and also the Photoshop enhanced image. The table clearly shows that the stochastic resonance is more effective technique with high F, CEF values while PQM is near 10 which are considered best. Table II shows the comparison of various colour enhancement techniques taken. The results obtained by averaging the individual results for image used in.

Table II – Performance Measures for different Techniques on enhancing image

METHOD	CEF	JPQM
AR	1.00	8.83
MCE	0.96	7.64
MCEDRC	1.00	8.66
TW-CES-DCT	1.37	7.87
DRC-CES-DCT	1.11	8.36
SF-CES-DCT	1.18	8.19
TW-CES-DCT-BLK	1.38	8.40
DRC-CES-DCT-BLK	1.11	8.73
SF-CES-DCT-BLK	1.18	8.64
CES-DWT	**1.41**	**9.08**

It is quite evident from the table that CES-DWT shows best performance among all the techniques for colour enhancement as well as minimum blocking artifacts. Conclusions from table I and table II suggests that Stochastic resonance for contrast enhancement and noise removal along with the CES-DWT technique for colour enhancement should come out to be an effective technique in the overall enhancement of image as compare to the available technique discussed. A new algorithm incorporating both the features may be constructed while considering the computational limitations. This may be achieved by applying both the Stochastic Resonance and CES in wavelet domain together.

IX. Acknowledgement

The research presented in this paper would not have been possible without the support of our college, at NRIIST College, Bhopal. We wish to express our gratitude to all the people who helped turn the World-Wide Web into the useful and popular forum of research. We also wish to thank the anonymous reviewers for their valuable suggestions.

REFERENCE

[1] Umbaugh Scot E, Computer Vision and Image Processing, Prentice Hall, NJ, 1998, ISBN 0-13-264599-8.

[2] Abend, K., Harley, T. J., and Kanal, L. N. (1965). “Classification of binary random patterns”. IEEE Transactions on Information Theory, 11(4):538--544.

[3] Hassner, M. and Slansky, J. (1980). “The use of Markov random field as models of texture”. Computer Graphics Image Processing, 12, 357-370.

[4] S. Geman And D. Geman, “Stochastic Relaxation,Gibbs Distributions, and The Bayesian Restoration of Images”, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. Pami-6, No. 6, November 1984

[5] J.M. Prewitt (1970). Object Enhancement and Extraction in Picture Processing and Psychopictorics, eds. B.S. Lipkin and A. Rosenfeld, Academic Press, pages 75-149, 1970.

[6] Y.A. Tolias, S. M. Panas, “Image Segmentation by a Fuzzy Clustering Algorithm using Adaptive Spatially Constrained Membership Functions”. IEEE Trans. Systems, Man, Cybernet., Vol. 28, 1998, pp. 359–369.

[7] I. Lizarazo, J. Barros, “Fuzzy Image Segmentation for Urban Land-Cover Classification”, Page(s) 6, ISPRS Proceedings, 2008.

[8] R. Krishnapuram, S. Medasani, “Recovery of geometric properties of binary objects from blurred images”, International Joint Conference of the Fourth IEEE International Conference on Fuzzy Systems, 1995.

[9] A. Chaudhary, J. Y. Kim, T. K. Tuan, “Improved Adaptive Fuzzy Punctual Kriging Filter for Image Restoration”, International Journal of Innovative Computing, Information and control, vol. no. 9, no. 2, February 2013.

[10] R. C. Gonzalez and R. E. Woods, “Digital Image Processing”, Third Edition, Prentice Hall, 2008.

[11] Manvi, R. S. Chauhan, M. Singh, “Image Contrast Enhancement Using Histogram Equalization”, International Journal of Computing & Business Research ISSN (Online): 2229 -6166, Proceedings of ‘I-Society 2012’ at GKU, Talwandi Sabo Bathinda, Punjab.

[12] M. Hongler, Y. Meneses, A. Beyeler, and J. Jacot, “Resonant retina: Exploiting vibration noise to optimally detect edges in an image,” IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 25, no. 9, pp. 1051–1062, 2003.

[13] Q. Ye, H. Huang, X. He, and C. Zhang, “Image enhancement using stochastic resonance,” in Proc. IEEE International Conference on Image Processing, vol. 1, Singapore, 2004, pp. 263–266.

[14] C. Ryu, S. G. Konga, and H. Kimb, “Enhancement of feature extraction for low-quality fingerprint images using stochastic resonance,” Pattern Recognition Letters, vol. 32, no. 2, pp. 107–113, 2011.

[15] E. Simonotto, M. Riani, S. Charles, M. Roberts, J. Twitty, and F. Moss, “Visual perception of stochastic resonance,” Physical Review Letters, vol. 78, no. 6, pp. 1186–1189, 1997.

[16] Rajib Kumar Jha, Rajlaxmi Chouhan, P. K. Biswas, “Noise-induced Contrast Enhancement of Dark Images using Non-dynamic Stochastic Resonance”, National Conference on Communications (NCC), 2012, pp 1-5.

[17] Z. Wang, H. R. Sheikh, and A. C. Bovik, “No reference perceptual quality assessment of jpeg compressed images,” in Proc. IEEE Int. Conf. Image Processing, vol. 1, New York, USA, Sep. 2002, pp. 477–480.

[18] P. S. Sengar, T. K. Rawat, H. Parthasarathy, “Color Image Enhancement by Scaling the Discrete Wavelet Transform Coefficients”, International Conference on Microelectronics, Communication and Renewable Energy (ICMiCR-2013).

[19] S. Lee, ‘‘An efficient content-based image enhancement in the compress -ed domain using retinex theory,’’ IEEE Trans. Circuits Syst. Video Technol., vol. 17, no. 2, pp. 199--213, Feb. 2007. S.

[20] Susstrunk and S. Winkler, ‘‘Color image quality on the internet,’’ Proc. IS&T/SPIE Electronic Imaging: Internet Imaging V, vol. 5304, pp. 118-131, 2004.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

Akanksha Singh, Persuing M.Tech from NRI-IST, Bhopal(Affiliated to RGPV University,Bhopal. B.E. (Computer Science) from Rajiv Gandhi Proudyogiki Mahavidhayalaya, Bhopal (Affiliated to RGPV University, Bhopal) in 2011. Intermediate from R. C. School, Affiliated to Madhya Pradesh Board, Chachai (M.P in year 2007. High School from R. C. School, Affiliated to Madhya Pradesh Board, Chachai (M.P) in year 2005.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.