Study of Salt and Pepper Noise Removal Filters- A Review

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***Abstract*- This paper involves study of Median Filter, Adaptive Median Filter and Decision based un-symmetric trimmed median filter, Modified Decision based un-symmetric trimmed median filter and Decision based un-symmetric trimmed midpoint filter. These are common filters to remove salt and pepper noise from images. Median filter is the basic filter to suppress salt and pepper noise. This filter replaces each pixel in the image by the median of the pixels selected from a chosen neighbourhood. Median filter replaces each pixel regardless of it noisy or not. Adaptive Median filter checks for the noise and only replace the corrupted pixel by an uncorrupted median value. Size of window varies in this filter. Decision based un-symmetric trimmed median filter uses the concept of trimming to find the median value. It removes all the corrupted pixels from the selected neighbourhood and finds the median of the rest of the pixels and use this median to replace the corrupted processing pixel. Modified Decision Based Un-symmetric Trimmed Median Filter uses same concept as that of previous one with one change i.e in case of window contains all noisy pixels, processing pixel is replaced by mean of the window. Decision Based Un-symmetric Trimmed midpoint Filter replaces each corrupted pixel by midpoint of two pixels from the current window selected by some strategy.**

***Keywords*- Median Filter, Adaptive Median Filter, Decision Based Filters.**

I. INTRODUCTION

In early days, linear filters were the primary tools in signal and image processing. But, in the presence of the non additive noise and in the systems with non linearity's or non Gaussian statistics, linear filters do not perform well. Linear filters result in blurring of edges, do not remove impulsive noise effectively, and also have poor performance in the presence of signal dependent noise. To overcome these limitations, various nonlinear filters have been proposed. [6]

With non-linear filters, the noise is removed without any explicit identification. Spatial filters are able to remove noise to a reasonable extent but result in blurring of images which in turn makes the edges in picture invisible. In past few years, a variety of nonlinear median type filters have been developed to overcome this drawback. [7]

A. Median Filter

Median filter, the most prominently used impulse noise removing filter, provides removal of impulse noise from corrupted images by replacing the individual pixels of the image as the name suggests by the median value of the gray level of the pixels from a chosen neighbourhood. [2]

Median filtering is done by, first sorting all the pixel values from the surrounding neighbourhood into numerical order and then replacing the pixel being considered with the middle pixel value. [8]

The median of a set of values is such that half of its values in the set are below the median value and half of them are above it and most appropriate value is chosen as median value for replacing the impulse corrupted pixel of a noisy image. Suppose there is a noise in the set chosen to determine the median, even then there will be no problem because it will strictly lie at the ends of the set because impulse noise will have lowest or highest value in the set and the chance of identifying an impulse as a median to replace the image pixel is very less. [2]

A 3× 3, 5× 5, or 7× 7 window of pixels is scanned over pixel matrix of the entire image. The median of the pixel values in the window is computed, and the centre pixel of the window is replaced with the computed median. [8]

The median value must be written to a separate array or buffer so that the results are not corrupted as the process is performed. The median is more robust compared to the mean. Thus, a single very unrepresentative pixel in a neighbourhood will not affect the median value significantly because an unrepresentative pixel will be on the one end in the sorted array and it may not be a median value. The median filter does not create new unrealistic pixel values because median is chosen from the existing values. For this reason the median filter is much better at preserving sharp edges than the mean

filter. These advantages aid median filters in de-noising uniform noise as well from an image. [8]
The main drawback of median filter is that, it often tends to remove fine details in the image, such as thin lines and corners. [9]
Another problem with the median filter is that it is relatively expensive and complex to compute. To find the median it is necessary to sort all the values in the neighbourhood into numerical order and this is relatively slow, even with fast sorting algorithms such as quick sort. [1]
It shows satisfactory performance for images corrupted by very low level of noise but as the noise density increases Median filter performance starts decreasing. One reason for that is median filter applies median of pixels from particular neighbourhood to all the pixels of the image irrespective of them being corrupted or not, means there is no decision regarding a pixel is corrupted or not which leads to noise suppression when the pixel is corrupted and signal suppression when the pixel is uncorrupted. The window size of the median filter also plays an important role in finding the most suitable value, larger and smaller windows lead to distortions when the impulse noise ratios are low and high respectively. Also the median value that is applied to the pixels of the noisy image is chosen from a neighbourhood without any constraints. This can be an inappropriate value i.e. an impulse when the noise level is high. [2]
Although median filter is a useful non-linear image smoothing and enhancement technique, it also has some disadvantages. The median filter removes both the noise and the fine detail since it can't tell the difference between the two. Anything relatively small in size compared to the size of the neighbourhood will have minimal affect on the value of the median, and will be filtered out. In other words, the median filter can't distinguish fine detail from noise.

B. Adaptive Median Filter

Adaptive median filter is an enhancement over the standard median filter. Impulsive like noise such as Salt and Pepper noise is usually reduced using the Adaptive median filter. Adaptive median filter preserves maximum amount of original information by modifying gray level of the image as little as possible. This filter makes use of two filters Centre Weighted Median filter and Median filter. The concept of Centre Weighted Median filter is used to build detection scheme means to check whether the pixel is noisy or not and Median filter is used for filtering purpose. It is necessary to replace the corrupted pixels through a valid filter as impulsive like noise does not follow uniform distribution which means a pre-processing is necessary to detect the corrupted pixel prior to filtering. [1]
Spatial processing is used to determine the pixels that are affected by the noise. A pixel is considered as noise based on the comparison of the pixel with its neighbourhood pixels. The size of the neighbourhood is adjustable. A 3×3 or 5×5 and so on up to a programmer defined neighbourhood is used to process the pixel. A processing pixel is considered as noise free if its value lies between the maximum and minimum value in the chosen neighbourhood, and it is left unaltered. If the processing pixel value is equal to minimum or maximum value from a chosen neighbourhood then it is considered as noisy. These noisy pixels are then replaced by the median pixel value of the pixels in the neighbourhood that have passed the noise labelling test. [9]

Algorithm :

Sxy = Currrent Window

Smin = minimum gray level value in Sxy

Smax = maximum gray level value in Sxy

Smed = median of gray levels in Sxy

Smax = maximum allowed size of Sxy

Zxy = Current Processing Pixel

W = window size

Step1. Initialize W=3
Step2. Compute Smin, Smed and Smax, which are minimum, median and maximum of pixel values in Sxy, respectively.
Step3. If Smin < Smed < Smax, then go to step 5. Otherwise increase window size ‘W’ until the maximum allowed size is reached.
Step4. If W ≤ Smax, go to step 2. Otherwise, we replace Zxy by Smed.
Step5. If Smin < Zxy < Smax, then Zxy is not a noise candidate and keep as it is, else we replace Zxy by Smed.
Step6. Stop. [1]

As long as the spatial density of the noise is small, median filter performs well but as the noise density increases performance of the median filter starts decreasing [2]. The adaptive median filter can handle impulse noise more effectively than the standard median filter. And also provides preservation of detail while removing non impulsive noise. The adaptive median algorithm performs well for average noise density. Depending on the application, maximum allowed size of window can be chosen and idea for maximum allowed size of the window came for experimenting the various size window in the standard median filter. [9]

Adaptive Median filter performs good when the noise density is low or at most average because number of corrupted pixels are less at lower noise density that are replaced by the median values. As the noise density increases, the number of replacements of corrupted pixel increases considerably and we increase window size for better removal of noise, but increasing window size lead to blurring of images and correlation is less between the corrupted pixel values and replaced median pixel values. So, the edges are smeared significantly recently. [3]

II. DECISION BASED FILTERS

As the name suggests, the Decision Based Algorithm processes the corrupted image by first detecting the salt and pepper noise. The Decision of whether a pixel is noisy or not is made by checking the value of the processed pixel, if it lays between the maximum (255) and minimum (0) then it is a noise free pixel and if its value equal to maximum (255) or minimum (0) value then it is a noisy pixel. Now, if the processing pixel value is within the range, then it is an uncorrupted pixel and left unchanged and if the processing pixel value does not lie within this range, then it is a noisy pixel and is replaced by the median value of the window or by its neighbourhood values. When the noise density increases and reached to a higher level, the median value may also be a noisy pixel then the replacement is done by the neighbourhood pixels. Replacement by neighbourhood pixels provides higher degree of correlation between the corrupted pixel and neighbourhood pixel which in turn gives rise to better preservation of edge. In Decision Based Algorithm window is of fixed size i.e 3×3, so it has lower processing time compared with the Adaptive Median filter. The main drawback of decision based algorithm is, at higher noise densities due to repeated replacement with the neighbourhood pixel values streaking effect is there. Hence, details and edges are not recovered satisfactorily, especially when the noise level is high. [3]

We have various decision based filter four of them are discussed below:

A. Unsymmetrical Trimmed Filter

Trimmed filter is used to reject the noisy pixels from a selected window. We know that Alpha trimmed mean filter also trim the uncorrupted pixels which lead to blurring of image and loss of image detail. So to overcome these limitations of Alpha trimmed mean filter an un-symmetric trimmed median filter is there. In this un-symmetric trimmed median filter, the selected 3X3 window elements are arranged in either increasing or decreasing order. Then the pixel values 0's and 255's in the image means the pixel values responsible for the salt and pepper noise, are removed from the image. Then the median value of the remaining pixels is taken. This median value is used to replace the noisy pixel. This filter is called trimmed median filter because the pixel values 0's and 255's are removed from the selected window. This procedure removes noise in better way than the Alpha trimmed mean filter. [5]

B. Decision Based Un-symmetric Trimmed Median Filter

Decision based unsymmetrical trimmed median filter is a combination of both Decision Based Algorithm and Unsymmetrical Trimmed Filter. It overcomes the drawback of Decision based algorithm of streaking effects in higher noise densities due to the repeated replacement by neighbourhood pixels. In Decision Based Unsymmetrical Trimmed Median Filter, the corrupted pixels are identified and processed. The Decision Based Unsymmetrical Trimmed Median algorithm checks whether the left and right extreme values of the sorted array, if these are noisy pixels then these pixels are removed from the sorted array and median of rest of the pixels is taken. The corrupted processing pixel is replaced by a median value of the pixels in the 3X3 window after trimming noisy values. [3]

Algorithm

Step 1) Select a 2-D window of size 3*3. The processing pixel is considered as Pxy.

Step 2) check if the processing pixel Pxy lies in between 0 or 255 then it is left unaltered and go to step 5.

Step 2) if the processing pixel Pxy hold value 0 or 255 then Sort the pixel values in the selected window in ascending order and store in 1-D array.

Step 3) in the array pixels having values 0 or 255 are eliminated and take the median of the uncorrupted pixel values.

Step 4) Replace the pixel being processed Pxy by median value.

Step 5) Move the window by one step and repeat above steps until the processing is completed for the entire image. [3]

C. Modified Decision Based Un-symmetric Trimmed Median Filter

As the name suggests Modified Decision Based Un-symmetric Trimmed Median Filter (MDBUTMF) [5] is an enhancement over the previous Decision Based Un-symmetric Trimmed Median Filter so, like Decision Based Un-symmetric Trimmed Median Filter (DBUTMF) [3] algorithm processes the corrupted images by first detecting the impulse noise. Each pixel in the image is checked for noise. If the processing pixel lies between maximum (255) and minimum (0) gray level value, then it is noise free pixel and it is left unaltered. If the processing pixel is equal to the maximum (255) or minimum (0) gray level then it is noisy pixel which is then processed by Modified Decision Based Un-symmetric Trimmed Median Filter. Now, we have two cases, First case is if all the pixel values in the selected window are 0's and 255's means are pixels are corrupted then the processing noisy pixel is replaced by mean value of all the pixels present in that selected window and in second case, if some pixel values in the selected window lies between 0 and 255 means not all pixel values are 0's or 255's then noisy pixel values i.e 0's and 255's are removed from the window and median of rest of the pixels is taken which is used to replace the processing noisy pixel. The throughput of Modified Decision Based Un-symmetric Trimmed Median Filter is a noise removal image. That is, if the processing pixel lies between maximum (255) and minimum (0) gray level value then it is noise free pixel, it is left unaltered and if the processing pixel takes the maximum (255) or minimum (0) gray level value then it is noisy pixel which is processed by MDBUTMF [5]. The steps of the MDBUTMF are given below:-

Algorithm

Step 1) Select 2-D window of size 3×3. Assume that the pixel being processed is Pij.
Step 2) If 0 < Pij < 255 then Pij is an uncorrupted pixel and its value is left unchanged. This is illustrated in Case 3) of Section IV.
Step 3) If Pij=0 or Pij=255 then Pij is a corrupted pixel then two cases are possible as given in Case 1) and 2).
Case 1): If the selected window contains all the elements as 0's and 255's. Then replace Pij with the mean of the element of window.

Case 2): If the selected window contains not all elements as 0's and 255's. Then eliminate 255's and 0's and find the median value of the remaining elements. Replace Pij with the median value.
Step 4) Repeat steps 1 to 3 until all the pixels in the entire image are processed. [5]

D. Decision Based Un-symmetric Trimmed Midpoint Filter

Decision Based Un-symmetric Trimmed Midpoint Filter (DBUTMPF) [4] is an enhancement over Modified Decision Based Un-symmetric Trimmed Median Filter [5] like Modified Decision based Un-symmetric Trimmed Midpoint filter it initially detects impulse and corrects it subsequently. All the pixels of an image lie between the dynamic ranges [0,255]. It is somewhat similar to the above two filters that we have discussed with minor changes. If the processing pixel hold value between 0 and 255 then it is left unaltered and If the processed pixel holds minimum (0) or maximum (255), pixel is considered as noisy and if the processing window contain some non noisy pixels then the processing pixel that is noisy is replaced by the midpoint of the two pixels that are not noisy and present in the processing window, these two pixels are selected by some strategy which is discussed in the algorithm. If the processing window contains all noisy pixels then the processing pixel is replaced by the midpoint of two noisy pixels selected by some strategy discussed in algorithm.

Algorithm

Step 1: Choose 2-D window of size 3x3. The processed pixel in current window is assumed as p_{xy}.
Step 2: Check for the condition $0 < p_{xy} < 255$, if the condition is true then pixel is considered as not noisy and left unaltered.
Step 3: If the processed pixel p_{xy} holds 0 or 255 then pixel p_{xy} is considered as corrupted pixel. Convert 2D array into 1D array. Sort the 1D array which is assumed as S_{xy}.
Step 4: Initialize two counters, forward counter (F) and reverse counter (L) with 1 and 9 respectively. When a 0 or 255 are encountered inside the window F is increased by 1 or L is decremented by 1 respectively. When pixel is noisy there happens to be two possible cases.
Case I: If the processing pixel is noisy and the current Processed window contains few 0'^{s} and 255'$^{s.}$ So check for 0 or 255 in sorted array S_{xy}, simultaneously counters would propagate along the S_{xy} array thereby eliminating outliers retaining only the pixel that hold values other than 0 and 255. After checking all the pixels F and L would hold a particular value indicating the number of outliers eliminated on either sides. The noisy pixel is replaced by the midpoint of the sorted array.
Case II: If every pixels that reside inside the kernel is the combination of 0 or 255. Even this condition is addressed by the case I operation. There by making the algorithm simple. When all the pixel elements hold 0 or 255 then the values are retained, assuming it as texture of the image.
Step 5: Steps 1 to 4 is repeated until all pixels of the entire image is processed. [4]

III. CONCLUSION

In this paper, five salt and pepper noise removing techniques i.e. Median Filter, Adaptive Median Filter and Decision Based Un-symmetric Trimmed Median Filter, Modified Decision Based Un-symmetric Trimmed Median Filter, Decision Based Un-symmetric Trimmed Midpoint Filter are discussed. Firstly Median Filter is discussed that is a basic filter to remove salt and pepper noise from images but often tends to remove fine details in the image, such as thin lines and corners. To overcome these drawbacks Adaptive Median Filter is discussed which is enhancement over the standard median filter. Impulsive like noise such as Salt and Pepper noise is usually reduced using the Adaptive median filter. Adaptive median filter preserves maximum amount of original information by modifying gray level of the image as little as possible but owing to increasing window size lead to blurring of images. Several other filters were proposed but no one had strong decision capability so perform poor in high noise densities. Then there are decision based filters which has a good decision making capability, among which there is Decision Based un-symmetric trimmed median Filter which has strong decision capability and various papers concluded that it performs better than other filters even in greater noise densities, but under high noise densities all the pixel inside the current would take all 0's or all 255's or combination of both 0 and 255. Replacement of trimmed median did not fare well for above case. In this case, Modified Decision Based Un-symmetric Trimmed Median Filter replaces processing pixel by mean of the current window, but when the noise densities scale greater than 80% the Smudging of edges occurs. This can be avoided using the Decision based Un-symmetric Trimmed Midpoint Filter which replaces each corrupted pixel by midpoint of two pixels selected by the strategy discussed above.

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