KNN Classification Based Nonlinear Noise Delineation in Color Image using Optimized BM3D Filter

Mandar D. Sontakke, Meghana Kulkarni

Abstract: Image enhancement using optimized methods along with optimized filters is need of current era. A novel technique is proposed in this paper, which have KNN based pixels classifications strategy. This classification is used to identify noise level and only noisy pixels are processed using optimized BM3D using particle swarm optimization. The outside group pixels are brought back into group thereby removing the noise. The process is further followed by resolution enhancement and Retinex for dynamic presentation purpose. The experimentation results are also included in the paper which shows optimum performance.

Index Terms: KNN, PSO, nonlinear noise delineation BM3D, Resolution enhancement, Retinex.

I. INTRODUCTION

Noise may get added in the image at the time of image generation while capturing using camera or at the time of transmission. Noises are having characteristics with respect to their categories. The linearity and non-linearity of the noise are most important aspects to be considered while processing image for noise removal. The removal of noise depends on the processing capabilities for particular noise type in case of linear noises. In case of non-linear noise types, combination of methods can be used to obtain the desired results. The results vary in accordance with density of noise and image sizes which effect on image quality measure has been done by parameters such as peak signal to noise ratio and mean square error. The random location of noise pixels is main concern while designing model for noise removal. The noise model has limits while relating to particular type and shows lots of limitations when used for non-linear noise removal filter design [1-3]. Variety of techniques can be seen so far which can be used to remove noise from the image and show that results depend on noise models considered while designing the noise removal filters. The thermal effect and its effect of noise generation is main cause of nonlinear noise.

The noise removal process involves stages such as detection and removal. While detecting the non-linear noise, existing models show limited approach and hence adaptive techniques are used to detect and remove them. The main concern at the time of noise removal is to retain much original information and less losses. These requirements are contradictory to each other and are difficult to achieve. It has been observed through the simulation of the existing schemes [4-6] that they also fail in providing satisfactory results under high noise conditions. Due to non-uniform distribution of impulse noise a preprocessing is required which will detect the corrupted location or noisy pixel before filtering process.

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II. RELATED WORK

In non-linear noise delineation of image there are variety of techniques developed so far by various researchers. Few papers are addressed here by considering the techniques used and their implementation feasibility as dedicated system and performance of the system.

In paper [7], underwater image enhancement is shown which makes use of fusion based approach. A single hazy image based this method makes use of dehazing and contrast improvements which provides correction in colored appearances of the input image. The visibility is enhanced along with removal of distortions. The process involves estimation of weight maps based on object distance based appearances in an image. The inputs and weights are blended using multi-scale fusion technique. The final image obtained contains most significant features of the image thereby keeping their losses negligible. Underwater hazy images are possible to enhance in terms of quality with the simple approach in effective manner.

In paper [8], transmittance correction method is used to enhance the underwater images by ignoring the polarization effects. The simple algorithm is capable of enhancing the images by transforming the transmittance of low depolarized objects thereby giving non negative values as output. The real time depolarized objects present in an image can be effectively enhanced in terms of appearances in underwater images using this method. The method in paper shows better performance compared to previous methods.

In paper [9], the debris removal is main application considered for enhancing the underwater images. The haziness and light attenuation properties of the water are main difficulties found during debris removal processes. The camera equipped autonomous underwater vehicles with sonar imagery as additional mechanism are considered as application of the method. The powerful object detection system in this vehicle is achieved with help of enhanced imagery process which shows precision in results while separating debris from other objects.

In paper [10], the underwater hazy image enhancement is shown with the use of wavelet based approach. The low contrast and color alteration issues are addressed. The results obtained through this method provides promising results.

In paper [11], a system is shown which provides open source platform for sequential image processing. The processing may involve the use of object detection and classification along with stereo calibration. The programming is simple and provides multithreading support thereby increasing processing speed. The same task for multiple images simultaneously are possible by using this platform for the applicable experimentations.

In paper [12], a method is shown which consists of two stages. At the first stage, the contrast correction technique is applied to the image, where the image is applied with the modified Von Kries hypothesis and stretching the image into two different intensity images at the average value with respects to Rayleigh distribution. At the second stage, the color correction technique is applied to the image where the image is first converted into hue-saturation-value (HSV) color model. The modification of the color component increases the image color performance. Qualitative and quantitative analyses indicate that the proposed method outperforms other state-of-the-art methods in terms of contrast, details, and noise reduction.

In paper [13], noise reduction methods are discussed which make use of gray value substitution. Also wavelet transform based results are obtained which show satisfactory performance. Mean square error parameter is used along with PSNR for evaluating the performance of the system.

In paper [14], underwater image enhancement is carried out in two steps. In the first step Haze in the underwater image is removed using dark channel prior. In the second step Hue alterations handled by wavelength compensation. Once depth map is derived, luminance of foreground and background inside the image can be separated and compared. To regulate the Hue alteration wavelength can be compensated using average RGB channels in the image. After computing the scale value of each RGB component, wavelength is compensated together with the average RGB and scale value of each channel in the image. Performance of the method of wavelength compensated image is evaluated using the PSNR, Focus Measurement, Contrast Improvement Index, and Feature Similarity Index. Performance measurement of the wavelength compensation produces better enhancement results than existing method.

In paper [15], contrast limited adaptive histogram equalization method is used for enhancing the underwater images. The dark channel estimation based on attenuation of artificial light used during image capturing process is done. The visual quality is enhanced during experimentation.

In paper [16] preprocessing techniques of underwater images are focused. Underwater image pre-processing is absolutely necessary due to the quality of images captured under water. An attempt has been made to compare and evaluate the performance of three famous filters namely, homomorphic filter, anisotropic diffusion and wavelet denoising by average filter used for under water image pre-processing. Out of the three filters, wavelet denoising by average filter gives desirable results in terms of Peak Signal to Noise Ratio and Mean Square Error. However the elapsed time of the three filters is also studied to identify the suitable filters that process the image quickly by preserving the image quality.

In paper [17], a dual-band underwater image denoising and enhancement algorithm, first the original image was decomposed into high-frequency part H and low frequency part L, and then H was filtered into F by mean shift algorithm which was improved by using the intermediate iteration results. A contrast enhancement method was proposed based on the haze imaging model and was applied on L and F. experiment results demonstrate the effectiveness of the proposed algorithm.

In paper [18] the method for underwater image enhancement is shown based on the amount of attenuation corresponding to each wavelength, color change compensation is conducted and color balance is restored. Effect of noise is also reduced by using the spatial filter. Using this technique the visibility and color of the image can be enhanced.

In paper [19], WCID algorithm for underwater image enhancement is shown. WCID means wavelength compensation and image dehazing. We also compare various underwater images processing techniques result with WCID algorithm.

In paper [20] image segmentation of underwater images using particle swarm optimization along with fuzzy c means clustering approach is shown. The efficient and speedy approach is seen which makes use of the weighted histogram thereby changing the membership of fuzzy based clusters. Also, quality of underwater images is seen to be improved using the approach. The segmentation quality of the method is improved when observed with results on various images. The method shows enhancement in efficient computation and hence, less complexity.

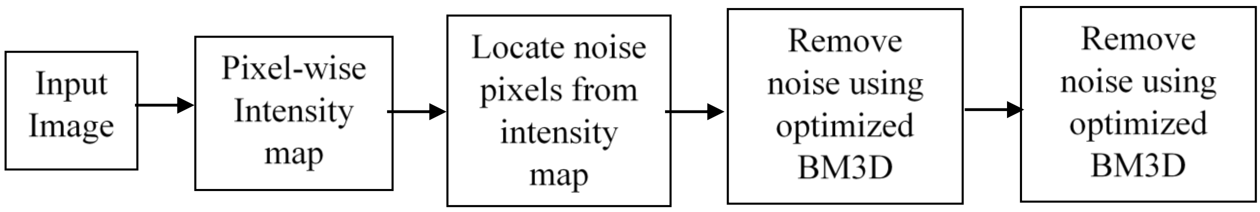

Figure1: System block diagram

III. PROPOSED WORK

The KNN clustering approach is used for noise detection method. From 0 to 255 we make 9 different classes such that it will possess grey values as detailed in table 1.

At a time, a block of pixels in the form 3X3 is taken into consideration. The gray value of these pixels is calculated. If each pixel has different values, then noise is supposed to be dense. The pixels in a block are identified by the named class. The class matrix map (cluster index) for all the 9 pixels in a block is generated as shown in figure 1(b). From figure 1 (a) and (b) the noise pixel can be identified located at P_{13} position. Using Sliding pattern of 3X3 block when next column comes into block we can easily identify that pixel with value 8 shows presence of noise.

Table I: Classification of pixels with respect to their grey values

Class	Grey value range
1	0-28
2	29-56
3	57-84
4	85-112
5	113-140
6	141-168
7	169-196
8	197-224
9	225-255

P_{11}	P_{12}	P_{13}
P_{21}	P_{22}	P_{23}
P_{31}	P_{32}	P_{33}

(a)

4	4	**8**
4	4	4
4	4	4

(b)

4	**8**	4
4	4	4
4	4	4

(c)

Figure 2: a) Pixel position map in 3X3 block b) Noise pixel class map (cluster index)

3.1 Pixel Intensity mapping:

95	**251**	95
95	95	95
95	95	95

Figure 3: Pixel-wise intensity map

According to [1], there are four possibilities of noise models based on pixel value which can be either one of 0 and 255 or it can be any value between 0 and 255. Here nonlinear probability of salt and pepper can be taken into consideration for better understanding.

3.2 Fitness function for PSO:

$vp(i + 1) = h(i) * vp(i) + \psi_p * rp * (xpbp(i) - xp(i)) + \psi_g * rg * ((xgbp(i) - xp(i))$

$xp(i + 1) = xp(i) + vp(i + 1)$

where, ψp and ψg are the positive learning factors respectively. rp and rg are random numbers in [0, 1]. i is the generation number in [1, IMAX]. IMAX is the maximum number of generations. h(i) 2 [0,1] is the inertia factor. fpB(i) and fgB(i) are the pBest value and gBest values at ith generation. $x_pB(i)$ and $x_gB(i)$ are the personal and global best positions of p^{th} particle at i^{th} generation respectively.

3.3 Particle swarm optimization based BM3D for noise removal:

Noise removal from the image is done by using particle swarm optimization based optimized BM3D technique. The algorithm of filtering is as given below:

1. Take input color image
2. Separate input color image into red, green and blue matrix
3. Convert input color image into grayscale
4. Take grayscale image matrix for processing
5. Prepare classification matrix (cluster index) for the image
6. Identify noise containing 3x3 blocks from entire image matrix and prepare blocks vector
7. Take on 3x3 block at a time from a grayscale image and respective block with similar coordinate from red, green and blue image matrices.
8. Process each block using optimized BM3D filter for noise removal
9. If all blocks finished stop else go to step5.

IV. RESULTS

Figure 3:Input Image

Figure 4:Noise added Image

Figure 5:Noise removed Image using proposed method with optimized BM3D

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Figure 6:Results of debluring and resolution enhancement of butterfly image using optimized BM3D

Retinex is used fFor represnting image with dynamic illumination. In computer vision color constancy is a desirable feature. Several retinex algorithms are available for dynamic illunmination. We have used multiscale retinex for dynamic illumination of resolution ehahnced image which also shows significant difference in PSNR values.

Figure 7:Output of retinex stage

Performance evaluation is done using the peak signal to noise ratio (PSNR) and mean square error (MSE) analysis. Table II indicates PSNR based comparative analysis of proposed and existing methods.

TABLE II. PSNR ANALYSIS OF IMAGES USING IMPROVED STRATEGY

Image	Size	BM3D	KNN + Optimized BM3D+ Enhancement	KNN + Optimized BM3D + Enhancement+ Retinex
Butterfly	256x256	22.49 dB	34.25 dB	45.66 dB
Satellite	256x256	23.45 dB	36.25dB	47.68 dB
Cameraman	256x256	24.14dB	34.24 dB	46.23 dB
Banana	256x256	23.28dB	33.25dB	41.25 dB
Butterfly	512x512	23.11 dB	35.55 dB	46.13 dB
Satellite	512x512	24.21 dB	34.22dB	48.78 dB
Cameraman	512x512	26.13dB	35.14 dB	47.11 dB
Banana	512x512	25.66dB	36.15dB	47.55 dB

From the analysis of the results it can be seen that the optimized BM3D along with enhancement and retinex output outperforms in terms of PSNR and MSE. The performance evaluation of the proposed method along with comparative methods is done using RENOIR - A Dataset of Real Low-Light Images [18] datset with average PSNR and MSE.

TABLE III. COMPARATIVE ANALYSIS OF PROPOSED METHOD USING AVERAGE PSNR AND MSE VALUES

Method	PSNR	MSE
BM3D	24.31 dB	0.331
BM3D+enhancement [17]	32.31 dB	0.288
BM3D+enhancement+retinex [19]	42.22 dB	0.191
Proposed	46.23 dB	0.123

From the result shown in table it can be seen that proposed method outperforms in terms of PSNR and MSE.

V. CONCLUSION

Though variety of techniques are available, there is requirement of optimized and effective technique for nonlinear noise removal. The proposed method in this paper outperforms in terms of nonlinear noise detection and removal followed by the image enhancement technique compared to other techniques. The output results are analyzed using PSNR and MSE parameters and show better performance.

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