A Review and Comprehensive Comparison of Image De-noising Techniques

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***Abstract*—Noise in an image arises due to imperfections of the imaging instruments, human instability errors while acquisition of images, various surrounding disturbing factors etc. Noise can also arise while transmission, compression or storage of image. Noise leads to degradation of an image. An image may even lose its data of interest. Image de-noising is the very first method of analyzing and processing an image. There are various kind of noise like noises appear grainy dots some periodic lines some may even overshadow the original image etc. Various de-noising algorithms and techniques are derived to de-noise an image of respective type of noises. In this paper, we will conclude some new de-noising methods and algorithms that have been created and discuss about their effectiveness, their limitations and their future scope.**

***Keywords* — Median filter, mean filter, frequency domain filter, RVIN, periodic noise, Gaussian noise**

I. INTRODUCTION

Digital images have a very important role in our life. Digital imaging has various applications ranging from photography, medical sciences, satellite imaging, television, smartphones etc. but every image generated always have some kind of imperfections referred to as noise. These imperfections are arisen due to incapability and uncertainty ofmeasurements of imaging devices or sensors to capture perfect image or natural disturbances in surroundings while acquisition of an image, insufficient light levels or sensor temperature which introduces noise or while transmission and compression. Data captured with these noises in them may even render the data unusable or may lose the data of interest in them so the first step to analyze any image is to de-noise itso the necessity arises for compensation of these data corruption in the images by using a suitable de-noising method. The main challenge of de-noising that has always been there is that it blurs the imageand image may lose its depth of detail.Image de-noising can be used to detect the defection in fruits combined with other techniques like image segmentation [1].

The different types of noise found in an image can be periodic uniform or randomly distributed.This paper concludes some of the most popular filters and methods used in de-noising an image along with their limitations and future improvements.

II. LITERATURE REVIEW

Image de-noising has been the primary concern as it's the first step to process the image. One can't get the desired data from the image without de-noising. Noisy image can't be used by the computer for functions like face recognition etc. Therefore it is important to de-noise the image before segmentation. Some of the most common noise found in an image:

1. Gaussian noise

The Gaussian noise is referred when the noise is distributed over an image evenly. In this noise, every pixel is a sum of a random Gaussian noise pixel value and its true pixel value.

The probability of density (P) function of the random variable of Gaussian noise is usually given by [2].

$$P_G(z) = (1/(\sigma\sqrt{2\pi})) * e^{-(z-\mu)^2/z\sigma_2} \quad (1)$$

The grey level is represented by z, mean value is represented by μ, and standard deviation is given byσ.

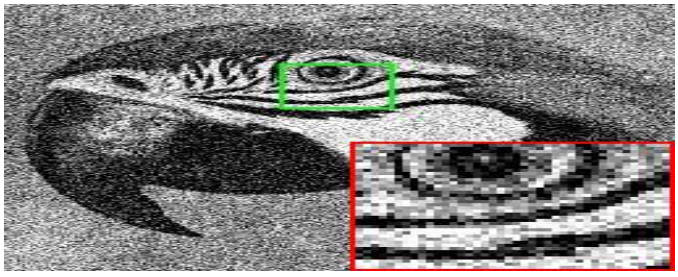

Fig. 1. An Image with Gaussian noise [3]

2. Salt &Pepper noise

Salt & pepper noise refers to the black and white pixels on the image. This noise generally found due to errors in transmission or insufficient exposure to light on camera sensor. Salt noise has a value of 255 and a pepper noise has a value of 0 for the scale of an 8-bit image [4]. The pixels which are corrupted are alternatively given the maximum and minimum value by default thereby giving the name salt and pepper.

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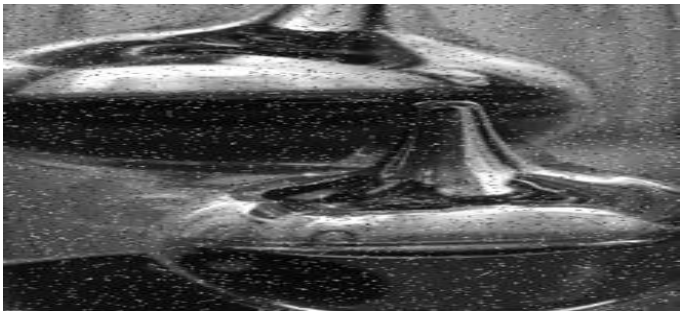


Fig. 2. Image with Salt and pepper noise[5]

3. Random value Impulse noise

This type of noise differs from salt & pepper noise as in RVIN these noisy pixels can be having any value ranging from 0-255 whereas the latter have fixed either 0 or just 255. So, it makes RVIN much difficult to de-noise it from the image.

Fig. 3(a). Original*Lena* Image (b) Image after Injected with RVIN [6]

4. Uniform noise or quantization noise

When the quantization of pixels takes to a number of distinct level in a uniform noise it is referred as quantization noise. The grayscale values are distributed uniformly in a specific range all across the image.

The uniform noise can be analytically described by [7].

$$\boldsymbol{P}(\boldsymbol{z}) = \left\{\frac{\boldsymbol{1}}{\boldsymbol{b-a}}\right\} \boldsymbol{if}\ \boldsymbol{a} < z < b\ \ else\ \ \mu = \frac{\boldsymbol{a+b}}{\boldsymbol{2}};\ \boldsymbol{\Sigma 2} = (\boldsymbol{b-a})^{\boldsymbol{2}}\ \boldsymbol{/12}$$
$$0 \qquad \ldots (2)$$

Fig. 4. Image of San Francisco Quantised to 4 bits [8]

5. Periodic noise

Periodic noise is observed in an image when the image has been through a periodic disturbance rather than any random disturbance e.g. if there is an electromechanical or electrical interference while the acquisition of the image.

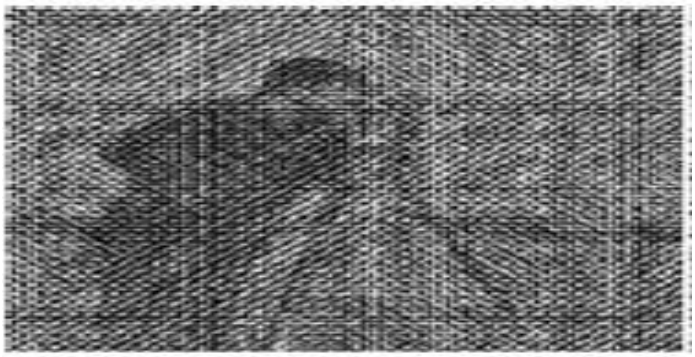


Fig. 5. Images with Periodic Noise[8]

III. METHODOLOGY

There are a number of filters used for de-noising an image. Some of the commonly used filters are:

Mean filter

One of the easiest and commonly used filters is the mean filter. Mean filter is also referred to as the smoothing filter. Mean filter is easy and intuitive method for removing noise from the image by smoothing it. By smoothing means it blurs the image to some extent to de-noise the image.

Mean filter works on the principle of changing the value of pixel from the mean value of its neighboring pixels of image. The effect is, it eliminates the values of those pixels which are unrepresentative of their surroundings.

Mean filter works on the basis of a kernel, which represent the size and the shape of a window to be sampled to calculate the mean. Generally, a 3x3 window is considered but a 5x5 window can also be taken for very extreme smooth filtering.

5	9	4
6	8	6
2	3	2

Mean = 5+9+4+6+8+6+2+3+2=45
45/9 =5

*	*	*
*	5	*

*	*	*

Center value 8 is replaced by the mean of all neighboring values. Impulse noise can be removed by mean filter from the images. Salt & pepper noise can be easily removed by using mean filter but main disadvantage of mean filter is that it blurs the image. Therefore, it does not provide desired result during de-noising of an image with Gaussian noise.

The mean filter is the basic filter and it has been modified into various forms to de-noise an image of fixed value impulse noises.

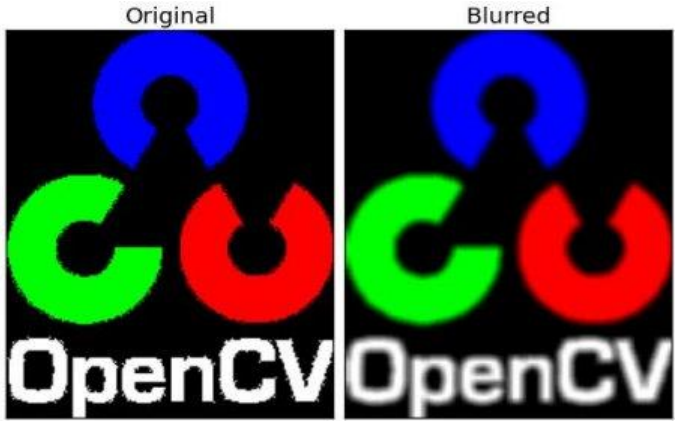


Fig. 6. Image Filtered by Mean Filter[9]

We shall now discuss the mean filter modification or a different approach made by the authors Haier Jomaa, RostomMarbrouk, Fredrik Moraine Nocolier, and NawresKhlifa in their research on, making a filter for de-noising PET images. In this approach, they used a non-local filter based on mean filter algorithm for de-noising positron emission tomography imagesPositron emission tomography or (PET) is a technique for nuclear-medicine imaging used for observing metabolic process in the body. Gamma rays are indirectly emitted by a tracer (positron emitting radio nuclide), which are detected by the system. These are introduced upon a biologically active module in the body. Three dimensional images are constructed by the computer of the tracer concentration. This aids in the detection of cancer metastasis.

In this research, an extension of non-local mean filter is used in which the spatiotemporal relationship in between the sequence of different frames is considered for the calculation of extent of similarity. There was very good result found by using non-local mean filter signifying reduction in noise in PET imaging while enhancing fine details and also preserving it in comparison to other methods [10].

The algorithm for the whole process was consisting of applying wavelet transformation on image then using non-local mean filter on detailed sub bands of wavelet transformed image. Curvelets transform was also applied then thresholding was done on curvelets coefficients. At last filtered image was generated by fusing image form.

Though this algorithm is very good than classical algorithms, still for real field images in cases of breast cancer the filtering will be critical and it will give wrong information on diagnosis [10].

In future modifications can be done to get real time results.

Median filter

Median filter considered the most popular filter that is used due to its high computational efficiency and effectiveness. It is a part of the de-noising method in the spatial domain of de-noising. The median filter runs through each element in an array of digital image.

Each element of an array that is the pixels of the images are replaced with the median of its all the surrounding neighboring pixels which generally is a square neighborhood around the evaluated pixel [11]. The median filter targets a pixel then replaces its value by the median of its neighboring pixels. This process is repeated on each and every pixel gets filtered in an image.

Median filter is considered a good method as it does not blur the image and also protects the distortion of the images. Median filter can be used to filter Gaussian noise as well as random valued impulse noises [6].

$$F(x,y) = med\{A(s,t)\}; (s,t) \in (s_{xy}) \ldots \quad (3)$$

	10	5	20	
	14	60	12	
	8	3	22	

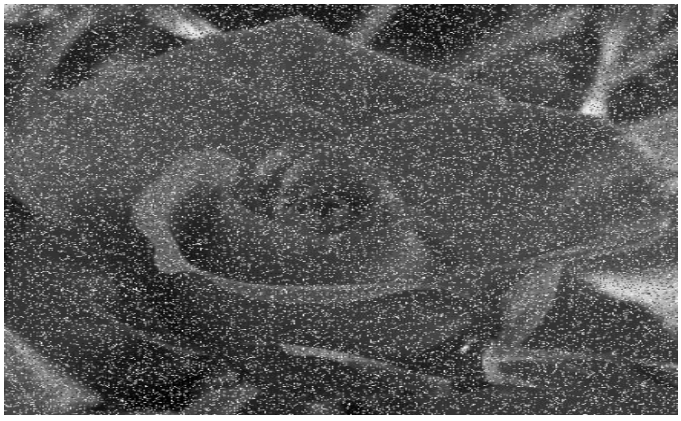
Here 3, 5, 8,10,11,14,20,22,60. Median central value 60 is replaced by 12.

There are various possibilities to enhance and modify median filter for better de-noising. We shall discuss these modification and enhancements made to the median filters to de-noise images through the research of their respective authors.

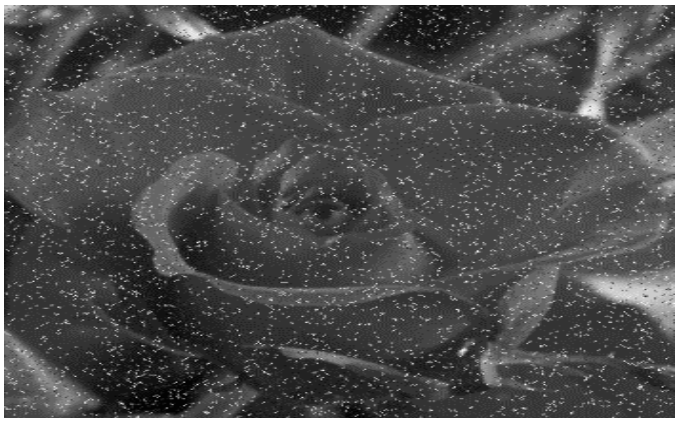
A modified hybrid median filter was made to remove RVIN from images by Muhammad Sail Uddin Darus1, Siti Noraini Sulaiman, IzaSazanita Isa & Zakaria Hussain, NooritawatiMd Tahir and Nor Ashidi Mat Isa .This proposed filter is a significant modification to the hybrid median filter. In this median sliding window value is taken in to account as well and

is compared with the sorted data of 2 sets 'x' of the sliding windows.

Results of the proposed modified hybrid medianfilter for removing RVIN are



(a)



(b)

(c)

Fig. 7 (a) RVIN Corrupted Image, (b) Hybrid Median Filtered Image and (c) Proposed Filter Image [6]

The drawback of this modified median filter is that when the density of the noise is increased the filter efficiency deteriorates. But still the proposed method filter is better than the hybrid median filter.

In future, several improvements could be made to discriminate the noisy pixels from noiseless pixels to improve the image reproduction of the filter as well as the detail-preserving ability.

Frequency Domain Filter

Frequency domain is the de-noising method in transform domain filtering. In this method, the image is broken down into its sine and cosine components (Fast Fourier Transform) and low pass filters are used. Since doing this kind of filtering is computationally faster with a filter multiply on performing 2D Fourier transform rather in the spatial domain to perform a convolution.

High frequencies are attenuated and low frequencies are retained unchanged by a LPF. De-noising is done by designing a cutoff frequency. Performing multiplication in the frequency domain weights equivalent to the convolution done between a kernel and image in spatial domain. Fourier transform is based on repetitive signal or oscillating series.

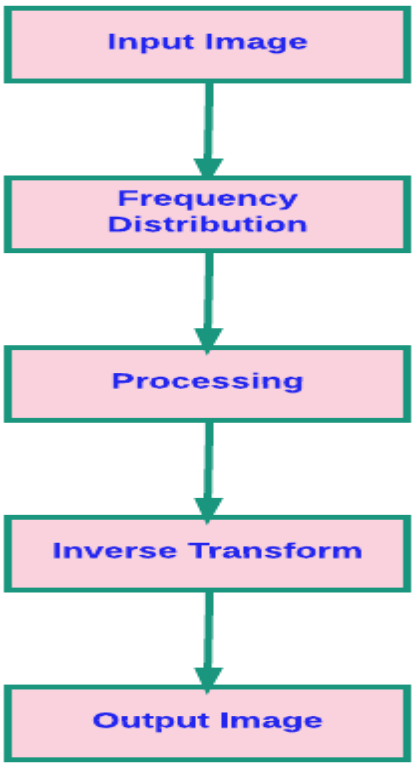


Fig. 8. Steps Involved in Frequency Domain Filter

A filter which was adaptive to switching windows on Fourier transform basis. Filter addresses the limitation of the restoration based on notch algorithm [12] and restores the image affected with periodic noise, by using measured, unique and stepped noise detection and various effective and distinct stages for correction towards the restoration of the image.

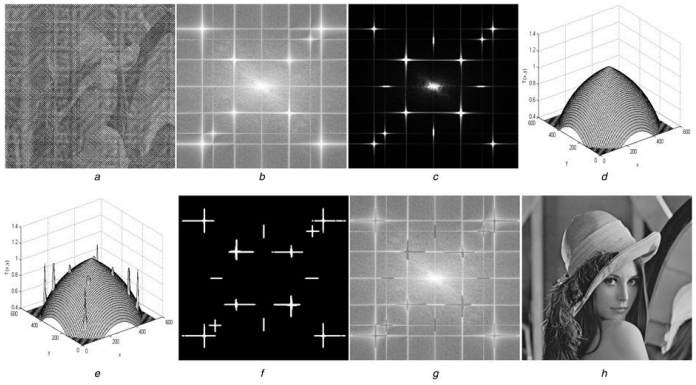


Fig. 9. Steps and Stages followed to De-noise the Image with Periodic Noise [8]

Now starting from first from left to right in Fig. 9, there is the corrupted image of Lena with say M1+M2+M3 noise of a=0.5 strength. Now Fourier transformation done to the noised image and a directional image is normalized. So, after these steps, in the step 'e' when normalized image was superimposed on the threshold function a surface plot is acquired. The noise map of the image is generated. In the next step, the image which was Fourier transformed is generated again. And after processing the final image is restored [8].Experimental results concluded that the filter has better performance in de-noising periodic noise corrupted image. Infuture, this method is used to de-noise periodic noise for color images. In table 1 various de-noising method are shown with their advantages, disadvantages and applications.

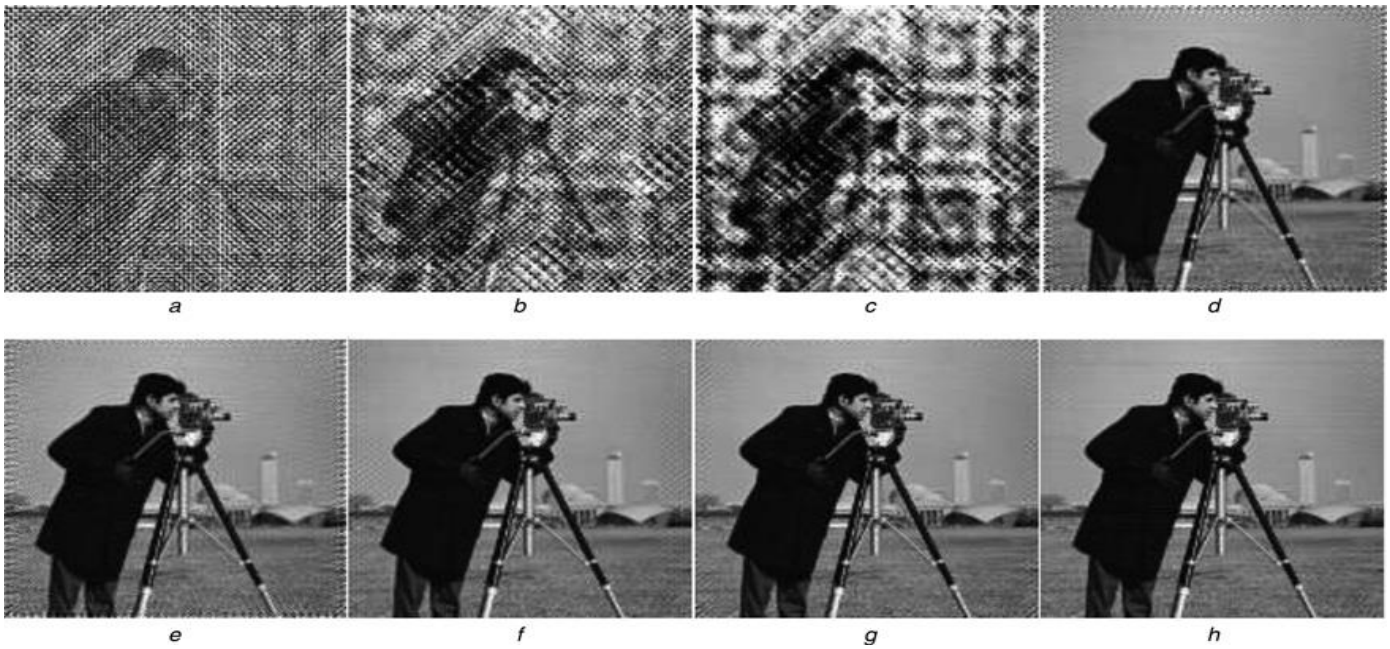


Fig. 10. Periodic Noise Filtered with The Proposed Filter Algorithm. [8]

TABLE 1: Comparison of Image De-noising Methods

Methods	Details	Advantages	Disadvantage	Applications
Mean Filter	In an image De-noising is done by changing the value of a pixel by the mean value of its nearby pixel in a particular selected window.	Simplest and easiest method for de-noising an image. Variations of means filters can be used for removing several other intensities of noises very easily.	Blurring of the image takes place which accounts for the loss of details and edges in the image.	Gaussian noises, salt and pepper noise.
Median filter	De-noising is done by changing the value of	Very less blurring and distortion in image takes	Works better only on image with less intensity	Random valued impulse images.

	each pixel by the median of all surrounding pixels. The pixel value is changed in respect to the representative pixel of its surrounding.	place. Best used for Image with low amount of noise but of high magnitude it preserves the sharp edges of the image.	of noises. As the size of the image exceeds this filter renders comparatively ineffective.	gaussian noise, Salt and pepper noises.
Frequency domain filter	De-noising is done by breaking down the image into its sine and cosine functions and then filtering them through low pass filters and high pass filters according to their varying intensities.	Quality of image is preserved and there is no blurring and distortion in image. Sharpness of the image is also preserved across the image. Less computational power is used in this case as there is no need to run every element of image through a window as the whole image is processed at once.	Since frequency domain filter processes the entire image at once.so it will be difficult to denoise the different noises present in the segmented part of the images at once.	Periodic noise, Gaussian noises, Uniform noise

IV. CONCLUSION

De-noising algorithms and their methods are very important for a corrupted image and continuous research and work is being done to de-noise various types of noise. The use of modified non-local mean filter to enhance PET image de-noising is a good and successful attempt. The future research on this method may prove to be very useful to greatly enhance the method's capability to even give better results in live test on cases like breast cancer. This method can also be modified for de-noising other similar types of medical imaging which are specific color oriented. The modified proposed filter for RVIN is a significant achievement to de-noise an image and results are also very promising. Though at high density of RVIN noises it has a disadvantage of decreased efficiency more research on this method might prove in better results in future. The method and planned steps to de-noise periodic image is also good and it is efficient to de-noise the image very well. The algorithm used to detect noise is indeed effective and gives an edge for de-noising periodic noise. Further, this algorithm can be optimized to remove other additive noises.

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