Image De-blurring using Adaptive Non-linear Filter

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ABSTRACT
Image deblurring is the process of removing blurring artifacts from images, such as the blur caused by camera misfocus, aberration or motion blur. Image is mostly degraded with the addition of noise such as salt and pepper noise, Gaussian , Exponential, uniform, periodic and others. Image de-blurring is required to reduce noise and recover the resolution loss. An efficient technique for modifying or enhancing an image is filtering which can be applied to emphasize certain features or remove other features. Linear filtering techniques are quick, although there is no detail preservation leading to loss of edge information. In this paper, the focus is on the adaptive median filtering technique for image de-blurring purpose as it restores the image without affecting edges and the image details. With the non-linear filters, noise can be minimized without recognizing it exclusively and it provides better results for salt and pepper noise.

Keywords
Power spectral function (PSF), MSE, adaptive filter, Peak signal to noise ratio (PSNR) , SSIM.

1. INTRODUCTION
Image Restoration is the process of taking a corrupt or noisy image and estimating the clean, original image. It is an objective process which improves the given image in some pre-defined sense. It is an essential pre-processing step in digital image processing [1]. Corruption in image may come in the form of motion blur, camera mis-focus and noise. It is the process of modeling the blur and noise, degradations and applying an inverse process to reconstruct the original image [1]. It is mostly performed by reversing the process that degraded the image and such an operation is performed by imaging a point source and using the point source image, which is referred to as the Point Spread Function (PSF) to restore the image information lost due to the blurring process. Image is degraded with the addition of noise such as salt and pepper, Gaussian , Rayleigh, gamma, exponential, uniform , impulse, periodic noise. On the basis of the estimation of these noise parameters and to restore the degraded image back, use averaging filter, higher Order Statistics filter, adaptive filter techniques, frequency domain operations, Optimum notch, Wiener filter and others. Image processing techniques are performed either in the image domain or in the frequency domain. Frequency domain filtering, spatial and linear filtering methods are conceptually pleasing and extremely useful in most applications [2]. The most conventional and a straightforward technique for image restoration is de-convolution, which is preferably performed in the frequency domain and after computing the Fourier transforms of both the images and the PSF and undoing the resolution loss being caused by the blurring factors. The block diagram (fig 1) represents an input image g(x, y), a degraded image be f(x, y) with some degraded function H and an additive noise η(x, y). Then in the spatial domain, the degraded image is: $f(x,y) = h(x,y) * g(x,y) + n(x,y)$

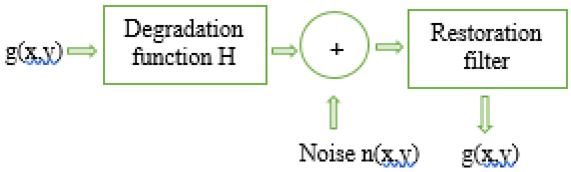

Fig 1. Image degradation/ restoration model

Median filters are the type of non-linear filters which can successfully overcome few of the limitations of the linear filters. Median Filtering technique mostly involves a filter which is highly effective in situations where white and black spots appear on image. With white and black spots on image, it is relatively typical to figure out which of the image pixels are the affected ones. Changing the corrupted pixels with mean values is not appropriate as those pixels are changed by a value which is not coherent to the original value. This is also noticed that on mutilated images, the MF has a better response than the averaging filters. Linear filters as mean filters perform noise filtering to an acceptable level but only to some limit, however they induce a blur impact on the preserved image. On the other hand, non linear filters as median filters are known for removing salt and pepper kind of noise due to acceptable denoising ability and better computational efficiency [5-6] [9]. Median filter (uses a fixed window size for determining the neighborhood pixels) change the pixel value by the median value of the intensity levels in the neighborhood of that particular image pixel. Maximum of these median filtering operations are performed on the complete image and thus it tends to change both the corrupted and uncorrupted pixels. So, there is a probability of uncorrupted pixels being changed by some unwanted value. They are known to remove salt and pepper type of noise and also preserve edges. It was found that the local adaptive median filter outperformed the rest in achieving the balance between speckle suppression and image detail preservation [3]. Adaptive filters which are based upon the spatial domain are more widely in use than the frequency domain filters [4]. Over last few decades, a number of filtering methods have been developed for salt and pepper suppression occurring in digital images. Few of these techniques are based on non-linear order statistics filters which make use of rank order details of the image pixels within a given filtering window. Standard median filter [5] attempts to remove salt and pepper noise from the center pixel of a given filtering window by changing the current pixel with the median value of the image pixels within the considered window. Following this approach is relatively simple and advantageous of being computationally very efficient, thereby providing good noise removal performance, however there is a drawback of thin lines being diminished and the image details appear heavily blurred even at noise density noises. Improved versions of the standard MF include WMF (weighted median filter) [6] and CWMF (center-weighted median filter) [7] which gives more weight to only certain pixels in the filtering window, were also been proposed so as to avoid the inbuilt problems in the standard MF. Filip Sroubek and Jan Flusser have proposed multichannel blind iterative image restoration, which is the edge preserving technique. This method however has some shortcomings which are due to the mis-registration and overestimated blur order [8]. The study explores the fact that the obtained image after AMF varies depending on the standard parameters of the input reference image. Therefore, the comparison analysis obtained provides the possible noise free image after processing these by the adaptive median filtering technique and also compares median filter and adaptive median filter in reference to standard parameters as the PSNR, MSE and others.

2. DEGRADATION MODELS

Image noise is a random variation of color information or brightness in images and is usually an aspect of electronic noise. This refers that the image pixel vlaues show different intensity values instead of their true pixel intensities. Noise can occur in an image from various sources [10]. It produces undesirable effects in the image that cause distortion such as the artifacts, unrealistic edges, visible lines, blurs different sections and disturbs the background scenery. In order to minimize these undesirable effects in image, a prior learning of the noise models is important for further processing. Various different factors are responsible for inserting and causing noise in the image during image acquisition or transmission. It can be of two types, independent noise and image dependent noise. Based on the type of disturbance, noise can affect an image to various different extent. *Salt and Pepper* can typically be caused by mal-functioning of pixels in the camera sensors, problematic memory locations, due to errors in the digitization process due to timing issues. For the images that are affected by Salt and Pepper corruption, the affected pixels assumes only the maximum and minimum values in the given dynamic range whereas the uncorrupted pixels remain unchanged [13]. *Gaussian noise* is also called electronic noise as it mostly arises in amplifiers or detectors [11]. It is caused by natural sources such as discrete nature of radiation of warm objects and thermal vibration of atoms. It generally disturbs the gray level values in digital images. Therefore, a Gaussian noise model is essentially designed and characteristics by its PDF (Fig 2) or normalizes histogram with respect to gray value. Gaussian noise is additive in its property and follows a Gaussian type of distribution [14]. Specifying that each image pixel in the noisy image is the result of addition of existing true image pixel value and a random, white Gaussian distributed value. *Poisson or shot photon disturbance* is the noise that occur, when the number of photons sensed are not sufficient to provide a detectable information which is statistical in nature[12]. Poisson disturbance has its rms value proportional to square root of intensity of the image pixels. Various pixels are affected by independent noise values. It follows a Poisson distribution, which approximates a Gaussian distribution, except at very low intensity levels.

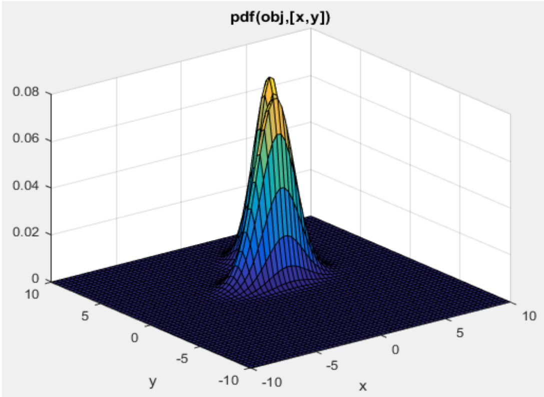

Fig 2. Gaussian Distribution (mean=μ, standard deviation= σ)

Depending on the noise type present in the image, the de-noising algorithms must be used. In various cases, the additive noise is uniformly distributed in the frequency domain (also referred as *white noise*), whereas the digital image contains low frequency components. Therefore, it can be safely derived that the noise is dominant in the higher frequency regions and can be effectively removed by using low-pass filtering techniques.

3. ADAPTIVE MEDIAN FILTER ALGORITHM

To overcome the problems that are appearing due to the existing median filtering methods, the adaptive median filtering is used. The salt and pepper disturbance is considered to be the worst case among all the types of disturbances. In order to recover the images affected by salt and pepper noise, adaptive median filtering is the most effective technique. For salt and pepper noise, the pixel value of the noisy image is converted to 0 (min) and 255 (max). When the primitive median filtering techniques are used, a 3×3 window is taken and figure out the median and then all the image pixels of the taken 3×3 window get replaced by calculated median. However, calculating the median using corrupted pixel values, provides us with erroneous result in our observation. Now, in order to deal with this situation, it must be ensured that the filtering is applied to only the corrupted pixels whereas the unaffected pixels are not replaced at all. In order to achieve so, first, define a threshold value. A window of suitable size is selected based on the number of corrupted pixels and the median is calculated. Each pixel value is then compared with the threshold value. If the pixel value < the threshold value, the pixel value is replaced by the calculated median value, else the pixel value remains unchanged. Choosing the window size can be done based on below conditions:

Case 1: If count of corrupted pixels ≤ 4, then a 3*3 window is selected and above method is applied.

Case 2: If count of corrupted pixels is between 5 and 12, then a 5*5 window is selected and above method is applied.

Case 3: If count of corrupted pixels ≥ 13, then further increasing the window size may cause additional blurring. So, take a 3*3 window. Find the average of the uncorrupted pixels in that window and replace the corrupted pixels by that average value. In this case, the average is taken in place of the median.

4. METHODOLOGY

A black and white image ("*cameraman.tif"*) is taken for observation purpose. Then introduce the salt and pepper type of disturbance in the image, by using the function *imnoise*(), which is an inbuilt function in the image processing toolbox in MATLAB. Upon receiving the noisy image, used the in-built median filter (making use of a 3*3 window) to restore the image by removing the noise. On getting the filtered image, compare the following metrics (MSE, PSNR, SSIM) for the noisy image and the filtered image, taking the original image as the reference image. After this, perform filtering of the noisy image using the adaptive median filter algorithm discussed above and compared the following metrics (MSE, PSNR, SSIM) for the noisy image and the filtered image, taking the original image as the reference image. Repeated the process for different gradients of salt and pepper noise and compared the results.

5. RESULTS

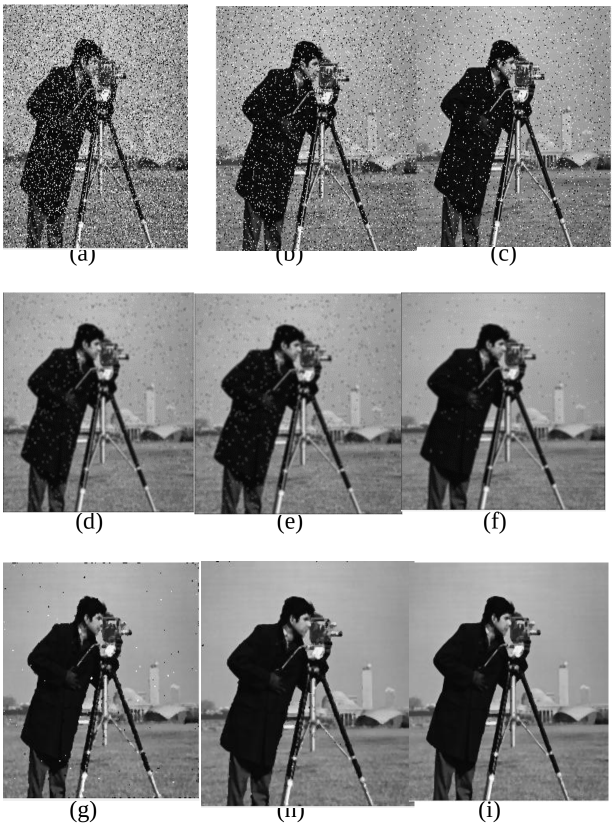

Fig 3. Salt and pepper noise removal for various gradients (a) 0.2, (b) 0.1, (c) 0.05, (d) Median filtered image for 0.2, (e) Median filtered image for 0.1, (f) Median filtered image for 0.05, (g) Adaptive Median filtered image for 0.2, (h) Adaptive Median filtered image for 0.1, (i) Adaptive Median filtered image for 0.05.

6. PERFORMANCE ANALYSIS

Table 1: MSE, PSNR, SSIM values for median and adaptive median filters for different values of the gradient

Salt &Pepper	Median			Adaptive Median		
Gradient	mse	Psnr	ssim	mse	psnr	Ssim
0.5	4.375	14.261	0.237	2.573	25.871	0.9714
0.2	2.771	23.703	0.789	0.981	32.536	0.9941
0.1	1.732	25.744	0.845	0.593	37.874	0.9967
0.05	1.411	26.608	0.857	0.453	38.787	0.9989

7. CONCLUSION

Through the analysis done on the various techniques, it can be concluded that the adaptive median filtering is a far better and improved method in comparison to the traditional median filtering techniques as here, filtering operation is performed only on the corrupted pixels in the image whereas the right (unaffected) pixels are not modified at all. Adaptive median technique provides a higher PSNR value and reduces the MSE as opposed to the median filter, thereby improving quality. This adaptive median filtering technique is utilized so as to minimize the disturbaning pixels present while filtering. A major advantage of the AMF include retaining the information of the edges even at worst cases where the density of noise is very high. It even retains the minute details of the image and the blurred images are restored with better quality. Ability of preserving the details also makes it best suited for medical image denoising purposes.

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