STUDY OF FILTERING TECHNIQUES FOR SALT AND PEPPER NOISE

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Abstract*— Noise is a very common phenomenon that leads to the distortion of pixels in an image. It is a contribution of the sensors that captures the images. Various kinds of noise exist in the literature. SAP is a very common type of noise where random pixels values get converted to either to a minimum value, i.e., 0 or to a maximum value, i.e., 255 indicating a complete white (salt) or a complete black (pepper) pixel. The Median Filtering (MF) technique promises to be the most effective filtering technique to restore an image with salt and pepper noise. The effect is a blurry image even at low noise intensities. The IMF identifies the neighbouring pixels of a noisy pixel and calculates the difference of the values of the adjacent neighbouring pixels. The maximum difference value replaces the noisy pixel. The ranked-order based AMF (RAMF) removes positive and negative impulse noise simultaneously while preserving the sharpness better than the nonlinear mean filter. The impulse Size based AMF (SAMF) on the other hand removes high density impulses, smoothes non-impulsive noise. The DAMF uses the concept of t-symmetric padding and k-approximate matrices to process the noisy pixels. We have used a proposed algorithm that can remove SAP noise for all densities.

***Keywords*— SAP, DAMP, IMF, MF, MSE, PSNR, SSIM.**

I. INTRODUCTION

1.1. *Overview*

An image is an artefact that depicts visual perception. It is a two-dimensional (2D) signal, f(x, y), where the values of the function f(x, y) represent the amplitude or intensity of the image [1]. Intensity of an image implies the intensity of pixels of an image. An image is composed of multiple pixels. An image can be captured by optical means like camera, lenses, microscopes, etc. Digital image is a rectangular arrangement of pixels sometimes called bitmap. It measures brightness of an image (mean pixel intensity) with respect to other image.

Image contrast can be determined by the difference in the colour and brightness of object and other object within same field of view. Meta data is information which provides details of an image that means image property. Grey scale image and binary images are called monochrome images as there is no colour component in these images. Grey scale image is different from binary image. Grey scale has many shades of grey between black and white. Binary image is composed of 0 or 1 pixels values. Binary image is created from a grey image using a threshold process. In an image total 256 pixels can be present.

1.2. *Image Noise and Filtering Techniques*

Noise is a common problem in digital images. Gaussian and impulse noise are very common types of noise. Gaussian noise unlike impulse noise affects every pixel of the image. Noise suppression is very important in image processing since performance of subsequent processing techniques like image segmentation, image compression, texture analysis, object detection and classification etc. highly depends on the quality of restored image. Image filtering makes possible several useful tasks in image processing. A filter can be applied to reduce the amount of unwanted noise in a particular image.

Filtering of an image is a procedure which tries to improve image from corrupted or distorted form. This is one kind of image enhancement technique [2].Basically noisy image is different from original image because values of pixels in original images are changed in noisy image. Different methods have been taken for image denoising, both in frequency domain [3-5] and spatial domain [6-9]. In spatial domain some filters are used such as box filter, Gaussian filter [1], gradient and Laplacian filter [1]. In frequency domain the filters are ideal 1D low pass filters, 2D low pass filters, Butterworth low pass filters [1], Gaussian low pass filters, 1D high pass filters, 2D high pass filters, Butterworth high pass filters [1], Gaussian high pass filters.

To remove the Salt and Pepper (SAP) noise, the most popular filtering technique is median filter which replaces central pixel with median of all pixels in a window. Example of a median filter is medfilt2, which removes noise and preserves edges. By default it considers window size of 3X3.

Maximum Filter is used to remove pepper (black) type noise from noisy image. This filter selects maximum value of pixel from sorted list and replaces central pixel with largest value of pixel. Median filter can give best result for low noise intensity otherwise resultant filtered image is very poor. Maximum, minimum filter use fixed size window for larger size they cannot work properly.

Minimum Filter is also used to remove salt (white) type noise from noisy image. This filter selects minimum value of pixel from the sorted list and replaces the central pixel with smallest value of pixel.

Nlfilter is another kind of filter to remove SAP noise. It selects a single pixel, determines the neighbourhood of pixel, apply a function to the values of pixels in neighbourhood.

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Find the pixel output image whose position is same to that of the centre pixel in the input image. Set this output pixel to value returned by function. For each pixel in input image need to be calculated this operation. Nlfilter uses a function for neighbourhood operation. Most of the time median function is taken. So, nlfilter does same thing like median filter. So those filters cannot give best result for removing SAP noise from corrupted image.

Drawback of low pass filter is it cannot preserve edges and it produces blurry images so SAP noise cannot be removed. High pass filter does opposite of low pass filter so it preserves edges but removes low frequency components (pixel values) so filtered image cannot provide best result.

In this thesis, we have performed comparative study of four filtering techniques for removing SAP noise from corrupted images. The fundamental purpose of our work has focused on to restoring the original image. Moreover to measure the closeness of the filtered image to the original image, we have used two image quality measurement functions such as Structural Similarity Index (SSIM) and Peak Signal to Noise Ratio (PSNR).

II. PROPOSED SCHEME

2.1. *Overview*

DAMF, IMF filters has been observed to fail to recover the original image for higher noise density. Accordingly, in this chapter, we propose a filtering algorithm which is able to recover the original image to more efficiently for higher noise intensities compared to the IMF and DAMF. The next section describes the proposed algorithm in details.

2.2. *Algorithm*

1. A 2D window of size w=3X3 is selected and centered around the processed pixel P(x, y) in the corrupted image.
2. Find the minimum, maximum and median of the pixels as P_{min}, P_{max} and P_{med}.
3. If $P_{min} < P(x, y) < P_{max}$, where $P_{min} > 0$ and $P_{max} < 255$ and P(x,y) = 0 or P(x,y) = 255,it is classified as a corrupted pixel.
4. If P(x, y) is corrupted pixel,

    a)If $P_{min} < P_{med} < P_{max}$ and $0 < P_{med} < 255$

    i) Replace the corrupted pixel P(x, y) with P_{med}.

    b)Else P_{med} is a noisy pixel. So replace value of P(x,y) with mean value of P(1,2)+P(3,2) positions with respect to the 3x3 window.
5. Steps 1 to Step 4 are repeated until the processing is completed for the entire image.

Here central pixel value of window has replaced by average pixel value of P(2) and P(8) pixel values. According to this algorithm we have also taken median operation but instead of taking median of all eight neighbouring pixel values we have taken specific two pixel values of P (2) and P (8) th positions.

FLOW CHART

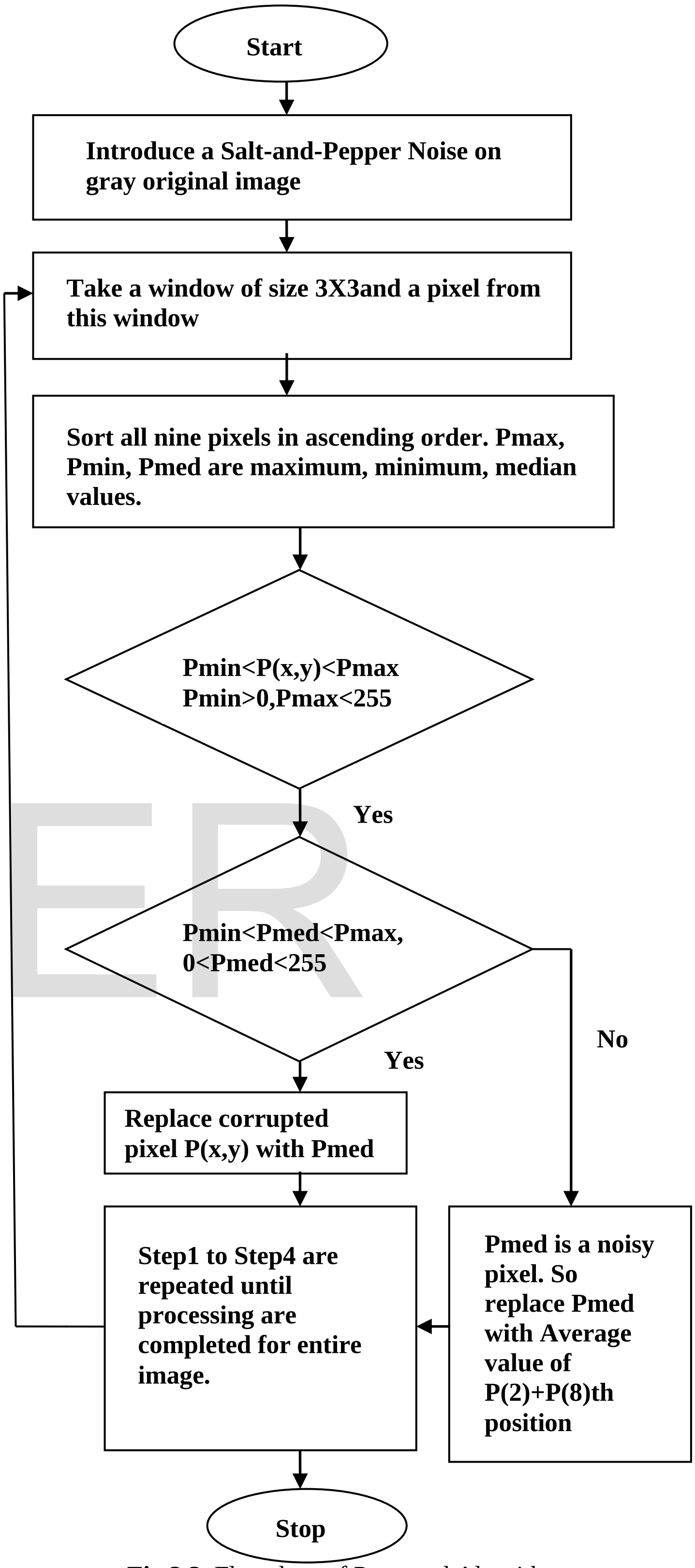


Fig 2.2. Flowchart of Proposed Algorithm

III. PERFORMANCE PARAMETERS

The performances of the algorithms have been compared in terms of Structural Similarity Index (SSIM) and Peak Signal to Noise Ratio (PSNR).

SSIM: The SSIM is a perceptual metric that quantifies image quality degradation caused by processing such as data compression or by losses in data transmission. It is calculated as:

$$SSIM(x,y) = (2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)/(\mu_x{}^2 + \mu_y{}^2 + c_1)$$ ……(13)

μ_x =average of x, μ_y =average of y, $\sigma_x{}^2$= variance of x, σ_{xy} =covariance of xy, x, y are two windows of size $n \times n$.

SSIM depends on three components
Light
Contrast
Structure

PSNR: The Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR) are the two error metrics used to compare image compression quality. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error.

Formula: $10\log_{10}(R^2 / MSE)$ ……………………………………………………………(14)

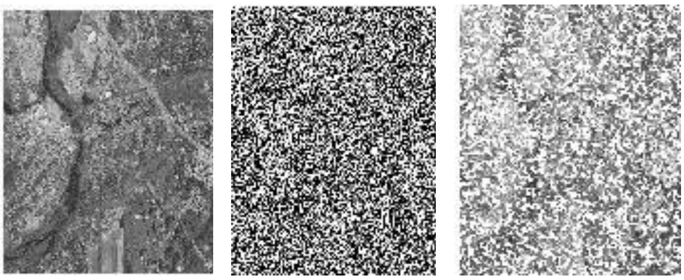
$R = 255$ for 8-uint data type , $R = 1$ for float data type
And MSE is given by eqn. (15).

MSE: $1/mn\sum_{i=1}^{m}\sum_{j+1}^{n}(x_{ij} - y_{ij})^2$ ……………………………………………………………(15)

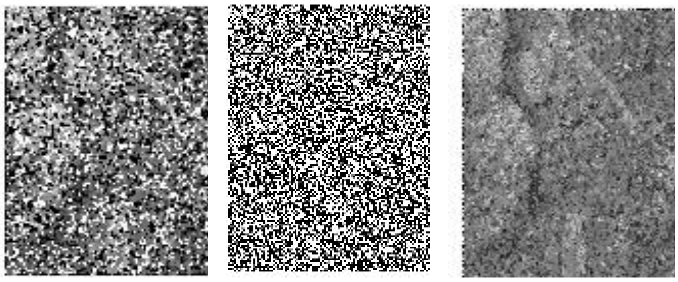
For images X=$[x_{ij}]_{m*n}$ and Y=$[y_{ij}]_{m*n}$
m, n are number of rows, column in input image.

IV. RESULT

Fig. 4.1 exhibits the effect of the various filtering algorithms considered for the image "concordariel" with SAP noise intensity of 0.7 for the size 256x256. As observed from the figures, medfilt2 could hardly recover the image. The DAMF algorithm leaves white patches while the IMF algorithm leaves black patches. For pixels represented as white by DAMF and black as IMF, the proposed algorithm performs a mean operation and hence the resulting pixel is grey in color. Hence, proposed algorithm can recover the original image to quite some extent unlike the DAMF and IMF. Moreover, the proposed algorithm also performs edge preservation like DAMF.

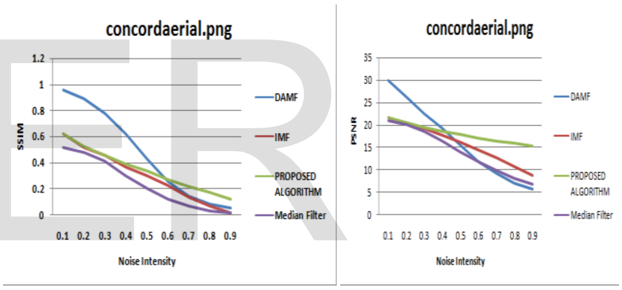


(a)Original Image (b) Image with 70% noise (c) DAMF



(d) IMF (e) medfilt2 (f) Proposed Filter

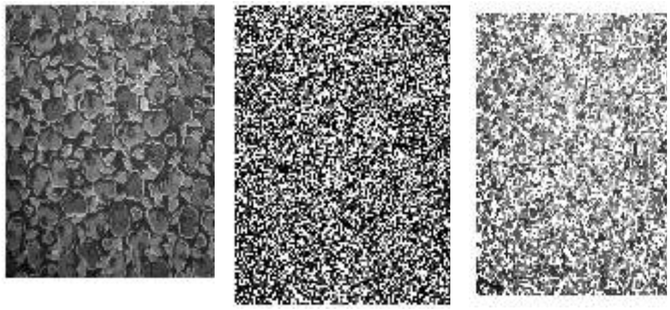
Fig 4.1 Experiment results on "concordaerial" with SAP noise ratio of 70%.



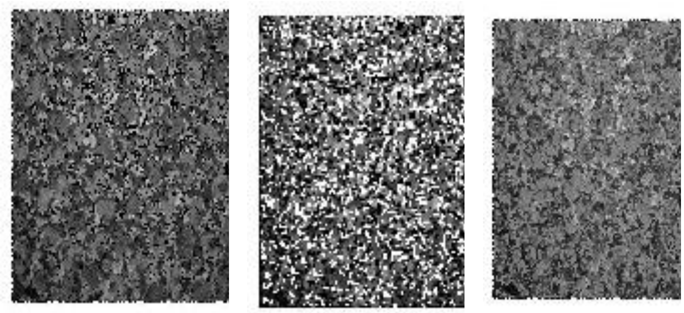
(a) (b)

Fig 4.2 (a) SSIM, (b) PSNR for "concordaerial"

The graphical interpretation of the pictorial representation exhibits similar results. For high noise intensity scenarios, the proposed algorithm is observed to outperform all the other 3 filtering algorithms considered in terms of both SSIM and PSNR. Using the mean of the specific neighbourhood pixels instead to sticking to the white (DAMF) or black (IMF) patches has resulted in the minimum deviation of the pixel value from the corresponding original pixel. Hence, the performance of the proposed algorithm is observed to outperform the other existing algorithms considered. Figs. 4.3-4.16 illustrate similar results.



(a) Original Image (b) Noisy Image with 70% noise (c) DAMF



(d) IMF (e) medfilt2 (f) Proposed Filter

Fig 4.3 Experiment results of several methods of “fabric” of size 256X256 with SAP noise ratio of 70%.

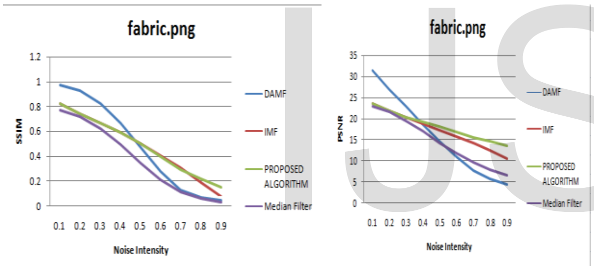
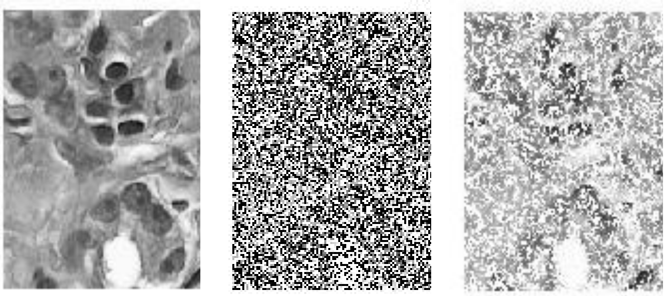
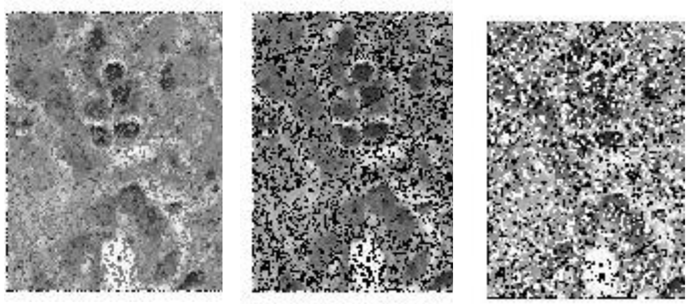


Fig 4.4 (a) SSIM Graph, (b) PSNR Graph



(a) Original Image (b) Noisy Image with 70% noise (c) DAMF



(d) Proposed Filter (e) IMF (f) medfilt2

Fig 4.5 Experiment results of several methods of “hestain” of size 256X256 with SAP noise ratio of 70%.

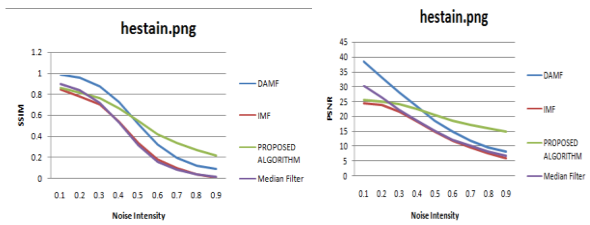
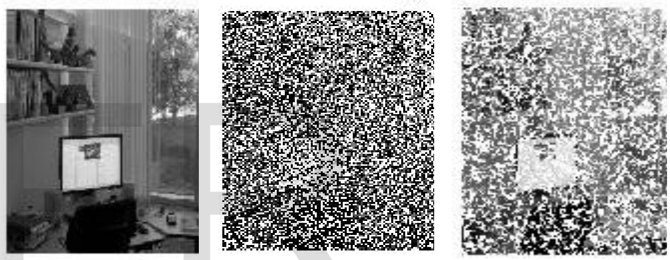


Fig 4.6 (a) SSIM Graph, (b) PSNR Graph



(a) Original Image (b) Noisy Image with 70% noise (c) DAMF

(d) Proposed Filter (e) IMF (f) Median

Fig 4.7 Experiment results of several methods of “office_4” of size 256X256 with SAP noise ratio of 70%.

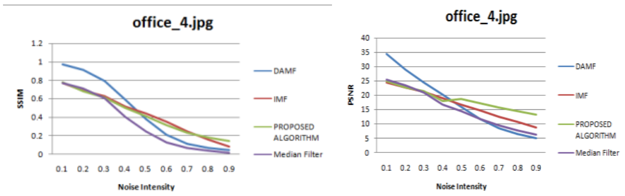
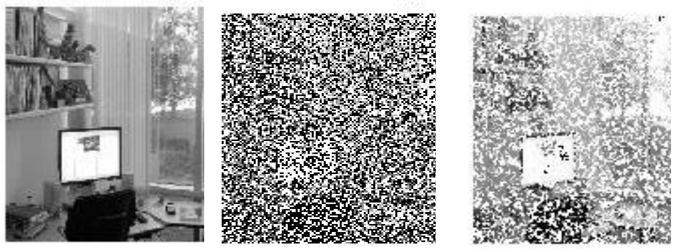
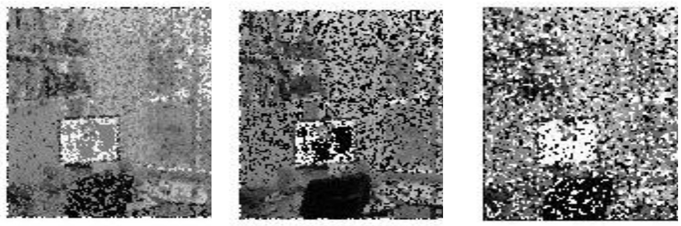


Fig 4.8 (a) SSIM Graph, (b) PSNR Graph



(a) Original Image (b) Noisy Image with 70% noise (c) DAMF



(d) Proposed Filter (e) IMF (f) Median

Fig 4.9 Experiment results of several methods of "office_5" of size 256X256 with SAP noise ratio of 70%.

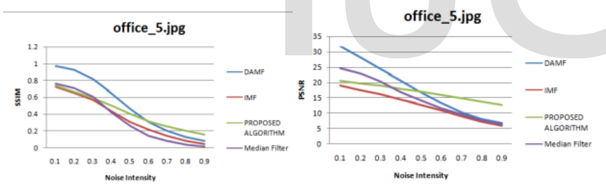
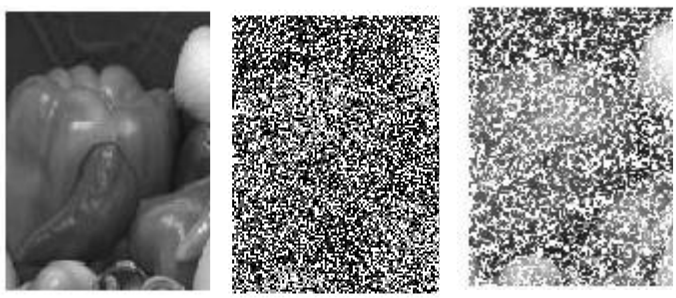
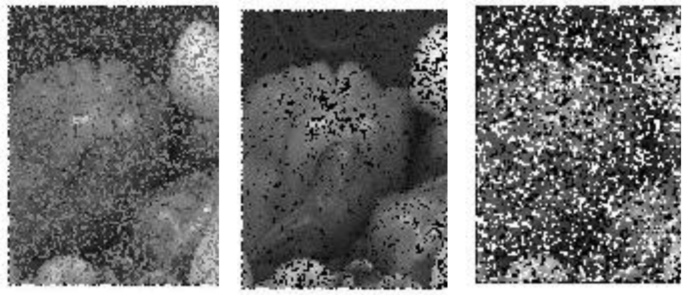


Fig 4.10 (a) SSIM Graph, (b) PSNR Graph



(a) Original Image (b) Noisy Image with 70% noise (c) DAMF



(d) Proposed Filter (e) IMF (f) Median

Fig 4.11 Experiment results of several methods of "onion" of size 256X256 with SAP noise ratio of 70%.

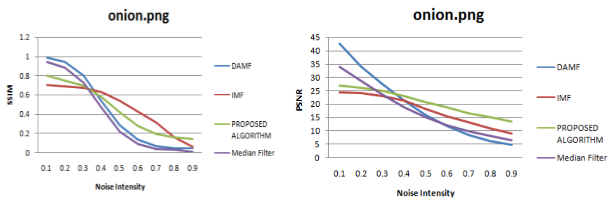
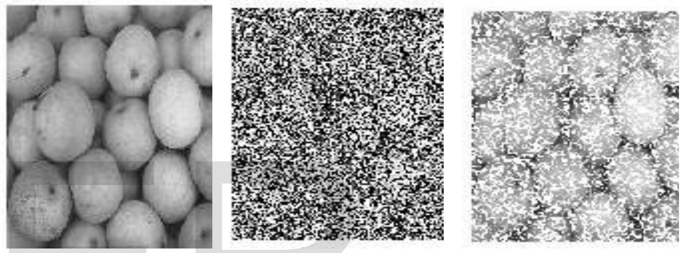
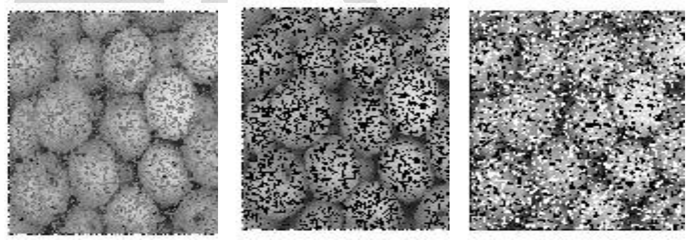


Fig 4.12 (a) SSIM Graph, (b) PSNR Graph



(a) Original Image (b) Noisy Image with 70% noise (c) DAMF



(d) Proposed Filter (e) IMF (f) Median

Fig 4.13 Experiment results of several methods of "pears" of size 256X256 with SAP noise ratio of 70%.

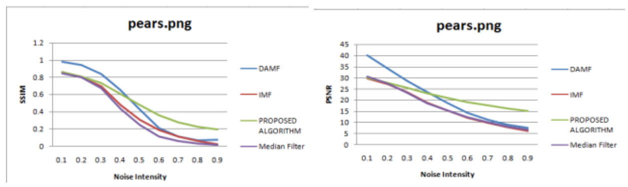
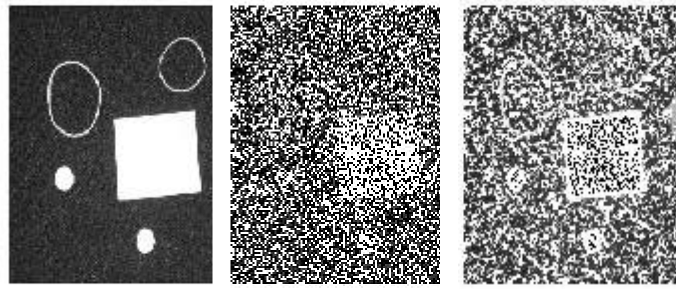
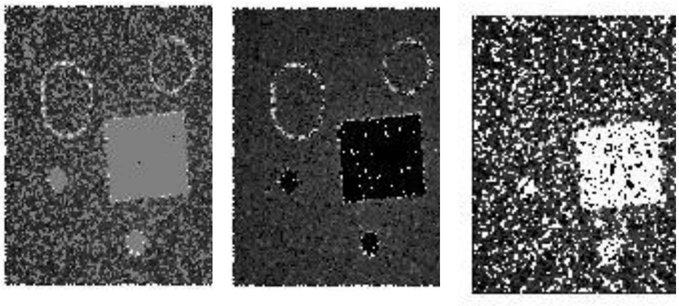


Fig 4.14 (a) SSIM Graph, (b) PSNR Graph



(a) Original Image (b) Noisy Image with 70% noise (c) DAMF



(d) Proposed Filter (e) IMF (f) Median

Fig 4.15 Experiment results of several methods of "pillsetc" of size 256X256 with SAP noise ratio of 70%

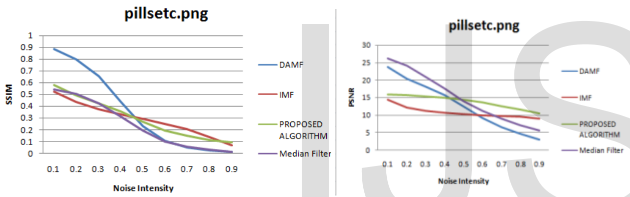


Fig 4.16 (a) SSIM Graph, (b) PSNR Graph

Fig. 4.17 illustrates the mean SSIM of the images for the algorithms considered. As observed, for most of the images proposed algorithm outperforms the IMF and the median filter. However, it outperforms the DAMF for a few specific images like the pears.png and hestain.png which has higher key compared to the others.

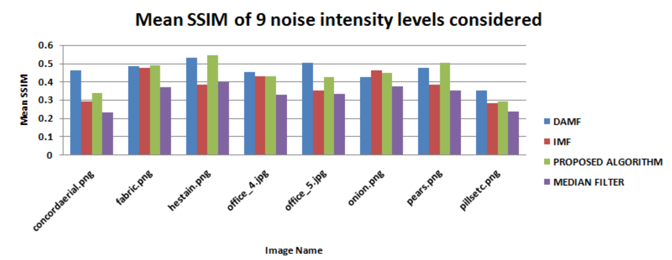


Fig 4.17 Comparisons among four algorithms of eight images with respect to mean SSIM values

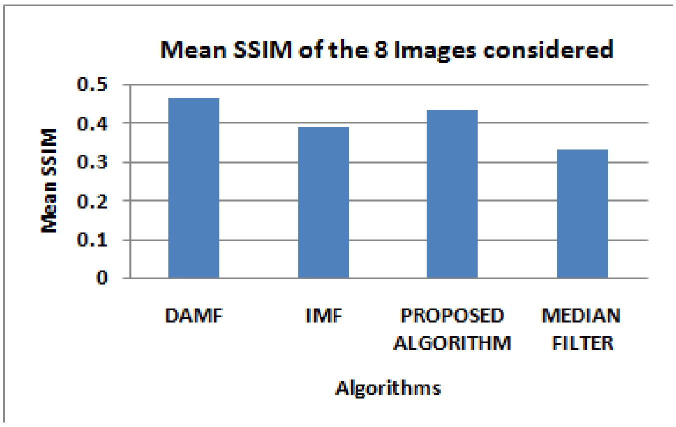


Fig 4.18 SSIM results of different algorithms

Fig. 4.18 exhibits the performance of each filtering algorithm considered in terms of mean SSIM. Since out of the 8 images considered, only 2 images have high key, the proposed algorithm is observed to outperform the IMF and median filter, medfilt2 only.

The PSNR of a noisy image is a inversely proportional function of the square of the deviation of each pixel value in the noisy image from the original image. As the proposed algorithm uses the concept of mean of specific neighbourhood pixels to replace a noisy pixel, it results in a gray pixel is situations where the DAMF may result in a white pixel and the IMF may result in a black pixel. Hence, the deviation is significantly low compared to them. Fig. 4.19 illustrates the performance of each filtering algorithm considered in terms of mean PSNR for each image in the data set. As observed, the proposed algorithm outperforms the existing algorithms in 5 out of the 8 images considered. Accordingly, as exhibited in Fig. 4.20, the PSNR of the proposed algorithm performs best among all the other algorithms considered.

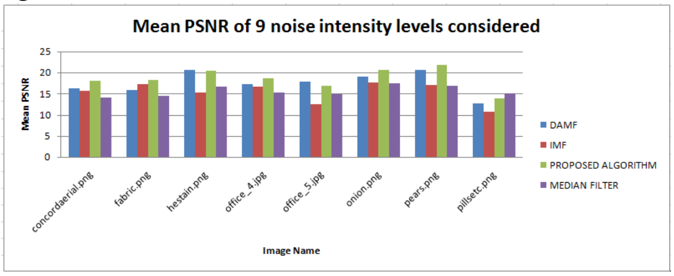


Fig 4.19 Comparisons among four algorithms of eight images with respect to mean PSNR

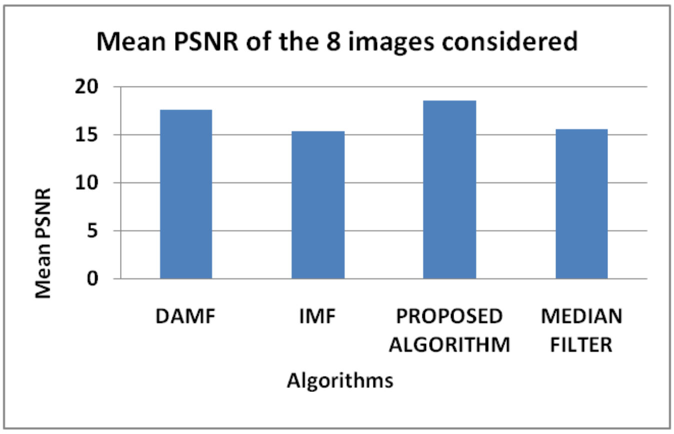


Fig 4.20 PSNR Results of Different algorithms

Table 4.1 provides a gist of the observed mean SSIM and mean PSNR values for the 8 images considered

Image Name	**Gray Level with Max. Intensity**	**DAMF**		**IMF**		**medfilt2**		**Proposed Filter**	
		SSIM	**PSNR**	**SSIM**	**PSNR**	**SSIM**	**PSNR**	**SSIM**	**PSNR**
concordarial.png	108	0.47	16.27	0.3	15.72	0.24	14.07	0.34	18.11
fabric.png	63	0.49	15.87	0.48	17.23	0.37	14.55	0.49	18.17
hestain.png	149	0.53	20.61	0.39	15.22	0.40	16.62	0.54	20.47
office_4.jpg	94	0.46	17.20	0.43	16.70	0.33	15.22	0.43	18.60
office_5.jpg	136	0.50	17.82	0.35	12.46	0.34	14.90	0.43	16.79
onion.png	50	0.43	19.12	0.46	17.72	0.38	17.37	0.45	20.66
pears.png	161	0.48	20.73	0.39	16.98	0.36	16.94	0.50	21.83
pillsetc.png	49	0.36	12.69	0.29	10.74	0.24	15.16	0.3	13.84

Table 4.1 illustrates the gray level of maximum intensity of the images considered along with the Mean SSIM and Mean PSNR of all the algorithms considered. As observed, the mean SSIM of the image filtered using the proposed algorithm is better than the others for images with higher gray level values, i.e., hestain.png and pears.png. Thus, we can conclude that the proposed algorithm performs better than the others in case of images of higher key.

IV.CONCLUSIONS

In this thesis, we have proposed a filtering algorithm that is efficient in removing SAP noise of higher intensity. The performance of the proposed algorithm has been evaluated in reference with 3 other existing algorithms namely DAMF, IMF and the median filter, medfilt2. All the algorithms are compared based on gray images of size 256x256. The size of the images has been so considered in order to receive a faster solution. The performance of the proposed algorithms has been evaluated in terms for SSIM and PSNR. As observed from the graphical and tabular results, the proposed algorithm is observed to perform better in case of higher noise intensity and for high key images. IMF algorithm on the other hand works best for low key images while medfilt2 works well for images with low noise intensity. DAMF works well with images having maximum white pixels.

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