CHAPTER 5

A STATISTICAL ANALYSIS OF PIXELS INVOLVED IN DIFFERENT NOISE FILTERS

5.1 Introduction

Digital images are spoiled by various noises such as impulsive noise, gaussian noise, random noise etc. Usually gaussian noise is introduced as a result of camera’s electronic noise whereas impulsive noise is due to the presence of inoperative or dead pixels in camera sensors. Both linear and non-linear filters are widely applied to enhance the quality of degraded images. Linear filters are frequently used for removing additive and gaussian noises whereas non-linear filters are effective in removing impulsive noise. Mean filters which fall into the category of linear filters do not preserve the edges of a given image. Application of linear filters to degraded images leads to blurred edges and image structures which may be more objectionable than the noise [Hardie and Barner, 1994]. Median based filters, the non-linear filters are found to be effective in removing impulsive noise. These filters have the characteristic of edge and details preservation while filtering impulsive noise when compared to linear filters [Qiu, 1994], Median based filters are also known as order statistics filters as a window of size \((n \times n)\) is made to slide over the digitized image and the median of the pixels bounded by that window is used to replace the central pixels of a chosen window [Bovik, Huang and Munson, 1983]. Such filters have a disadvantage of distorting the uncorrupted pixels too, as every pixel that lies in the center of a window is assumed to be corrupted. Later, median filters accomplished with suitable decision making procedure to identify the corrupted pixels gained popularity for its better performance than standard median filter [Abreu and Lightstone, 1996]. Many of the successful noise detection techniques use threshold to decide between corrupted pixels and uncorrupted pixels. Based on this concept, two decision
based median filters - Modified Median filter with Threshold I (MMTH I) and Modified Median filter with Threshold II (MMTH II) are being proposed. In these filters, a predefined threshold value is used to decide whether each pixel of the given image is corrupted or not. Such identified corrupted pixels are only replaced by the median of pixel values identified by the given window size and shape. Detail preservation is an important property in the analysis and design of non-linear filters. It is always desirable use filters with higher detail preservation ability for filtering application and in denoising applications in particular. In this chapter, we present an analysis of the number of corrupted pixels that are rightly identified and replaced appropriately using a threshold based decision-making system. The results obtained are compared with the results of standard median (SM) filter, center weighted median (CWM) filter, standard median filter with threshold (SMTH) filter and center weighted median filter with threshold (CWMTH) filter. This analysis gives information about the details preserving ability of those filters.

5.2 The Noise Filters

In this section, the principle of two standard filters namely, standard median (SM) and central weighted median (CWM) filters are given. In this analysis, the size of the input image and the output image is an array of size 256×256 pixels and is denoted by X(·,·) and Y(·,·) respectively.

In SM filter, every pixel in the center of a sliding window of size n×n is replaced by the median of neighbourhood pixels bounded by that window. Normally the value of n is chosen as an odd number where n>1. This filter processes n² pixels for a window of size n×n. Though it is a standard image denoising technique especially for impulsive noise, it tends to remove image details such as thin lines and corners while reducing noise. CWM is a special type of SM filter, wherein the central pixel of the window is given more weightage. This filter preserves more details at the cost of less noise suppression. The number of pixels processed at a given time for a window of size (n×n) is ((n² − 1) + Wₖ ⊙ Xᵢⱼ) where Wₖ is the weight of the central
pixel and $Xy$. If $W_c = 0$, the CWM behaves as SM and if $W_c > n^2$, where $n^2$ is the number of pixels in $W$, it behaves as an identity filter. If $W_c$ is chosen to be small, the filter does better denoising and for a larger center weight it does better details preservation.

Both SM and CWM filters attenuate noise at the cost of details preservation as the pixels of a corrupted image are uniformly replaced irrespective of the presence of noise.

5.3 Median Based Filters with Threshold

It is evident from SM and CWM filters that these filters do not treat the noisy pixels alone but process the entire image to denoise that results in modifying the good pixels too. So it is essential to identify the noisy pixels in a corrupted image and then to correct them accordingly. Recent studies state that inclusion of a parameter namely threshold (TH) helps in detecting the noisy pixels. Hence, both SM and CWM filters use threshold as a parameter, to detect the presence of noise and are given as SMTH and CWMTH respectively.

In chapter 4, we had proposed two median based filters MMTH I and MMTH II with an assumption that the central pixel of a chosen window is more related to neighbouring pixels lying in horizontal and vertical direction, compared to the diagonal pixels. In these filters, the median is computed using a crossbar window and threshold is used to decide whether the in-process pixel is corrupted or not. We carry out the analysis of pixels that are corrupted and detected for SMTH, CWMTH, MMTH I and MMTH II methods.
5.4 Results and Discussion

To compute the number of pixels being preserved, the above mentioned filters are implemented using MATLAB. The standard grayscale image mandrill of size 256x256 pixels is taken. The salt and pepper noise of varying probability from 10% to 90% is introduced in the test image mandrill. The window size is varied from 3x3 to 11x11 and the threshold values are varied from 10 to 80. Based on the underlying principle of each filter, the number of pixels that are identified as corrupted is computed as ‘Noisy Pixels Handled’ (NPH) and then the number of corrupted pixels that are replaced by each filter is also computed as ‘Number of Pixels Replaced’ (NPR).

This study reveals the advantage of including the parameter TH, as it reduces the number of actual pixels being replaced in the process of denoising. These results are recorded for further analysis and are shown in figure 5.1, 5.2 and 5.3 for the noise ratio of 10%, 40% and 80% respectively. The number of pixels got replaced in noise suppression are plotted against the chosen window sizes for the threshold of 20, 40 and 80 and are given in the legends along with the filter type.

From figure 5.1.a it is evident that for 10% of noise, CWMTH 80, SMTH 60 and CWMTH 60 give lesser count of replacement for the given threshold values indicating higher degree of details preservation. For this level of noise, CWM exhibits the least count for replacement.

Figure 5.1.b shows the performance of MMTH I and MMTH II filters. MMTH I gives the best details preservation for TH = 80 when compared to other filters. So, MMTH I filter retains the actual pixels better than all other filters taken for comparison.
Figure 5.1: Performance of noise filters for 10% of noise (a) SMTH and CWMTH  (b) MMTH I and MMTH II
The performance of SMTH and CWMTH for the noise level of 40% is shown in figure 5.2.a. This figure clearly shows that the CWMTH preserves the details when TH = 80. The details preserving ability of this filter is the maximum for the window size of $3 \times 3$. The performance of this filter decreases when the window size was varied from 5x5 to 11x11. Moreover, performance of SMTH 80 finds a place in-between CWMTH 80 and CWMTH 60, which is found to be almost consistent for the entire range of window sizes. For a window size of 3x3, CWMTH 20 and CWMTH 40 also are found to preserve the details noticeably.

We note from figure 5.2.b that MMTH I filter shows higher details preservation for all the given window sizes and produces the best results for the $3 \times 3$ window when TH = 80. For this noise level, MMTH II 80 is also found to give better degree of details preservation and progresses with the increase in the window size. MMTH II 60 performs better for a window size of 5x5 pixels and for higher window sizes. For the entire range of given threshold values, the detail preserving ability of MMTH I is found to decrease with the increase in window size and it is reverse for MMTH II.
Figure 5.2: The performance of noise filters for 40% of noise (a) SMTH and CWMTH (b) MMTH I and MMTH II

Figure 5.3.a shows the results obtained for SMTH and CWMTH for 80% of noise. The detail preservation ability of CWMTH is maximum, when the window size is $3 \times 3$ for the entire given threshold values and decreases with the increase in window size. However, SMTH gives a better results, at TH = 80.

Figure 5.3.b shows the performance of MMTH I and MMTH II for 80% of noise. The MMTH I filter is found to preserve the details of the image for the entire range of given threshold values; whereas MMTH I gives the best results for a window size is $3 \times 3$. 

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Figure 5.3: The performance of noise filters for 80% of noise (a) SMTH and CWMTH (b) MMTH I and MMTH II
5.5 Conclusions

To know the detail preserving capability of our noise filters an analysis is carried out. The results show that irrespective of the given noise probability, CWMTH invariably exhibits the best detail preserving capability compared to SMTH, when the threshold is 80. For a noise probability of 80%, the performance of CWMTH is the maximum for the entire range of threshold values for a window size of 3x3. For a given range of threshold values, the performance of SMTH is higher if the threshold is 80, when compared to the other given threshold values. MMTH I exhibits a good details preserving behaviour for all the given threshold values and is found to be the highest for 80% of noise and for a window size of 3x3, among the MMTH I and MMTH II filters. For the same level of noise, the details preserving characteristic of MMTH I decreases with the increase in window size whereas for MMTH II, it increases when the window size increases.