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A Survey Paper on Various Median Filtering Techniques for Noise Removal from Digital Images

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***Abstract**: One of the noise types that is normally degrades digital images, including grayscale digital images, is impulse noise. Therefore, researches regarding to impulse noise removal have become one of the active researches in the field of image restoration. The existence of impulse noise is one of the most frequent problems in many digital image processing applications. Median based filter is normally becoming the choice to deal with this type of noise. However; there are many variations of median filter in literature. In addition to standard median filter there are weighted median filter, iterative median filter, recursive median filter, directional median filter. Switching median filter, and adaptive median filter. Therefore, this paper will survey these median filtering frameworks.*

***Index Terms**: Impulse noise, median filter, standard median filter, weighted median filter, iterative median filter, recursive median filter, directional median filter, switching median filter, adaptive median filter.*

I. INTRODUCTION

Similar to other digital signal, digital images are sometimes could be corrupted by noise. One of the noise types normally related to digital image is impulse noise [1].Impulse noise is a set of random pixels which has a very high contrast compared to surroundings. In general impulse noise appears as a sprinkle of bright or dark spots on the image, and the normally these spots have relatively high contrast towards their surroundings areas.Therefore, even at low corruption level, impulse noise can significantly degrade the appearance and quality of the image [2],[3].Malfunctioning pixels in camera sensors, faulty memory locations in hardware or transmission of the image in a noisy channel, are some of the common causes for impulse noise[4].

A popular solution to deal with impulse noise is by using rank –order filters. This type of filters is order-statistic-filters. This type of filters is non linear and works in spatial domain. It uses sliding window approach, where on each sliding –iteration, only the value of the pixel corresponds to the center of the window is changed. This value is obtained based on the ordered intensity values of the pixels contained in the area defined by the filtering window [4], [5]. Among these rank –order filters, median based filters are the most popular technique to reduce both bipolar and unipolar impulse noise [4], [5].Generally median filters uses median value in its filtering process. A median filter works in a window of size WM × WN, where WM and WN are both odd. It replaces the center pixel with a value equal to the median of all the pixels in window. So using a median filter will help reduce least and highest intensity value pixels, generally represented by the impulse noise and so the picture clarity improves. [5].

II. VARIOUS MEDIAN FILTERING TECHNIQUES

Much wider range of algorithms is provided to filter the digital images from the impulse noise. Here in this Survey paper we study various median filtering techniques to remove impulse noise.

A. Standard median filter (SMF)

The standard median filter [6] is a simple rank selection filter also called as median smoother, introduced by tukey in 1971 that attempts to remove impulse noise by changing the luminance value of the center pixel of the filtering window with the median of the luminance values of the pixels contained within the window. Although the median filter is simple and provides a reasonable noise removal performance, it removes thin lines and blurs image details even at low noise densities. The filtered image $S = \{S(i,j)\}$ from SMF can be defined by the following equation[1]:

$$S(i,j) = Median_{(k,l)\in Wm,n}\{D(i+k, j+l)\} \quad (1)$$

Where Wm,n is a sliding window of size $m\times n$ pixels centered at coordinates (i, j). The median value is calculated by using equation (1) with $ns= m\times n$

Although SMF can significantly reduce the level of corruption by impulse noise, uncorrupted pixel intensity values are also altered by SMF. This undesired situation happens because SMF does not differentiate between uncorrupted from corrupted pixels. Furthermore, SMF requires a large filter size if the corruption level is high. Yet, large filter of SMF will introduce a significant distortion into the image [7].

It is worth noting that equation (1) is normally using sorting algorithm such as quick-sort or bubble-sort to arrange the samples in increasing or decreasing order. Even though sorting algorithm can be easily implemented, sorting procedure requires long computational time when $Wm,n$is alarge filter because the number of samples (i.e. $ns= m\times n$) is big. Thus, in order to avoid from using any direct sorting algorithm, the use of local histograms has been proposed for median value calculation. The time required to form local histogram can be reduced by using a method proposed by Huang et al. [8], where instead of updating $m\times n$samples, only $2m$samples need to be updated in each sliding-iteration.

B. Weighted Median Filter (WMF)

Weighted median filter is one of the branch of median filter (WMF). It was first introduced by Justusson in 1981, and further elaborated by Brownrigg. The operations involved in WMF are similar to SMF, except that WMF has weight associated with each of its filter element. These weights correspond to the number of sample duplications for the calculation of median value.

The filtered image $S= \{S(i, j)\}$ from WMF can be defined by the following equation [7]:

$$S(i,j) = Median(k,l)\epsilon\ W_{m,n} \{W_{m,n}\ (k,l\ )\otimes \mathrm{D(i+k, j+l)}\} \qquad (2)$$

Where operator $\otimes$ indicates repetition operation. The median value is calculated using equation (1) with ns is equal to the total of $Wm,n(k,l)$. Normally, the filter weight Wm,n is set such that it will decrease when it is located away from the center of the filtering window. By doing so, it is expected that the filter will give more emphasis to the central pixel, and thus improve the noise suppression ability while maintaining image details [9-12]. However, the successfulness of weighted median filter in preserving image details is highly dependent on the weighting coefficients, and the nature of the input image itself. Unfortunately, in practical situations, it is difficult to find the suitable weighting coefficients for this filter, and this filter requires high computational time when the weights are large [13–15].

1. Central Weighted Median Filter (CWMF)

It is special type of median filter. CWM is a filtering technique in which filter gives moreweight only to the central value of a window, and thus it is easier to design and implement than general WM filters [16].

2. Adaptive Weighted Median Filter (AWMF)

Adaptive weighted median filters (AWMF), which is an extension to WMF. By using a fixed filter size Wm,n,, the weights of the filter will be adapted accordingly base on the local noise content. This adaptation can be done in many ways, mostly based on the local statistics of the damaged image[17].

C. Recursive Median Filter

Several researches in median filtering, such as [16], use recursive approach in their methodology. Theoretically, recursive median filters can be considered analogous to infinite impulse response (IIR) filter because their outputs at curtain position are determined not only from the input intensities, but also from the calculated outputs at previous locations. In implementation of recursive median filter, normally the degraded image and the filtered image share the same data array.

In this method, the already processed pixels are now considered as noise free input pixels. Thus, by replacing the input pixels with these values, it assumes that the median value calculation will be more accurate. However, if the filter fails to remove the noise at previous locations, the error might be propagated to other area of the image. Furthermore, it is worth noting that the result from recursive median filter is dependent to the direction of filtering.

D. Iterative Median Filter

Iterative method requires the same procedure to be repeated several times. In general, iterative median filter with ni iterations, requires ni -1 temporary images. Iteration procedure enables median filtering process to use smaller filter size and reduce the computational time, while maintaining local features or edges of the image. The number of iterations nican be set by the user, or the iteration process stops when the output image converged (i.e. the current output image is equal to the previous output image). In practical, the number of iterations needed is dependent to the level of corruption and also the nature of the input image itself [21-24].

E. Directional Median Filter

Directional median filter, or also known as stick median filter, works by separating its 2-D filter into several 1-D filter components [18-20]. Each filter component or stick, presented as a straight line, corresponds to a certain direction or angle θ. For a window of size $m \times n$ pixels, there are $m+n-2$ sticks that will be used. The computed median values from these 1-D filters are then combined to obtain the final result. In [20], the output intensity is defined as:

$$S(i,j) = max\{Median_{(k,l) \in W\Theta} \{D(i+k, j+l)\}\} \tag{3}$$

Where W_θ is is the stick. Here, the output intensity is defined as the largest median value determined at each location.

F. Switching Median Filter

Nowadays, one of the popular median filtering approaches is switching median filter, or also known as decision based median filter. This approach has been used in recent works, such as [26-29]. Switching median filter tries to minimize the undesired alteration of uncorrupted pixels by the filter. Therefore, in order to overcome this problem, switching median filter checks each input pixel whether it has been corrupted by impulse noise or not. Then it changes only the intensity of noisy pixel candidates, while left the other pixels unchanged. Normally, switching median filter is built from two stages. The first stage is for noise detection, while the second stage is for noise cancellation. The output from the noise detection stage is a noise mask M. This mask is a binary mask.

Noise detection procedure used by researchers are normally depending on the noise model been used. For fixed-valued impulse noise (i.e. salt-and-pepper noise), mostly the noise detection is done by thresholding the intensity values of the damaged image. Other popular noise detection methods include by checking the difference between intensity of the current pixel with its surrounding, inspecting the difference of the damaged image with its median filtered versions, or by applying some special filters. Next, mask **M** will be used in the noise cancellation stage, where only pixels with $M = 1$ are processed by the median filter. For the calculation of median, only "noise-free" pixels (i.e. pixels with $M = 0$) are taken as the sample.

G. Adaptive Median Filter

The Adaptive Median Filter is designed to eliminate the problems faced with the standard median filter. The basic difference between the two filters is that, in the Adaptive Median Filter, the size of the window surrounding each pixel is variable. This variation depends on the median of the pixels in the present window. If the median value is an impulse, then the size of the window is expanded.

Otherwise, further processing is done on the part of the image within the current window specifications. „Processing" the image basically entails the following: The center pixel of the window is evaluated to verify whether it is an impulse or not.

If it is an impulse, then the new value of that pixel in the filtered image will be the median value of the pixels in that window. If, however, the center pixel is not an impulse, then the value of the center pixel is retained in the filtered image. Thus, unless the pixel being considered is an impulse, the gray-scale value of the pixel in the filtered image is the same as that of the input image. Thus, the Adaptive Median Filter solves the dual purpose of removing the pulse noise from the image and reducing distortion in the image. Adaptive Median Filtering can handle the filtering operation of an image corrupted with impulse noise of probability greater than 0.2. This filter also smoothens out other types of noise, thus, giving a much better output image than the standard median filter.[1]

H. Median Filter Incorporating Fuzzy Logic

In order to preserve the local details of the image, median filter should only change the intensity of corrupted pixels on the damaged image. However, it is very difficult to detect the corrupted pixels from this image correctly. Even for fixed-valued impulse noise (i.e. salt-and-pepper noise), where the noise only takes values 0 and L-1, simple thresholding method still cannot classify the pixels effectively. This is because some of the uncorrupted pixels are also been presented by these two values. Thus, researches such as [14], [23], and [30-33], incorporate fuzzy logic approach into median filtering process.

There are several ways on how fuzzy logic been used in median filtering process. Fuzzy logic can be used to grade how high a pixel has been corrupted by impulse noise. Normally, based on this fuzzy degradation measure, a proper correction will be applied. On the other hand, some of the methods use fuzzy logic as a decision maker that selects a proper filter, from a filter bank, for a given input image.

In order to use fuzzy logic, the damaged image must first undergo a fuzzification process. Normally, the input for the fuzzification process is the intensity of the pixels, or the intensity differences between the current pixels with its surrounding. The system then executes the noise filtering process based on the fuzziness values obtained.

The results are then found through a defuzzification process.
Although fuzzy logic can improve impulse noise suppression, methods such as [32-33] use too many fuzzy rules to obtain an acceptable result. As a consequence, this condition makes their filtering methods becoming computational expensive. Furthermore, their restoration results are also too dependent to the number of membership functions, and also to the parameters that control the shape of the membership functions. Therefore, such methods are difficult to be implemented as an automatic impulse noise reduction filter, and also cannot be used for real-time processing.

III. Summary

This paper surveys eight common median filtering techniques. Each technique has its own advantages, and disadvantages. From literature, we found that most of the recent median filtering based methods employ two or more than two of these frameworks in order to obtain an improved impulse noise cancellation.

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