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Evaluating the Performance of NLM and NLEM Image Denoising Techniques

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Abstract— The search for efficient Image denoising is one of the most essential challenges in the ground of image processing. In image denoising original image is estimated by removing noise from a noisy version of the image. Many algorithms have been proposed for removal of noise from the digital images. the image denoising methods are divided into two types: local and non-local. The methods that only use the spatial redundancy in local neighbourhoods are known as Local methods. The method that estimate pixel intensity from the complete image and shows the occurrence of similar patterns and features in an image are referred as Non-Local. This technique [3] estimates a noise-free pixel value as a weighted average of all other neighbourhood pixels in the image with similar neighbourhood. This paper evaluates the performance of NLM and NLEM image denoising techniques. It has been found that the most of the previous denoising techniques like gaussian filtering, bilateral filtering may remove some details from the image. So a non local method known as non-local means solve this problem by preserving those details. the second method is named as Non local euclidean median. This method improves the performance of NLM at high noise level. Denoising performance of a noisy image improved by replacing the mean by the euclidean median and this new denoising algorithm the non-local euclidean medians (NLEM)

Keywords— Denoising, NLM, NLEM

I. INTRODUCTION

Many image denoising algorithms have been proposed for the purpose of removal of noise from the noisy image. Main goal of these algorithms is to recover the original image from the noisy image. Image denoising plays very important job in a various applications such as image restoration and in image segmentation, where obtaining the original image is important for better performance. The basic idea behind this paper is the evaluation of the uncorrupted image from the distorted or noisy image, and is also referred to as image "de-noising". There are various methods [2][3] that assist to reinstate an image from noisy image. But choosing the suitable technique plays a key role in receiving the desired image.. Here a study is made on the different filters for de-noising and each is implemented in Matlab [14]. Each method is compared and classified in terms of its effectiveness. In order to compute the performance of these de-noising algorithms, a high class image is in use and some noise is added to it. This would be known as input to the filter, which produces an image close up to the original high quality image. The performance of each filter is compared by evaluating its Noise Ratio .a good image denoising techniques is one that will remove noise at the same time preserving edges. Previously some general approach such as a gaussian filter [2] is used for removal of noise from the image and this kind of denoising is acceptable. One big benefit of linear noise removal technique is its rapidity. But a limitation of this technique is that they are not able to save edges in a advanced method. Other approach is bilateral filtering [6], which is a non-linear.This technique work as edge-preserving and noise-reducing smoothing filter for images. Median filtering is also a denoising technique but it is less capable in removing gaussian noise. Many of these algorithms [15] [16] remove the fine facts and structure of the image in addition to the noise. In this paper we evaluate the performance of two image denoising techniques known as NLM and NLEM. These two techniques have been designed and implemented in MATLAB using image processing toolbox. Different kind of the images has been taken for experimental purpose. This study shows the improvement of the NLEM algorithm over the NLM .the non-local means algorithm is a denoising technique based on the fact that image contains an wide amount of redundancy. These redundancies can then be oppressed to remove the noise in the image. Non local median is also a denoising technique that is proven to be better than previous technique.The rest of the letter is organized as follows. In Section II, we discuss NLM image denoising technique .in section III we discuss NLEM image denoising technique .in Section IV we discuss related work. This is followed by some denoising results in Section V, where we compare NLEM algorithm with NLM. We show some remarks in Section VI

II. NON LOCAL MEANS

Non-local means [9]]is an algorithm that is used in image processing for image denoising. Various local smoothing methods and the frequency domain filter focus on noise reduction and at a restoration of the central geometrical configurations but not at the conservation of the fne structure, and texture. Due to this fine points and structures are smoothed out because they behave they all behave as noise. The NL-means algorithm tries to take advantage of the high

quantity of redundancy of any image detailed survey of this method is available in [3] [5]. It mean that every small windowpane in a natural image has many similar window in the same image. Now in simple words we can defines neighborhood of a pixel *i*" as any set of pixels *j* in the image such that a window around *j* looks like a window Around *i*. All pixels in that neighborhood can be used for predicting the value at *i*, Other filters such as local filters that modernize a pixel's value with an average of the pixels in the region of it. But non local filters updates the pixel value by means of a weighted average of the pixels that are judged to be mainly similar to it. This technique use some non local concepts described in [7] [8].A non local method called as non-local means estimates noise-free pixel intensity as a weighted average of all pixel intensities in the image, and the weights are relative to the similarity between the local neighbourhood of the pixel being processed and local neighbourhoods of neighbouring pixels. Psnr and ssim parameters [1] are used to evaluate the result in base paper.. Given a noisy image, the denoised image at pixel is computed using the given formula. This sum is ideally performed over the whole image.

$$NL[U](i) = \sum_{j \in I} w(i,j)v(j)$$

Where the weight w(i,j) [11] [12] depends on the distance between observed gray level vectors at points i and j.such distance can be represented as

$$d = ||v(N_i) - v(N_j)||^2_{2,a}$$

So the weight [4][8]can be defined as

$$w(i,j) = \frac{1}{Z(i)} e^{\frac{-||v(N_i)-v(N_j)||^2_{2,a}}{h^2}}.$$

Advantage

a) This technique [13] work for the removal of noise and it give better result as compare to the previous denoising techniques that leads to the smoothning of image.

Disadvantage

a) This denoising method work only for low noise level.

III. NON LOCAL EUCLIDEAN MEDIANS

Non local Euclidean [9] is a image denoising technique that is used for removal of noise from the image. by replacing the mean by the euclidean median [13] better performance is achieved at high noise level. This technique proves that the median is more vital to outliers than the mean . Nlem performs superior than nlm in the close by area of edges, generally at large noise levels. Nlem can be professionally implemented by using iteratively reweighted least squares. [4] the euclidean mean is the minimizer of $||v(N_i) - v(N_j)||^2$ Over all patches and euclidean median is the minimizer of $||v(N_i) - v(N_j)||$ .after that from all patches the patch that minimize this distance is considered .ventral value of that patch is used to replace the value of pixel in order to get noise free image. When concept of euclidean median is used over all patches then much better result is obtained as compare to non local means but at high noise level.

Advantage

a) This technique is used to improve the denoising performance of nlm in the vicinity of edges using the euclidean median.

Disadvantage

a) This technique work only for high density noise.

IV. RELATED WORK

Related work that is done in this field is as follow. Gaussian filters, bilateral filtering and median filtering are filtering techniques that remove noise from the image but these techniques also remove some fine details from the image.

.NLM (non-local means) is a denoising technique that is used for the preservation of structure in digital image and it perform well only at low noise level and it does not work for vicinity of edges or preservation of edges.

NLEM (non-local euclidean means) is also a denoising technique that is used for the removal of noise from a noisy image and it improves the performance of NLEM in the vicinity of edges by using the concept of euclidean median.

Main limitation of NLM and NLEM is that NLM work only for low noise level and NLEM works only for large noise level so we conclude that both of these techniques are not suitable for every kind of noise level i.e one can work for low density noise and other work for high density noise. Both of these techniques not work for the preservation of edges.

V. EXPERIMENTAL RESULTS

This section contains the experimental results. The overall section contains the original image, noisy image with noise level 20 and 80 and these noisy images are denoised by using **NLM and NLEM.** Fig 1 to Fig 4 shows the performance of NLM and NLEM at noise level 20 and Fig 5 to Fig 7 shows the performance of NLM and NLEM at noise level 80

Fig 1: Original Image

Fig 2: Noisy Image (20)

Fig 1 shows the original image in which noise is added in order to compute the performance of algorithms. fig 2 shows the noisy image with noise level 20.

Fig 3: Non Local Means

Fig 4: Non Local Euclidean Median

Fig 3 shows the performance of NLM denoising technique at noise level 20. fig 4 shows the performance of NLEM at noise level 20.

Fig 5: Noisy Image (80)

Fig 6: Non Local Means

Fig 5 shows the performance of NLM denoising technique at noise level 80. Fig 6 shows the noisy image with noise level 80.on this noisy image we apply the denoising algorithms in order to obtain noise free image.

Fig 7: Non Local Euclidean Median

This figure shows the performance of NLEM at noise level 80.

VI. PERFORMANCE ANALYSIS

In this section we evaluate the performance of NLM and NLEM by using some well-known image performance parameters.

1. MEAN SQUARE ERROR:

Mean square error is a parameter used to calculate an error signal by subtracting the test signal from the reference, and then computing the average energy of the error signal. The mean-squared-error (MSE) is the simplest, and the most widely used image quality measurement.

Table 1: Mean Square Error Analysis

Image		**20 %**	**80%**
1.	NLM NLEM	46 169	906 483
2.	NLM NLEM	36 115	955 524
3.	NLM NLEM	62 172	975 625
4.	NLM NLEM	60 225	1010 631
5.	NLM NLEM	47 144	857 572
6.	NLM NLEM	78 494	1296 1076
7.	NLM NLEM	65 189	991 709
8.	NLM NLEM	65 396	1346 1163
9.	NLM NLEM	56 206	1025 739
10.	NLM NLEM	186 333	1170 823

This table shows the results of applying denoising algorithm NLM and NLEM over noisy images. from these results we conclude that NLM shows better results at low level noise(20%) and NLEM shows better result over high level noise(80%).

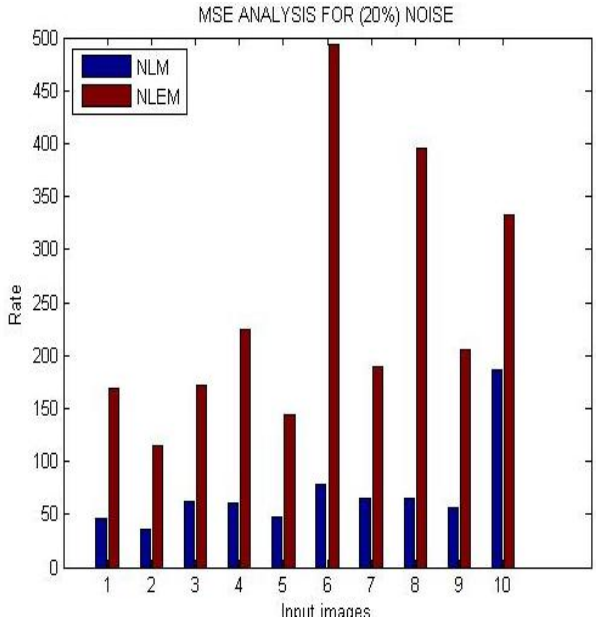

Fig 8 Analysis of Mse (20%)

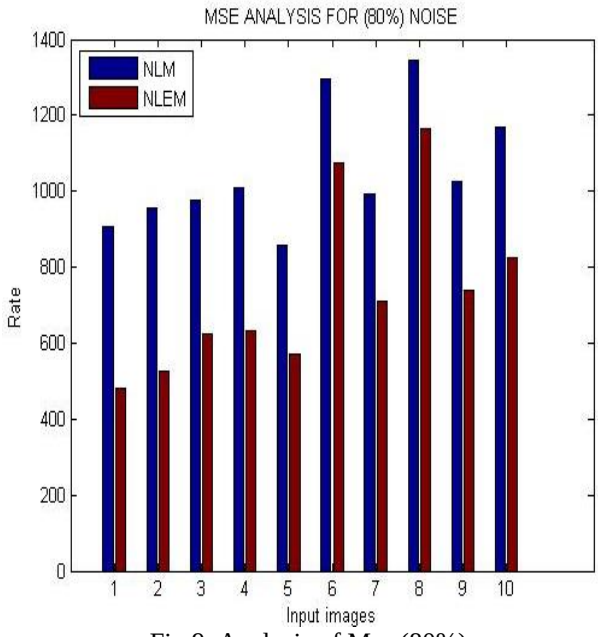

Fig 9 Analysis of Mse (80%)

Fig 8 And Fig 9 Shows The Graphical Results Of MSE At Noise Level 20% And 80%.From These Results We Conclude That NLEM Perform Better Then NLM At High Level Noise In Order To Obtain A Noise Free Image.

2. PEAK SIGNAL TO NOISE RATIO:

PSNR is used to specify the ratio between maximum power of signal to the power of corrupting noise. Larger PSNR indicate a smaller difference between the original (without noise) and reconstructed image.

Table 2: Peak Signal To Noise Ratio

Image		**20%**	**80%**
1.	NLM NLEM	27.3390 25.2752	18.5595 21.2913
2.	NLM NLEM	27.7169 26.5171	18.3308 20.9375
3.	NLM NLEM	25.8519 24.726	18.2408 20.1720
4.	NLM NLEM	26.0357 24.0654	18.0876 20.1305
5.	NLM NLEM	26.8923 24.4947	18.8010 20.5568
6.	NLM NLEM	24.8267 20.8473	17.0048 17.8127
7.	NLM NLEM	25.4357 24.4201	18.1701 19.6243
8.	NLM NLEM	24.8064 21.5890	16.8404 17.4750
9.	NLM NLEM	26.0625 24.1514	18.0236 19.444
10.	NLM NLEM	25.4357 22.9064	17.4489 18.9768

This table shows the results of applying denoising algorithm NLM and NLEM over noisy images. from these results we conclude that NLM shows large PSNR value(better results)at low level noise(20%) and NLEM shows large PSNR values (better result) over high level noise(80%).

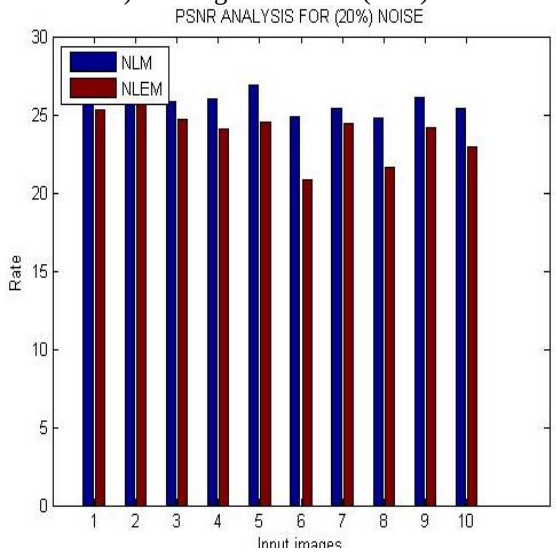

Fig 10 Analysis Of Psnr (20%)

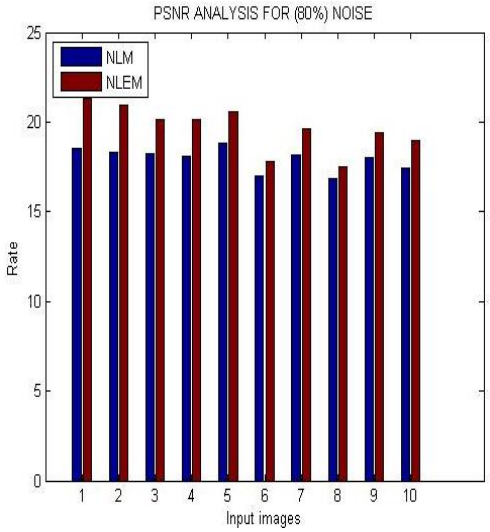

Fig 11 Analysis Of Psnr (80%)

Fig 10 and fig 11 shows the graphical results of PSNR at noise level 20% and 80%.from these results we conclude that NLEM perform better then NLM at high level noise in order to obtain a noise free image

3. ROOT MEAN SQUARE ERROR

The root mean square error is a normally used to calculate of the difference between values predicted by a model and values observed from the environment that is being modelled.

Table 3: Root Mean Square Error

Image		**20%**	**80%**
1.	NLM NLEM	10.9545 13.8924	30.0998 21.9773
2.	NLM NLEM	10.4881 12.0416	30.9031 22.8910
3.	NLM NLEM	13 14.7986	31.2250 25

4.	NLM NLEM	12.7279 15.9687	31.7805 25.1197
5.	NLM NLEM	11.5326 15.1987	29.2746 23.9165
6.	NLM NLEM	14.6287 23.1301	36 32.8024
7.	NLM NLEM	13.6382 15.3297	31.4802 0.0510
8.	NLM NLEM	14.6629 21.2384	36.687 34.1028
9.	NLM NLEM	12.6886 15.8114	32.0156 27.1846
10.	NLM NLEM	13.6382 18.2483	30.3222 28.6880

This table shows the results of applying denoising algorithm NLM and NLEM over noisy images. from these results we conclude that NLM shows better results at low level noise(20%) and NLEM shows better result over high level noise(80%).

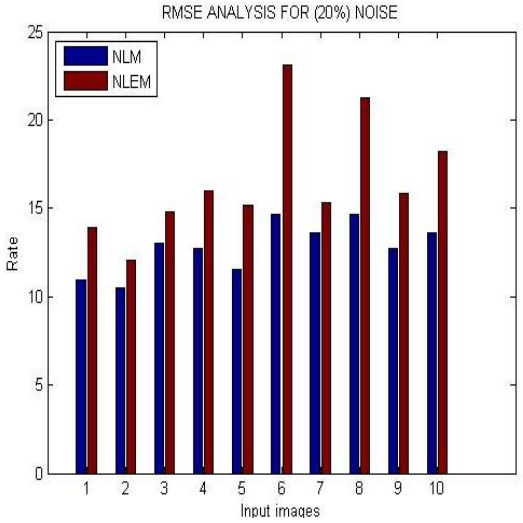

Fig 12 Analysis of Rmse (20%)

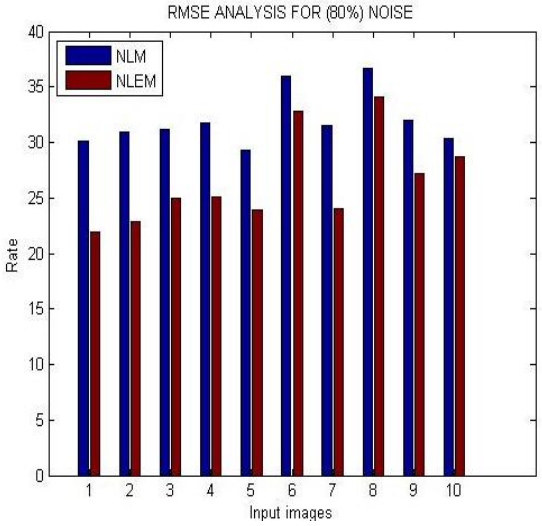

Fig 13 Analysis of Rmse (80%)

Fig 12 and fig 13 shows the graphical results of RMSE at noise level 20% and 80%.from these results we conclude that NLEM perform better then NLM at high level noise in order to obtain a noise free image

4. MAXIMUM DIFFERENCE

This parameter is used to compute the maximum difference between original image and denoised image. Less value of maximum difference implies better result.

Table 4: Maximum Difference

Image		20 %	80%
1.	NLM NLEM	93.7842 130.2314	178.6037 143.6284
2.	NLM NLEM	75.7465 129.3201	200.4529 173.3978
3.	NLM NLEM	75.4063 75.8942	115.3012 90.0938
4.	NLM NLEM	72.5584 102.1013	137.8555 15.0685
5.	NLM NLEM	55.1802 72.5144	107.9234 132.7086
6.	NLM NLEM	65.8928 152.3212	188.7570 156.3650

7.	NLM NLEM	66.1487 111.9924	150.9301 168.5912
8.	NLM NLEM	80.7459 170.5040	188.447 189.7006
9.	NLM NLEM	70.2214 117.6788	138.8817 131.4619
10.	NLM NLEM	77.5636 124.2640	165.7766 150.9445

This table shows the results of applying denoising algorithm NLM and NLEM over noisy images. from these results we conclude that NLM shows better results at low level noise(20%) and NLEM shows better result over high level noise(80%).

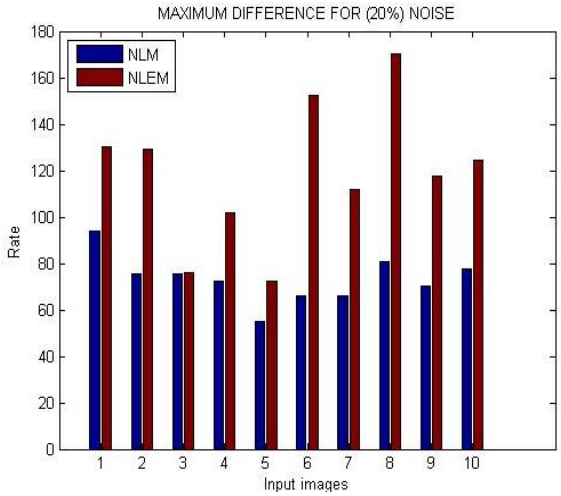

Fig 14 Analysis of Max Diff (20%)

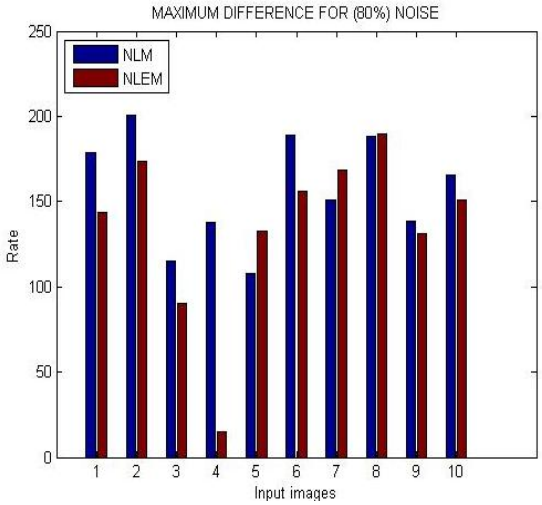

Fig 15 Analysis of Max Diff (80%)

Fig 14 and fig 15 shows the graphical results of MAXIMUM DIFFERENCE at noise level 20% and 80%.from these results we conclude that NLEM perform better then NLM at high level noise in order to obtain a noise free image

5. BIT ERROR RATE

In order to achieve better result Bit error rate need to be minimized. NLM have low bit error rate at low level noise and NLEM have low bit error rate at high level noise.

Table 5: Bit Error Rate

Image		**20%**	**80%**
1.	NLM NLEM	0.036 0.0396	0.0539 0.0470
2.	NLM NLEM	0.0361 0.0377	0.0546 0.0478
3.	NLM NLEM	0.0387 0.0404	0.0548 0.0496
4.	NLM NLEM	0.0384 0.0416	0.0553 0.0497
5.	NLM NLEM	0.0372 0.0408	0.0532 0.0486
6.	NLM NLEM	0.0405 0.0480	0.0588 0.0561
7.	NLM NLEM	0.0393 0.0409	0.0550 0.0510
8.	NLM NLEM	0.0403 0.0463	0.0594 0.0572
9.	NLM NLEM	0.0384 0.0414	0.055 0.054
10.	NLM NLEM	0.0393 0.0437	0.0573 0.0527

This table shows the results of applying denoising algorithm NLM and NLEM over noisy images. from these results we conclude that NLM shows better results at low level noise(20%) and NLEM shows better result over high level noise(80%).

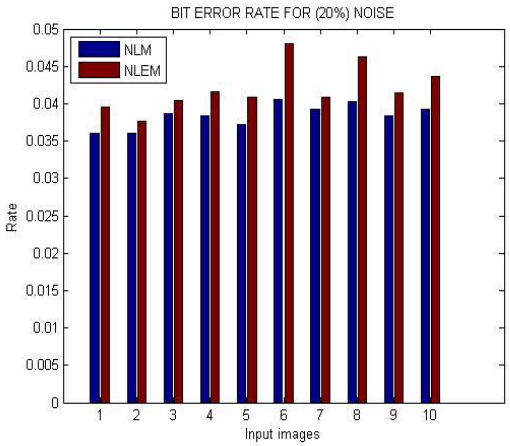

Fig 16 Analysis Of Max Diff (20%)

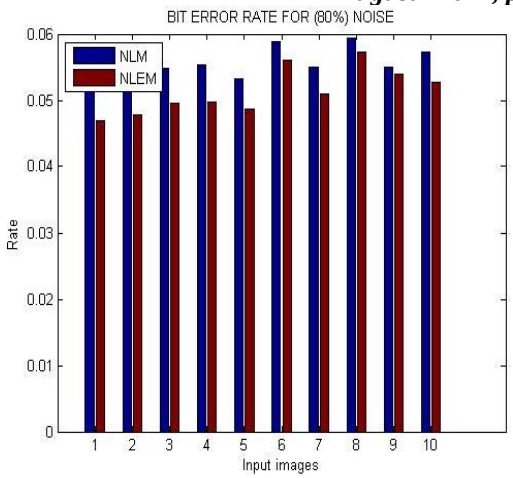

Fig 17 Analysis Of Max Diff(80%)

Fig 16 and fig 17 shows the graphical results of BIT ERROR RATE at noise level 20% and 80%.from these results we conclude that NLEM perform better then NLM at high level noise in order to obtain a noise free image

VII. CONCLUSION AND FUTURE DIRECTIONS

In this paper two denoising techniques are discussed in this paper. These two techniques have been designed and implemented in MATLAB using image processing toolbox. Different kind of the images has been taken for experimental purpose. This study shows the improvement of the NLEM algorithm over the NLM at high noise level. At noise level 20 NLM perform better result and at noise level 80 NLEM perform better. From this we conclude that out of these denoising techniques NLM perform well for low level noise and NLEM perform well for high level noise. NLEM (non-local Euclidean means) improves the performance of NLM in the vicinity of edges by using the concept of Euclidean median. But the main limitation of NLM and NLEM is that NLM work only for low noise level and NLEM works only for large noise level therefore both are not suitable for every kind of noise level.. Also both techniques does not focus on preserving the edges.

To overcome the shortcomings of the available techniques in near future we will modify the existing method with a new one that work for every level of noise. we can alsol use the concept of image gradients as a post processing operation to preserve the edges in an efficient manner.

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