An improved image denoising method based on Gradient Histogram Preservation

SwathiLakshmanan U and Jeseena A
* College of Engineering Chengannur, Alapuzha, Kerala, India, 689121
swathilakshmi638@gmail.com

Abstract — Digital Image Processing is an evergreen problem of computational scientists. Among, noise reduction and preservation of finer features of image is fundamental. Wide variety of applications starting from digital photography to medical image processing makes image denoising a key problem. Large number of method has been published so far in the journals and the effort to develop a sophisticated method is continuing. Digital Image Processing has broad spectrum of applications ranging from radars, medical images to the digital photographs of day to day life. The present study aims to develop an improved denoising method based on Gradient Histogram Estimation and preservation. The method gives better results for the Gaussian Noise. The noise level of input image is estimated and then denoised by using the improved method. The Edge enhancement and denosing by preserving gradient histogram gives better accuracy than the existing method.

Keywords— Image Processing; Denoising; Gradient Histogram; Histogram Estimation; Gaussian noise, Fuzzy, Edge detection,

INTRODUCTION

Digital Image Processing is an interdisciplinary area of research where computer scientists, data analysts, statisticians and mathematicians look together to solve problems. Also the Digital Image Processing has broad spectrum of applications ranging from radars, medical images to the digital photographs of day to day life. One of the grand challenge of Digital Image Processing is to separate noise from the image. Noises, the unwanted component of the image are crawled into various stages of imaging that ranges from during acquisition to image processing [1]. In the digital photography noise can be developed because of low light or wrong exposure. In the Digital Image Processing Domain, by and large deals with removal of such noise from image [2].

Denoising of an image involves the manipulation of the image data to produce a visually high quality image. There are numerous models that has been published so far which are used for denoising an image[3]. Sparse representation for image restoration[4,5,6],Total variation model [6], Wavelet based model [7], BM3D [8] model, Nonlinear total variation based noise removal[9], and histogram preservation algorithm [10] are some of them. Each method has its own characteristics, benefit and also demerit [5]. Two major classes of denoising methods are (i) model based and (ii) Learning based method. In model based method, a statistical/mathematical model will be used for the denoising [6]. Whereas in Learning based method, an algorithm will be trained by using sufficient parameters and then the model is allowed to work based on its weightage function [7,9].

METHODS

In the present work the denoising is done in more realistic way as in practical situations, only the noisy image will be available. A noisy image is taken as input to the algorithm. We have adopted patch-based noise level estimation algorithm by Xinhao Liu et al [11]. Patches are generated from single noisy image and its weak textured patches are identified. Then Noise level is estimated from the Principal Component Analysis [12].

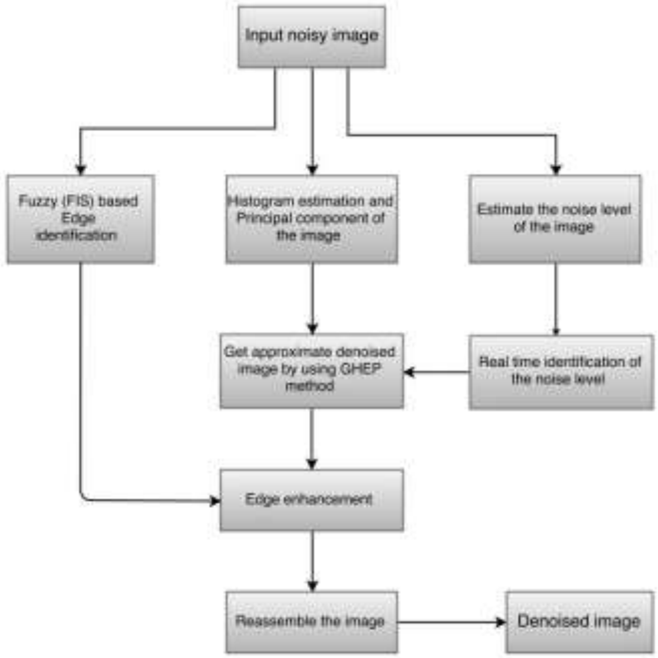

Figure1. Flowchart of the proposed algorithm.

In most of the denoising method, it is seen that, after its implementation, the image will be blurred than that of the original image. Also the edge of the denoised image gets smoothened and will have lesser details than that of the original image. A study has been conducted to find edge of the original and noisy image by using sample data. In this study it is found that there less details of edges in the denoised image. To address this issue we have employed fuzzy based edge detection and then the edge is enhanced in the denoised image that we have received by using our method.

Now the denoising is performed based on the Gradient Histogram Preservation (GHP) adopted from WangmengZuo, et al. [9] focus on texture enhanced image denoising method implementing the gradient histogram preservation.

NOISE ESTIMATION

Input image is decomposed into overlapping patches by

$$y_i = z_i + n_i \, , \qquad (1)$$

Where $\mathbf{z}_i$ represents the original image patch with the i-th pixel at its center and $\mathbf{y}_i$ is the observed vectorized patch corrupted by i.i.d zero-mean Gaussian noise vector $\mathbf{n}_i$.

Aim of the noise level estimation is to find the standard deviation σ_n when only the observed noisy image is given. In this method the Horizontal and vertical derivative ($\mathbf{D}_h\mathbf{y}$ and $\mathbf{D}_v\mathbf{y}$ are calculated and then the gradient vector $\mathbf{G}_y$ *is* obtained by taking $[\mathbf{D}_h\mathbf{y}\ \mathbf{D}_v\mathbf{y}]$

Now the covariance matrix Cov_y is calculated by

$$Cov_y = G_y{}^T G_y \, ; \qquad (2)$$

The Directional Derivative in both Horizontal Direction and Vertical Direction is calculated and trace of Gradient Matrix is calculated by

$$D = tr(D_h \times D_h + D_v \times D_v) \, ; \qquad (3)$$

Now the initial noise level is estimated by computing the First component of Eigen value of the covariant matrix. This is taken as the initial value for calculating noise level by using iterative noise estimation.

$$\tau_0 = \Gamma_{inv}(\delta, \alpha, \beta)\,; \qquad (4)$$

Now the noise level estimation form weak textured patch is performed. For this Inverse gamma function $\tau_0 = \Gamma_{inv}(\delta, \alpha, \beta)$ with the shape parameter α and scale parameter β is used

$$\tau = \sigma(k-1) \times \tau_0\,; \qquad (5)$$

If the selected patch size is less than tau then the patch is selected as a Weak Texture Patch. To measure the texture strength of the image patches maximum eigenvalue of the gradient covariance is calculated.

Now the Noise Level of Weak Texture Patch is found by using the Eigen Value of Covariance Matrix of weak textured patch and its principal component. The iteration is continued until the difference between sigma in step n-1 and n is less than 10^{-4}

EDGE DETECTION AND ENHANCEMENT

Use In the present work, fuzzy based edge detection is employed. In the fuzzy based edge detection method, the intensity differences between the neighboring pixels are found. The membership function used here defines the degree to which a pixel belongs to an edge or a uniform region. The image gradients along x-axis and y-axis is (Ix and Iy) are obtained from the noisy image. A Fuzzy Inference System (FIS) is created for the edge detection and input is defined as image gradient.
Membership function with a zero-mean Gaussian function is defined for each input. The input is classified in such a way that it belongs to the zero membership function with a degree of 1 if the gradient value is zero

Now, the rules for the edge detection is defined as If Ix is zero and Iy is zero then Iout is white and If Ix is not zero or Iy is not zero then Iout is black. This defines whether a pixel is whether included as edge or not.

GHP BASED DENOISING

Gradient histogram preservation model is used for getting the reference denoised image.

Let $y = x + v$, where **x** is the desired estimation, **v** is additive white Gaussian noise, **y** is noisy observation

Firstly input image is converted into patches and clustered by using K- means clustering. Let $\mathbf{x}_i = \mathbf{R}_i\mathbf{x}$ be a patch extracted at position *i*. Patches are grouped into a dictionary D. For the dictionary D, patch xi over D defined as α_i.
The whole image is reconstructed by using

$$x = D \circ \alpha \stackrel{\Delta}{=} \left(\sum_{i=1}^{N} R_i^T R_i \right)^{-1} \sum_{i=1}^{N} R_i^T D \alpha_i \qquad (6)$$

Where . Regularization term R(x) is defined as

$$R(x) = \sum_i \left\| \alpha_i - \beta_i \right\|_1 \;,\; s.\; t.\;\; x = D \circ \alpha \qquad (7)$$

$$\beta_i = \sum_q w_i^q \alpha_i^q \qquad (8)$$

Now the histogram preservation method uses the model

$$\hat{x} = \arg\min_{x,F} \left\{ \frac{1}{2\sigma^2} \left\| y - x \right\|^2 + \lambda . R(x) + \mu \left\| F(\nabla x) - \nabla x \right\|^2 \right\} \qquad (9)$$

Such that $h_F = h_r$. Where h_F is the histogram of transformed gradient image, hr is the Gradient histogram, F is monotonically non-descending odd function, λ- positive constant. The reference histogram estimated is used for the denoising.

The denoised image by using GHP method is then taken to the algorithm the final output is defined as

$$I_{out} = I_{ref} \oplus I_{edge} \qquad (10)$$

Results

One of the main advantage of the present work is, it uses only the noisy image and estimates the noise. Noise level estimated is converted to the standard deviation (sigma) and then it is used for the downstream analysis. The method doesn't uses the PSNR values because reference image is need to calculate it. In the present work, Gradient histogram preservation and denoising is performed. The Edges of the noisy image is identified and then the edges were enhanced. The edge enhancement has resulted the better the denoised image.

Noise level (sigma)	**ENL**	**ENL denoised**	**ENL final**
5	3.3190	2.6018	2.2336
10	3.4247	2.1402	1.8430
15	3.7456	1.8734	1.6039
20	3.9537	1.5548	1.2788
25	4.3785	1.5250	1.2908

Table 1: Result of the proposed method

The present method is evaluated with images with addictive white gaussian noise of different standard deviation and results were analysed. Results are given in Table 1.

Figure 2. Results of Proposed method

The result in Figure 1 when an image with noise $\sigma = 25$ is given as input shows that the present method gives better denoised image. Also the image looks more natural.

DISCUSSION

Merits of improved method for denoising over other existing method are (i) it uses only noisy image as input and doesn't need a reference image. (ii) It enhances edges by preserving the gradient histogram. Both these results better result and the image looks more natural. Sample set of Addictive White Gaussian Noise (AWGN) with different noise standard deviation is tested and found to be promising results. The method reduces noise upto 95% in different cases. Also the performance of the algorithm also improved 40% than that of WangmengZuo et al [9]

ACKNOWLEDGMENT

We wish to thank HOD of CS department, Project Coordinator and all friends of College of Engineering, Chengannur, for their immense support and encouragement for the fulfillment of this work

CONCLUSION

The present method can be used for denoising image which is mixed with AWGN. The algorithm is best suited for practical applications as it doesn't need any reference image. Fuzzy based edge enhancement improves the quality of the image.

The result can be improved by introducing more statistical analysis and parameter refinement. The current method is best suited for AWGN. However any other type of noise can be converted to AWGN and the method can be employed. Accuracy and fine tuning of the algorithm may also be done for better accuracy. In the present work Fuzzy based edge detection and fuzzy triangular membership function is used. Instead Gaussian or any other membership function can be used. Also edge detection can be improved to get the finer results.

Even though in the present work, most of the parameters were selected from the image itself, some are fixed based on statistical inference. This is a hurdle for denoising a different kind of image. Real-time parameter estimation can solve this even though it compromise on the performance time.

REFERENCES:

[1] Ajay Kumar Boyat1 and Brijendra Kumar Joshi,"A Review Paper: Noise Modelsin Digital Image Processing "Signal Image Processing : An International Journal(SIPIJ) Vol.6, No.2, April 2015 DOI : 10.5121/sipij.2015.6206 63
[2] Rajani,anutam, Image Denoising Techniques-An Overview" International Journal of Computer Applications (0975 8887) Volume 86 No 16, January 2014
[3] Buades, B. Coll, and J. Morel, "A review of image denoising methods, with a new one," Multiscale Model. Simul., vol. 4, no. 2, pp. 490530, 2005
[4] K. Dabov, A. Foi, V. Katkovnik, and K. Egiazarian, "Image denoising by sparse 3-D transform-domain collaborative filtering," IEEE Trans. Image Process., vol. 16, no. 8, pp. 2080–2095, Aug. 2007.
[5] W. Dong, L. Zhang, G. Shi, and X. Li, "Nonlocally centralized sparse representation for image restoration," IEEE Trans. Image Process., vol. 22, no. 4, pp. 1620–1630, Apr. 2013.
[6] M. Elad and M. Aharon, "Image denoising via sparse and redundant representationsover learned dictionaries,"IEEE Trans. Image Process., vol. 15, no. 12, pp.37363745, Dec. 2006
[7] Pankaj Hedaoo and Swati S Godbole "Wavelet Thresholding Approach for Image Denoising" International Journal of Network Security Its Applications (IJNSA),Vol.3, No.4,July 2011
[8] H. C. Burger, C. J. Schuler, and S. Harmeling, "Image denoising: Canplain neural networks compete with BM3D?" in Proc. Int. Conf. CVPR,Jun. 2012, pp. 2392–2399
[9] L. Rudin, S. Osher, and E. Fatemi, "Nonlinear total variation based noise removal algorithms,"Phys. D, vol. 60, nos. 14, pp. 259268, Nov. 1992.
[10] S. Subha, I. Jesudass and K. Thanushkodi "Image denoising by using iterative histogram and preservative algorithm" ARPN Journal of Engineering and Applied Sciences VOL. 10, NO. 11, JUNE 2015
[11] Liu, Xinhao, Mitsuru Tanaka, and Masatoshi Okutomi. "Noise level estimation using weak textured patches of a single noisy image." Image Processing (ICIP), 2012 19th IEEE International Conference on. IEEE, 2012.
[12] S. Pyatykh, J. Hesser and L. Zheng, "Image Noise Level Estimation by Principal Component Analysis," in IEEE Transactions on Image Processing, vol. 22, no. 2, pp. 687-699, Feb. 2013.doi: 10.1109/TIP.2012.2221728
[13] Law, Todd, Hidenori Itoh, and Hirohisa Seki. "Image filtering, edge detection, and edge tracing using fuzzy reasoning." Pattern Analysis and Machine Intelligence, IEEE Transactions on 18, no. 5, 1996
[14] WangmengZuo , Chunwei Song, David Zhang and Huijun Gao, "Gradient Histogram Estimation and Preservation for Texture Enhanced Image Denoising," IEEE Trans. Image Process., vol. 23, no. 6, 2013