Efficient Image Denoising Using Gaussian Low Pass Filter and Total Variation Scheme

Pratik Sharma[1], Prof. Nikesh Tiwari[2]

[1]M Tech Research Scholar, [2]Research Guide, LNCTS, Bhopal

Abstract - Image denoising is the fascinating research area among researchers due to applications of the images in everywhere, social networking sites, High Definition videos and stills. The need of it is to enhance the facility to imaging devices and the processing devices for denoising and enhancement of images. In this paper, Total Variation (TV) regularization is used to allow for accurate registration near such boundaries. We propose a novel formulation of TV-regularization for parametric displacement fields and Wavelet Filter to enhance or denoising of images. The proposed methodology's performance are usually compared in terms of peak-signal-to-noise ratio (PSNR). These are simply mathematically defined image metrics that take care of noise power level in the whole image.

Keywords - PSNR, Image Denoising, TV, Wavelet Filter.

I. INTRODUCTION

Noise in an image is a serious problem. The noise could be Additive White Gaussian Noise (AWGN), Salt & Pepper Impulse Noise (SPIN), Random Value Impulse Noise (RVIN), or a mixed noise. Efficient suppression of noise in an image is a very important issue. Denoising finds extensive applications in many fields of image processing. Conventional techniques of image denoising using linear and nonlinear techniques have already been reported and sufficient literature is available in this area and has been reviewed in the next paragraph. Recently, various nonlinear and adaptive filters have been suggested for the purpose. The objectives of these schemes are to reduce noise as well as to retain the edges and fine details of the original image in the restored image as much as possible. However, both the objectives conflict each other and the reported schemes are not able to perform satisfactorily in both aspects. Hence, still various research workers are actively engaged in developing better filtering schemes using latest signal processing techniques. In the present exploration, efforts have been made in developing some efficient noise removal schemes.

Image denoising is a common procedure in digital image processing aiming at the suppression of additive white Gaussian noise (AWGN) that might have corrupted an image during its acquisition or transmission. This procedure is traditionally performed in the spatial-domain or transform-domain by filtering. In spatial-domain filtering, the filtering operation is performed on image pixels directly. The main idea behind the spatial-domain filtering is to convolve a mask with the whole image. The mask is a small sub-image of any arbitrary size (e.g., 3×3, 5×5, 7×7, etc.). Other common names for mask are: window, template and kernel. An alternative way to suppress additive noise is to perform filtering process in the transform-domain. In order to do this, the image to be processed must be transformed into the frequency domain using a 2-D image transform. Various image transforms such as Discrete Cosine Transform (DCT), Singular Value Decomposition (SVD) Transform, Discrete Wavelet Transform (DWT) etc. are used.

Most of the classical linear digital image filters, such as averaging low pass filters have low pass characteristics and they tend to blur edges and to destroy lines, edges and other fine image details. One solution to this problem is the use of the median (MED) filter, which is the most popular order statistics filter under the nonlinear filter classes. This filter has been recognized as a useful filter due to its edge preserving characteristics and its simplicity in implementation. The median filter, especially with larger window size destroys the fine image details due to its rank ordering process. Applications of the median filter require caution because median filtering tends to remove image details such as thin lines and corners while reducing noise. One way to improve this situation is the weighted median WM filter, which is an extension of the median filter that gives more weight to some values within the window. It emphasizes or de-emphasizes specific input samples, because in most applications, not all samples are equally important. The special case of the median filter is the center-weighted median (CWM) filter, which gives more weight only to the central value of the window. It is also reasonable to give emphasis to the central sample, because it is one that is the most correlated with the desired estimate. The median filter, as well as its modifications and generalizations are typically implemented invariantly across an image.

II. FREQUENCY DOMAIN FILTERING

The frequency domain is an alternate way to represent an image. It deals with the frequency of the gray levels of the pixels in the image i.e. the variation in the gray level. Considering the frequency components of an image can provide an insight and rationale for certain filtering and processing operations.

Filtering in the frequency domain is a common image and signal processing technique. It can smooth, sharpen, de-blur, and restore some images. Essentially, filtering is equal to convolving a function with a specific filter function. So one possibility to convolve two functions could be to transform them to the frequency domain, multiply them and transform them back to spatial domain

In frequency domain filtering the image is mapped from spatial domain to frequency domain by taking Fourier transform of the image. After mapping filtering operation is done on the image (like low pass and high pass filtering etc). After doing the filtering operation the image is remapped to spatial domain by inverse Fourier transform to obtain the restored image.

Gaussian Low Pass Filter

Gaussian filters are important in many signal processing, image processing and communication applications. These filters are characterized by narrow bandwidths, sharp cutoffs, and low overshoots. A key feature of Gaussian filters is that the Fourier transform of a Gaussian is also a Gaussian, so the filter has the same response shape in both the spatial and frequency domains [1, 2]. The form of a Gaussian low pass filter in two-dimensions is given by

$$H(u,v) = e^{-D^2(u,v)/2\sigma^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

The parameter σ measures the spread or dispersion of the Gaussian curve as shown in Fig. 2.1. Larger the value of σ, larger the cutoff frequency and milder the filtering is.

When letting $\sigma = r_0$, which leads a more familiar form as previous discussion. So Equation 2.1 becomes:

$$H(u,v) = e^{-D^2(u,v)/2r_0^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.2)$$

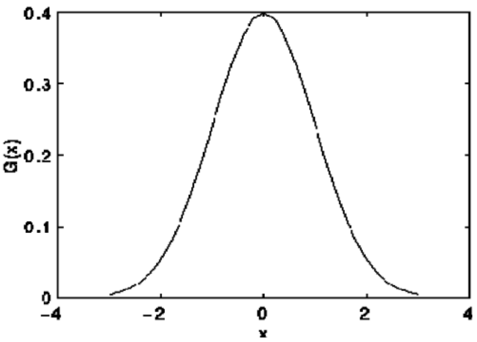

Fig. 2.1-D Gaussian distribution with mean 0 and σ=1.

III. PROPOSED METHODOLOGY

Implementation efficient image denoising using Gaussian low pass filter and total variation scheme has done in Matlab image processing environment and performance of proposed algorithm has evaluated based on simulation.

Fig. 3.1 shows image denoising process where Gaussian noises are mixed with original image to get noisy image, further noisy image is denoised with proposed algorithm.

In proposed approach various spatial domain and frequency domain filters are used.

Block representation of proposed methodology has been shown in figure 3.2. The proposed algorithm is segmented in three major blocks described as follows.

a. Median Filtering

Median filter is a type of order-statistics filters this filters are based on ordering the pixels contained in the mask. Median filter comes under this class of filters. Median filter replaces the estimation of a pixel with the median estimation of the gray levels inside the filter window or cover. Median filters are very effective for impulse noise.

$$\hat{f}(x,y) = median_{(s,t)\varepsilon Sxy}\{g(s,t)\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

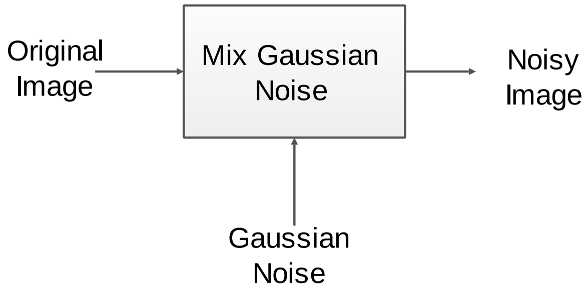

Fig. 3.1 Denoising Process.

b. Total Variation Denoising

TVD is an approach to recover a signal x from a noisy data y, where x is a sparse or sparse derivative signal vector. Consequently, it is more efficient to formulate the problem in terms of l_1 norm in order to promote sparsity. This leads to the constrained optimization problem.

$$arg\ \min_x ||D_X||_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

$$\text{such that } ||y - X||_2^2 \leq N\sigma^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

Problem (3.3) is equivalent, for suitable λ, to the unconstrained optimization problem.

$$arg\ \min_x\{\frac{1}{2}||y - X||_2^2 + \lambda||D_X||_1\} \ldots\ldots\ldots\ldots\ldots (3.4)$$

The solution to the unconstrained problem (3.4) is denoted as

$$TVD(y,\lambda) \coloneqq arg\ \min_x\{\frac{1}{2}||y - X||_2^2 + \lambda||D_X||_1\} \ldots. (3.5)$$

there is no express answer for (3.4), but yet a fast algorithm to figure the correct arrangement has been produced. Expanding the parameter λ has the impact of making the solution x more nearly piecewise constant. Rather than the main order contrast, other approximation of derivative can be used for sparse derivative denoising.

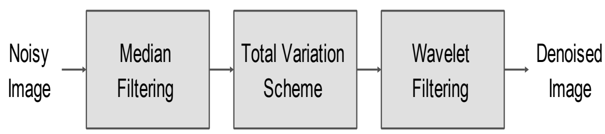

Fig. 3.2 Block diagram of proposed methodology.

c. Wavelet Filtering

Wavelet domain filters essentially employs Wavelet Transform (WT) and hence are named so. Fig. 3.3 shows the block schematic of a wavelet-domain filter. Here, the filtering operation is performed in the wavelet-domain. A brief introduction to wavelet transform is presented here in below fig.

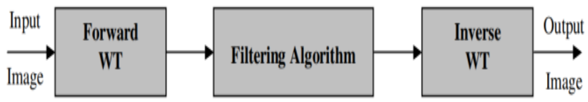

Fig. 3.3 A wavelet domain filter.

Process flow of proposed algorithm in Matlab has shown in Fig. 3.4.

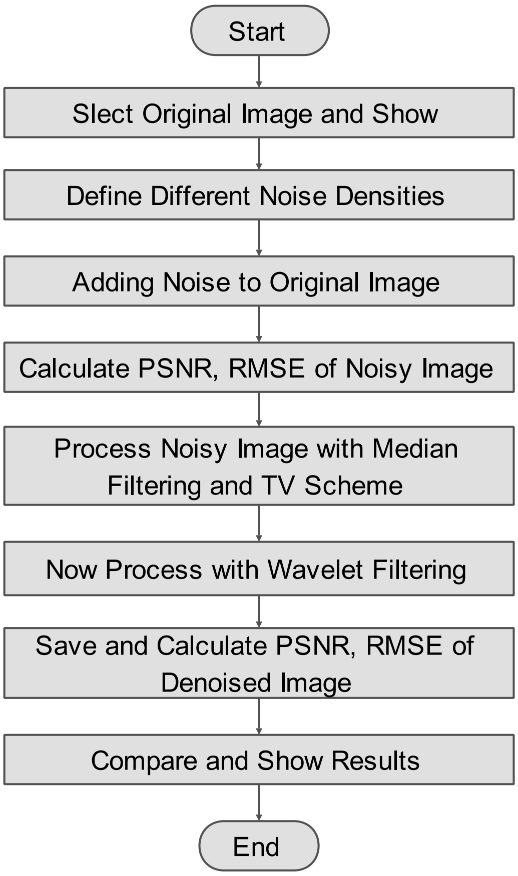

Fig. 3.4 Flow chart of Proposed Methodology.

IV. SIMULATION OUTCOMES

This work introduces combination of spatial-domain filtering (Median filtering), frequency domain filtering (Gaussian Low Pass Filter) and wavelet domain filtering WT with total variation denoising are simulated on MATLAB platform. The test images: Lena, Subaru, Red Flower, Beach are corrupted with Gaussian noise of standard Noise Level 0.05 are used for simulation purpose. The peak-signal-to-noise ratio (PSNR), root-mean-squared error (RMSE), method noise are taken as performance measures.

Image denoising has been successfully achieved using various filters. Image features such as PSNR, RMSE, mean, variance have been extracted and different filters have been applied in terms of their features.

(a) with noise level sigma = 0.01

(b) with noise level sigma = 0.03

(c) with noise level sigma = 0.05

(d) with noise level sigma = 0.07

(e) with noise level sigma = 0.09

Fig. 4.1 Lena image outcomes of different Gaussian noise levels from 0.01 to 0.1 from (a) to (e) respectively.

The PSNR values of the proposed image denoising using various filtering for Lena images for different noise level is shown in Fig, 4.2.

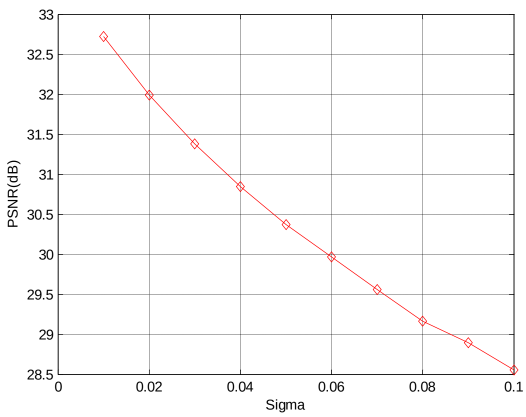

Fig. 4.2 PSNR Curve of Lena Image for Different Noise Levels.

The RMSE values of proposed filtering algorithm are given in Fig. 4.3. The smallest (best) RMSE value for a particular standard deviation of Gaussian noise is shown for analysis RMSE curve of Lena image for different noise levels in Fig. 4.3.

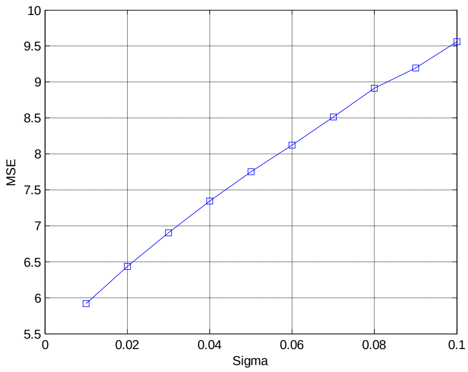

Fig. 4.3 RMSE Curve of Lena Image for Different Noise Levels.

The robustness and performance of the proposed approach is checked with calculation if parameters i.e. figure of merit like peak signal to noise ratio(PSNR) and root mean square error(RMSE). The graph of values of PSNR and RMSE for all images is shown in above figures. The robustness is clearly visible from the PSNR values calculated before and after denoising and denoising PSNR is quite improved.

A bar chart of comparison of PSNR levels displayed in table 1 are plotted in Fig. 4.4.

Table 1: Comparison of PSNR

	Noise Level	Previous	Proposed(Our)
Lena	0.05	25.0727	30.37
Subaru	0.05	23.7548	29.91
Red Flower	0.05	24.1452	30.85
Beach	0.05	22.9790	29.86

The PSNR values of the proposed image denoising method images are given in Table 1 for four different test images. The highest (best) PSNR value for a particular standard deviation of Gaussian noise is highest bar to show the best performance in 4.4.

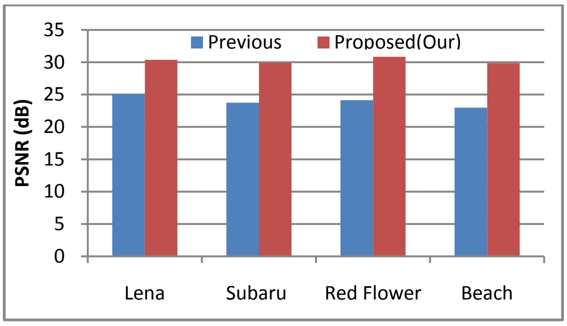

Fig.4.4 Bar chart comparison of PSNR Levels.

V. CONCLUSION AND FUTURE SCOPES

The Fundamental objective of improvement is to process an image with the goal that the outcome is more appropriate than the first image for a particular application. The word particular is essential, since it builds up at the beginning that the methods executed in this examination work are especially problem oriented. Denoising is additionally utilized as a preprocessing step in applications where human visualization of an image is required before additionally processing..

The performance of proposed work based on Median filtering, wavelet-domain filtering and total variation denoising for Gaussian noise in images are studied and examined for Lena image, Subaru, image, Red Flower image and Beach image.

For proper judgment of performance of proposed algorithm, the subjective evaluation should be taken into consideration. The filtering performances of various filters on a smooth region and a complex region of various mages are shown.

The future extension of this work may be to design even more robust method which should be adaptive as per the need or particular application. Some more image statistics may be calculated to make the enhancement techniques adaptive. Improvement of colour images turns into a more troublesome errand not just as a result of the additional measurement of the information yet in addition due to the additional unpredictability of colour observation. So, a robust colour image enhancement may be designed with greater flexibility. All the filters discussed may also be implemented individually along with the noise signal analysis thereby addressing image restoration problem.

REFERENCES

[1]. Kethwas and B. Jharia, "Image de-noising using fuzzy and wiener filter in wavelet domain," 2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), Coimbatore, 2015, pp. 1-5.

[2]. S. Anissa, S. Hassene and B. b. Ezzedine, "Adaptive median filter based on ANFIS for impulse noise suppression," 2014 IEEE 23rd International Symposium on Industrial Electronics (ISIE), Istanbul, 2014, pp. 950-953.

[3]. M. Duraisamy and F. M. M. Jane, "cellular neural network based medical image segmentation using artificial bee colony algorithm," 2014 International Conference on Green Computing Communication and Electrical Engineering (ICGCCEE),

[4]. M. H. F. Zarandi and M. Zarinbal, "A new image enhancement method Type-2 Possibilistic C-Mean Approach," 2013 Joint IFSA World Congress and NAFIPS Annual Meeting (IFSA/NAFIPS), Edmonton, AB, 2013, pp. 1131-1135.

[5]. T. Wilkin, "Image reduction operators based on non-monotonic averaging functions," 2013 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), Hyderabad, 2013, pp. 1-8.

[6]. T. Mu-Ling and Y. Jie-Ming, "Pre-processing of Froth Image of Coal Flotation Based on Weighted Fuzzy C-Mean Clustering by One-Dimensional Histogram," 2012 International Conference on Computing, Measurement, Control and Sensor Network, Taiyuan, 2012, pp. 396-400.

[7]. Chu, G. Li, Y. Lou and J. Li, "An improved model of double-entry adaptive TV," 2012 9th International Conference on Fuzzy Systems and Knowledge Discovery, Sichuan, 2012, pp. 1730-1734.

[8]. R C Gonzalez and R .E.Wood Digital image processing Prentice hall, upper saddle river, N J.,2nd edition, 2002.

[9]. J. S. Lim, Two-Dimensional Signal and Image Processing. Englewood Cliffs, NJ: Prentice-Hall, 1990.

[10]. H. C. Andrews and B. R. Hunts, Digital Image Restoration, Englewood Cliffs, NJ: Prentice-Hall, 1977.

[11]. Li Ke, Weiqi Yuan and Yang Xiao, “An Improved Wiener Filtering Method in Wavelet Domain”, IEEE Trans., ICALIP, pp. 1527-1531, August 2008.

[12]. Nevine Jacob and Aline Martin “Image Denoising In the Wavelet Domain Using Wiener Filtering” December 17, 2004.