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Suppression of Random Valued Impulse Noise in Image Processing: A Review

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ABSTRACT: Nowadays a good low complexity denoising technique is necessary as pre-processing operation in many real-time practical applications. Images get corrupted with impulse noise due to the process of image transmission and image acquisition. In the process of impulse noise filtering it is necessary to preserve edges and details of the image. Also to avoid image smoothing, only corrupted pixel must be filtered. Comprehensive survey of various denoising techniques has been focused in this paper. This paper illustrates the survey of different low complexity methods such as Median, Adaptive Center Weighted Median (ACWM), Adaptive Median Filter (AMF) and high complexity methods such as Alpha-trimmed Mean Based Method (ATMBM), Differential Rank Impulse Detector (DRID) and Rank Ordered Relative Difference (RORD).The most effective technique to remove random valued impulse noise without losing useful information with pleasing denoised image is by decision-tree based impulse detector and direction oriented edge preserving image filter. This design requires low computational cost, few memory buffers, no iterations and most suited to be applied to many real-time applications. Also this design can be efficiently designed with FPGA.

KEYWORDS: corrupted pixel, denoising, direction oriented edge preserving image filter, impulse detector, random valued impulse noise.

I.INTRODUCTION

During the process of image digitization, transmission and also due to malfunctioning pixel elements in the sensors of the camera, incorrect memory locations, and incorrect timing in analog-to-digital conversion, images are often corrupted by impulse noise. An important characteristic of this type of noise is that only parts of the pixels are corrupted and the rest are noise free. There are many applications in image processing such as face recognition, edge detection, medical imaging, scanning, printing, license plate detection where it is important to remove noise in the images before these subsequent processes. Noise in the image affects the subsequent process. Thus various techniques for removing impulse noise in images are described in this paper.

Impulse noise is categorized into two methods based on distribution of the pixel values. The noise which has either minimum or maximum pixel value in grey scale image is called fixed valued impulse noise. It is also known as salt and pepper noise. The noise in which pixel values are uniformly distributed in the rang [0 255] in grey scale image is known as random valued impulse noise. Removal of salt and pepper noise in image is easy as compared with random valued impulse noise. There are most of the techniques which are reported till now works very well for salt and pepper noise but fails under random valued impulse noise. It is also observed that detection mechanism decides the performance of the filtering scheme. Thus better detector gives the good performance of filtering scheme. So performance of the detector is very important. The performance of the detector is depend on the threshold value which is compared with pre computed numerical value. The performance of the detector can be improved with adaptive threshold. This threshold can be determined by noise present in the image and characteristic of image. Preserving the edge details and attenuation of noise are the two important issues in image processing. There are different adaptive techniques to remove impulse noise present in the image. These technique consist of main two steps first is noise detection and then application of non-linear filter. If the incoming pixel value is corrupted then only adaptive filter is applied to reconstruct the pixel value. If pixel value is noise-free then original value is not changed.

A median filter is one of the most widely used filter for reduction of impulse noise. When median filter applied to image it modified the noise free pixels also. There is no prior detection of impulse noise and applied to entire image.

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This causes the loss of useful information. So to improve performance, an impulse detector is used by many existing methods to determine whether a pixel should be modified or not. Then, the filtering process is applied only for the identified noisy pixels. Since not every pixel is filtered, inappropriate distortion is avoided. This technique has been shown to be simple and effective, for example, the adaptive impulse detection using center-weighted median filter (ACWMF), the alpha-trimmed mean-based detector using a linear combination of the median and original value filter, differential rank impulse detector (DRID), and rank ordered relative difference (RORD).

The rest of the paper is organized as follow, the section II describes literature survey in short. Section III describes comparison of various impulse noise removal techniques. Section IV illustrates Decision-tree based denoising method.

II.LITERATURE SURVEY

Many researchers have worked on impulse noise removal techniques. Use of standard median filter for impulse noise suppression is described [8]. Adaptive center weighted median filter (ACWM) which is based on difference between output of center weighted median filter and the current pixel is presented [7]. A novel adaptive median filtering technique for the removal of random valued impulse noise is proposed in [2]. Circuit detects the existence of noise in the image neighbourhood and applies the corresponding median filter only when it is necessary is presented [5]. Alpha-trimmed mean which is special case of order statistics filter is used for removal of random valued impulse noise [4]. A new impulse detector method is proposed to identify the corrupted pixels. This detector is based on the comparison of signal samples within a narrow rank window by both rank and absolute value [6]. To increase the accuracy of impulse noise detection the rank ordered relative differences impulse detector (RORD) is described [3].
Various methods for impulse noise removal are conferred as follow.

1) Median
2) Adaptive Center Weighted Median
3) Low Complexity Noise Removal
4) Adaptive Median Filter
5) Alpha Trimmed Mean
6) Differential Rank Impulse Detector
7) Rank Ordered Relative Difference

1) MEDIAN FILTER

Median filter removes the impulse noise keeping edges of the images unaffected. Median filter is easy to implement digitally. For the applications like segmentation and for parallel processing it execute fast. This filter performs well for fixed value impulse noise but poor for random valued impulse noise or vice-versa. This median filter eliminates impulse noise while doing so it changes the luminance of the target pixel value with the median value of the pixels in the filter window. But as the no of corrupted pixels in the image is increases this filter will not produce efficient result it blurs the image details and loss the some useful information. It is also shown that the recursive filter is more correlated as compared with non-recursive filter. Recursive filter increases the blurring in the images [8].

2) ADAPTIVE CENTER WEIGHTED MEDIAN FILTER (ACWM)

Adaptive center weighted median (ACWM) filter is works on switching method. This switching method is depending upon impulse detection strategy. A difference between output of center weighted median filter and the current pixel is calculated. With this calculation a more general operator that depends upon impulse detection is estimated. It performs well and results in better output with the use of single thresholding technique. Main advantage of this method is it suppresses both types of noise signals i.e. fixed valued impulse noise and random valued impulse noise. Its computational structure is simple [7].

3) LOW COMPLEXITY NOISE REMOVAL (LCNR)

This is an adaptive median filtering technique for the removal of random valued impulse noise. In comparison with median filtering, the adaptive techniques do not modified the noise-free pixels. Because of this it reduces the total computational load. This system is implemented on FPGA for window size of 3X3 and 5X5. It achieves low complexity and high quality processing under low cost requirement on image denoising hardware [2]. This method is implemented with two steps, noise detector and filtering. It detects random valued noisy pixels and apply median filter only for noisy pixels. This process is illustrated in figure 1.

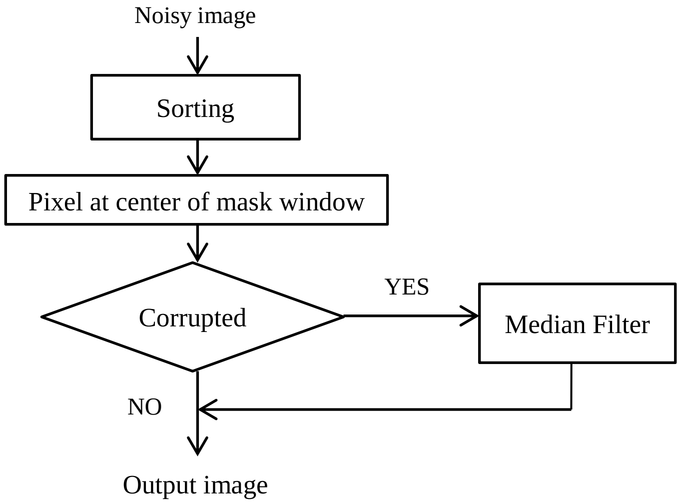

Fig.1 Flow of LCNR

4) ADAPTIVE MEDIAN FILTER (AMF)

I. Andreadis and G. Louverdis presents a novel design of an adaptive median filter, which can be used for impulse noise suppression for 8-bit grayscale images using a mask of size 3x3 or 5x5 pixel neighbourhoods. This system detects the existence of noise in the image neighbourhood and applies the corresponding median filter only when it is required.

In this paper the noise detection procedure can be control. Thus pixel values other than the two extreme ones can be considered as impulse noise. But they should be different from the central pixel value. So the blurring of the image is avoided. Also the both edge and detail information is not affected. Experimental results confirm the improved performance. The architecture of the filter consists of four basic functional pipelined stages and processing is performed in parallel, in order to improve computational times.

The system is most widely used for real-time imaging applications such as real time applications where fast processing is required. To adopt larger size windows the design of the circuit can be easily redesigned. The size of the memory and the sorter module, these are the first two units which require small modifications. The proposed digital hardware structure was successfully simulated in FPGAs. The device used for the circuit implementation is the EPF10K200SRC240-1 chip of the FLEX10KE device family. The clock frequency is 65 MHz [5].

5) ALPHA-TRIMMED MEDIAN BASED METHOD (ATMBM)

It is a new efficient method for impulse removal which is based on alpha-trimmed mean. Alpha-trimmed mean is example of order statistics filter. In this paper the alpha trimmed mean is used only in impulse detection. It is not used in pixel value calculation. Instead of applying filtering on all the pixel values it is applied only to identified noisy pixels. The process is divided in 3 steps, first impulse noise detection, second refinement and third impulse noise cancellation. The system presented in this paper used 3X3 mask window, full frame buffer and four iteration times. Hence the computational complexity is high [4].

(a) Impulse Noise Detection

Alpha-trimmed mean within window $W_{i,j}(I)$ is given as (1),

$$\bar{M}_{i,j}{}^{\alpha}(I) = \frac{1}{t-2*\lfloor \alpha t \rfloor}\sum_{i=\lfloor \alpha t+1 \rfloor}^{t-\lfloor \alpha t \rfloor} X(i) \quad (1)$$

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Where, I is the noisy image of size $l_1 \mathrm{x}\, l_2$. W is the window of size (2Ld+1) x (2Ld+1) centered about $x_{i,j}$. t = $(2\mathrm{Ld}+1)^2$. α is the trimming parameter assumes between 0 and 0.5.$\lfloor\cdot\rfloor$ is floor function. X(i) is the i^{th} data item in increasingly ordered samples.

$$r_{i,j} = |x_{i,j} - \bar{M}_{i,j}{}^{\alpha}(I)| \tag{2}$$

Absolute difference between $x_{i,j}$ *and* $\bar{M}_{i,j}{}^{\alpha}(I)$is large for noisy pixels and small for noise free pixels. It is denoted by $r_{i,j}$ as shown in (2). Next fuzzy impulse detection technique is used which is more suitable for removing random impulse noise. Each pixel gives fuzzy flag $n_{i,j}$ as in (3).

$$n_{i,j} = \begin{cases} 1, & r_{i,j} * \varphi_{i,j} \geq w_u \\ \frac{r_{i,j}*\varphi_{i,j}-w_l}{w_u-w_l}, & w_l \leq r_{i,j} * \varphi_{i,j} \geq w_u \\ 0, & r_{i,j} * \varphi_{i,j} < w_l \end{cases} \tag{3}$$

(b) Refinement

If the image is more corrupted which is denoted by fuzzy flag $n_{i,j}$, it is refined by (4),

$$n_{i,j} = \begin{cases} 0, & \text{if } X(s) < x_{i,j} < X(t-s+1) \\ n_{i,j}, & \text{Otherwise} \end{cases} \tag{4}$$

Where, s is constant and 1≤ s ≤ (t-1)/2.

(c) Impulse noise cancellation

Linear combination of median of $W_{i,j}(I)$ which is $m_{i,j}(I) = Median\ (W_{i,j}(I))$ and $x_{i,j}$ is given by the equation (5).

$$y_{i,j} = n_{i,j} \text{ x } m_{i,j}(I) + (1-n_{i,j}) \text{ x } x_{i,j} \tag{5}$$

Where, $y_{i,j}$ is denoised value of $x_{i,j}$.

6) DIFFERENTIAL RANK IMPULSE DETECTOR (DRID)

A new impulse detector method is proposed by Igor Aizenberg to identify the corrupted pixels. This detector performs the comparison of signal samples within a narrow rank window. This is done by both rank and absolute value. This detector is also known as differential rank impulse detector. It consist of two estimation, the first estimation is comparison of rank of the pixel of interest and the median. The second estimation is comparison between the brightness value of the pixel of interest and the pixel closest to pixel of interest in the series of pixel value in the filter window arranged in ascending order. The mask size used is 5X5. It requires the full frame buffer with four iteration times. Thus the computational complexity is high [6].

7) RANK ORDERED RELATIVE DIFFERENCE (RORD)

Hancheng Yu, Li Zhao, and Haixian Wang proposed a rank-ordered relative differences (RORD) statistic impulse detector. This method is Different from rank order absolute detector (ROAD). This impulse detector improves the impulse noise detection accuracy by using a reference image. Then we introduce a simple weighted mean filter to suppress the impulse noise while preserving image details. At the end they propose an efficient algorithm that combines the RORD impulse detector with the simple weighted mean filter for the removal of random valued impulse noise. This method performs significantly better than all other techniques [3].

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III. COMPARISION OF DIFFERENT IMPULSE NOISE REMOVAL TECHNIQUES

Table 1. Shows theoretical comparative study of different denoising techniques. All these methods are compared with complexity parameter with their advantages and disadvantages described shortly. Some methods have good pleasing output but high complexity or vice-versa. From the comparison it is clear that the decision tree based denoising method has low complexity as well as good pleasing output. Also it is better than all other low complexity method

Table 1.Comparision of Different Denoising Techniques

Sr.No	Technique	Complexity	Advantages	Disadvantages
1.	Noise suppression with median filter	Low	Simple	1) Blur the image 2) Modify both noisy and noise-free pixels 3) Perform well for fixed impulse noise and poor for random valued impulse noise& vice- versa.
2.	Adaptive Center Weighted Median filter impulse detection	Low	Suppresses both noise	Reconstructed image quality is not good enough.
3.	Low Complexity Noise Removal with FPGA	Low	Less logic elements are used	Reconstructed image quality is not good enough.
4.	Impulse noise suppression with adaptive median filter	Low	1) Most suitable for real-time and industrial imaging applications 2) Good where fast processing is required	1) Require four line memory buffer 2) Reconstructed image quality is not good enough
5.	Alpha-trimmed mean based denoising method	High	Denoised image quality is good	1) Requires full frame buffer 2) Requires four iteration time
6.	Differential rank impulse detector	High	Denoised image quality is good	1) Requires full frame buffer 2) Requires four iteration time
7.	Rank-ordered relative differences with weightd median filter	High	High performance	1) 7X7 mask size is used 2) full frame buffer is used 3) iteration time is three
8.	Decision Tree based denoising method	Low	1) High Performance 2) Denoised image quality is good 3) Requires few line buffer 4) suitable for many real-time applications 5) No iteration time 6) Suppresses both types of noise	.....

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IV. DECISION-TREE BASED DENOISING METHOD

Decision-tree is very powerful and simple form for the analysis of multiple variables. It is a binary tree. It divides the complex decisions into simpler decisions. It is efficient impulse noise suppression technique which requires no previous training. Decision-tree based denoising method (DTBDM) consists of two main concepts. First is decision-tree based impulse detector. Where decision for whether the pixel $p_{i,j}$ is noisy or not is taken with three modules such as isolation module (IM), fringe module (FM) and similarity module(SM). First isolation module is applied to check the desired pixel value is in smooth region. If the result is true pixel may be noisy or situated on edge. Otherwise pixel is noise free. If pixel is situated on edge then output of fringe module is noise free otherwise it is noisy. Similarity between the desired pixel and neighbouring pixel is compared by similarity module. If output of this module is true then the pixel is noisy pixel otherwise it is noise free. Second is edge preserving image filter. It is based on direction oriented filter. It reconstructs the corrupted pixels otherwise original pixel is kept as it is. This method obtains high performance in terms of both quantative output and visual quality than all other low and high complexity methods. This system can be efficiently designed and simulated with FPGA [1].

V. FUTURE WORK

There are so many high complexity denoising techniques that yields pleasing output but require large computational resources which increase its cost. Hence future challenge is to have technique that performs well in terms of both visual quality and quantitative evaluation than other low complexity methods.

VI. CONCLUSION

This paper review different techniques to remove random valued and fixed valued impulse noise. There are many methods that perform well for salt and pepper noise but fail for random impulse noise.From the survey we came to conclusion that Decision Tree Based Denoising Method yield visually pleasing images when denoising an image corrupted by random valued impulse noise. Futher quality of the reconstucted image is improved with adaptive technique. This method is simple and easily implemented with VLSI circuits.DTBDM is low complexity design and it is better than other low complexity methods in terms of reconsructed image quality, performance but comparable with high complexity method. Also it has high PSNR as compared with other methods.Because of less memory, easy computation and low cost , DTBDM is more suitable to be applied to different real-time applicatons.

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