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Implementation of Cluster based Adaptive Fuzzy Switching Median Filter for Impulse Noise Removal

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Abstract: A new framework for suppression of impulse noise from corrupted digital images is presented in this paper. A Filter called Cluster based Adaptive Fuzzy Switching Median Filter(CAFSM) for window size 5x5 is designed for noise removal. The filter consists of a impulse noise detector and a detail preserving noise filter. The noise detector has been used to discriminate the uncorrupted pixels from the corrupted pixels. These corrupted pixels are then subjected to the second phase of filtering action where the noise free pixels are retained and left unprocessed. The filtering mechanism also employs fuzzy reasoning to handle the uncertainities present in the local information. A window of size 5x5 is used in this paper for more accuracy. Many existing filters focus only on a particular impulse noise whereas CAFSM filter is capable of filtering all kinds of impulse noise – the random valued and/or fixed valued impulse noise models. In this paper, we also describe the design and implementation of the proposed filter in VLSI. Simulation experiments shows that the proposed filter can efficiently remove impulse noise from digital images without distorting the useful information in the image.

Index terms: **Impulse noise; image denoising; switching median filter; fuzzy filtering.**

I. INTRODUCTION

The visual information from high quality digital images plays a major role in many daily life applications and thus image processing has become an ordinary component in modern science. Unfortunately, during image acquisition, transmission and storage many types of distortions contaminate the image. In digital image processing, denoising is one of the important and active research area. Reduction of noise without producing distortion in the image is very difficult and challenging task.

Three main types of noise existing are impulse noise, additive noise and multiplicative noise. In this paper, we focus only on impulsive noise. Malfunctioning of pixels in camera sensors, faulty memory locations in hardware, transmission of the image in noisy channel, electromagnetic interferences and timing errors in analog-to-digital conversion are some of the common causes for impulse noise. Impulse noise is an instantaneous sharp noise where the amplitude of corruption is relatively very large compared to the strength of the original signal. As a consequence, when the signal is quantized into L intensity levels, the corrupted pixels are generally digitized into either of the two extreme values which are minimum or maximum values in the dynamic range (i.e., 0 or L-1). Thus the impulse noise normally appears as white or black dots in the image. Large number of sensors are packed on a chip per unit area and

hence image capturing devices are more exposed to impulse noise. Thus to improve the quality of the image, digital camera manufacturers depend on image denoising algorithms. As a result, for the removal of impulse noise large numbers of techniques have been proposed.

Normally, non linear filters are used for the removal of impulse noise. Standard Median Filter(SM) [2] is one of the popular non linear filters. Median Filter is an order statistics filter where image blurring occurs since it replaces the median value for all the noise and noise free pixels. But due to its simplicity, various modifications are done in SM filter such as Weighted Median Filter (WM)[3], Centre Weighted Median Filter(CWM) and Directional Weighted Median Filter (DWM)[4]. Then Simple Adaptive Median Filter (SAM) [5] was introduced which adaptively changes the size of the median filter based on the number of noise free pixels in the neighbourhood.

Median filtering applies the filtering operation to all the pixels without considering the uncorrupted pixels which leads to serious image blurring. To overcome this problem, Switching Median Filters [7] are developed where only noisy pixels are considered and noise free pixels are left unchanged. Image degradation occurs in all the above filters. To avoid this, we go for fuzzy filters [8] [9] [10]. Then to attain more efficient result, Noise Adaptive Fuzzy Switching Median Filter [11] is introduced.

This paper explains a robust filter called Cluster Based Adaptive Fuzzy Switching Median Filter (CAFSM) [12] for detail preserving restoration. None of the above mentioned filters touched on the heavily corrupted images and they all focus on only particular impulse noise model. This filter overcomes that problem and can remove noise effectively for higher noise densities also that is it can operate on wide range of noise densities.

In this paper, we use 25 pixels as sample size that is a window size of 5x5. Always sample size should be greater than or equal to 8 pixels. If sample size is small, it is not good enough to present the local information of the image properly. The local information cannot be presented even if the sample size is very large since the samples come from many objects in the image. Large sample size

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also requires more computational time and introduces distortions. Thus 25 pixels are used.

The outline of this paper is as follows. Section II elaborates the algorithm and flow chart. Section III describes the impulse noise models. The CAFSM filter design is explained in the Section IV and V. VLSI implementation and simulation results are explained in VI and VII. Finally, conclusion and future work is explained in section VIII.

II. ALGORITHM AND FLOW CHART

A. Flowchart

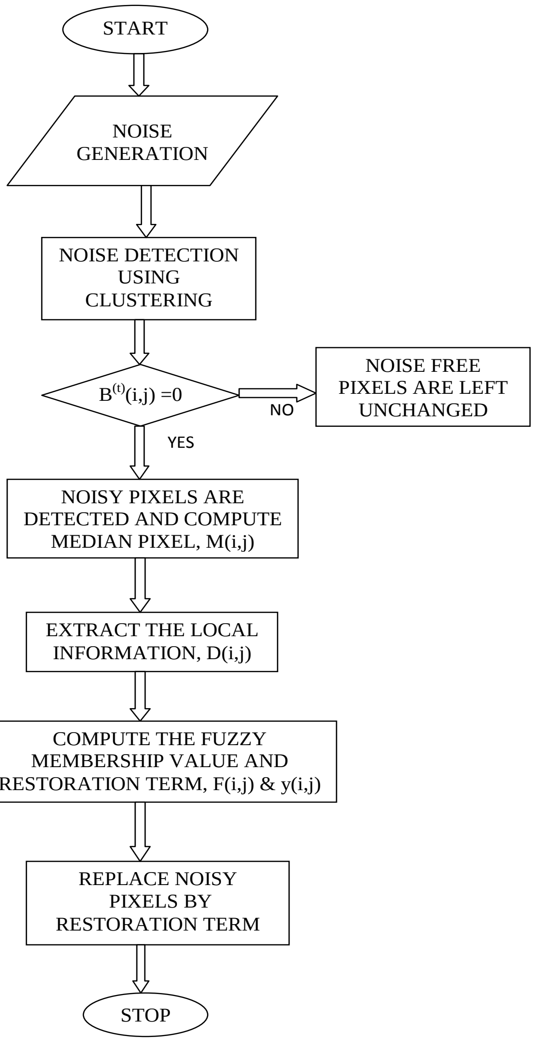

Fig 1. Flow chart for the CAFSM filter

The flow chart for converting a noisy image into a noise free image is given in fig.1. It describes steps to be followed while denoising. The generation of the noise is the first step where the original image is converted into a noisy image. The noise generation is done by multiplying a magnitude of noise density with the original image. Thus the noisy image has been obtained. Then a robust impulse noise detector is used for detecting the noisy pixels where clustering algorithm is applied. In clustering a 5x5 window size is used. The clustering algorithm distinguishes the noisy and noise free pixels and then the filtering operation is performed. During filtering as we see in switching median filters only noisy pixels are considered and noise free pixels are left unchanged. For filtering, many computations are to be done. The fuzzy membership value and the restoration term are to be calculated. Then the noisy pixels are to be replaced with the restoration term. Finally, comparison is done by calculating PSNR and MSE values.

B. Algorithm

1. The process starts with reading the original image.
2. Convert the original image into a noisy image by adding some noise with a particular density.
3. Calculate the PSNR value for the noisy image.
4. The pixels in the noisy image are converted to window of sample size 5x5.
5. Detect whether each pixel is noisy or not using clustering procedure.
6. Then the noisy pixels and noise free pixels are separated.
7. Compute fuzzy membership value for the noisy pixels.
8. For each and every noisy pixel, compute the median value of the neighboring pixels.
9. Compute the restoration term.
10. Replace all the noisy pixels with the corresponding restoration term.
11. The above steps are to be followed iteratively for each and every pixel in the noisy image with the window size of 5x5.
12. A noise free image is obtained. Now calculate the PSNR value for the noise free image.

III. IMPULSE NOISE MODELS

In this section, we describe about the types of impulse noise. For an image of size MxN, the pixel intensities lies in the range [Lmin and Lmax], where Lmin is the lowest intensity and Lmax is the highest intensity.

The model for impulse noise with probability ρ is defined as follows:

$$x(i,j) = \begin{cases} 0(i,j) & : \text{with probability } 1-\rho \\ f(i,j) & : \text{with probability } \rho \end{cases}$$

where x(i,j) represents the pixel in the location (i,j) and o(i,j) and f(i,j) represents the original and noisy image respectively.

There are two types of impulse noise in the image processing: the fixed valued impulse noise, also called as Salt and Pepper(SNP) impulse noise and the random valued impulse noise, also known as Uniform noise(UNIF). The salt and pepper impulse noise takes the value of minimal and maximal intensities, i.e., fsnp (i, j) ϵ (Lmin, Lmax). Whereas, the uniform impulse noise takes any value within the dynamic range, i.e., funif ϵ [Lmin, Lmax]. The impulsive noises have random amplitudes which results from interference of noise signals. Consequently, the amplitude of the impulse noise could lie within the image dynamic range or out of it. When the amplitude of impulse noise lies within the dynamic range it appears as salt and pepper noise and when it lies out of the dynamic range it is said to be uniform noise.

The general impulse noise model can be defined as:

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$$x(i,j) = \begin{cases} o(i,j) & : \text{ with probability } 1-\rho \\ funif(i,j) & : \text{ with probability } \rho/2 \\ fsnp(i,j) & : \text{ with probability } \rho/2 \end{cases}$$

IV. CLUSTER BASED IMPULSE NOISE DETECTOR

The impulse detection is carried out by analyzing the local image statistics within a window patch whose size is bounded by the filter. A local window $W_d(i,j)$ with odd $(2L_d+1) \times (2L_d+1)$ is defined as:

$$W_d(i,j) = x(i+k, j+l) \ \forall \ k,l \in \{-L_d, L_d\}$$

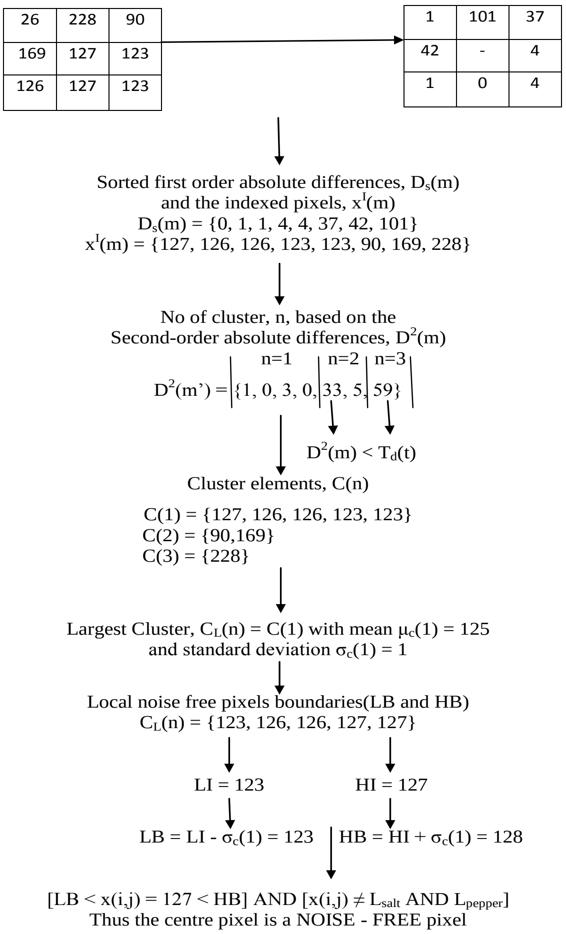

Fig 2. Clustering algorithm for noise detection

If we define *LB* and *HB* as the lower and higher boundaries for the set of noise-free pixels in $C_L(n)$, *LB* and *HB* are:

$$LB = LI - \sigma_{C(n)} \text{ and } HB = HI + \sigma_{C(n)}$$

At the end of the detection stage, a two-dimensional binary decision map $b^{(t)}(i,j)$ is formed based on

$$b(t)(i,j) = \begin{cases} 1 & : \quad [LB \le x(i,j) \le HB] \cap [x(i.j) \ne Lsalt \cap Lpepper \\ 0 & : \quad otherwise \end{cases}$$

where logic '1s' indicate the positions of noise-free pixels and logic '0s' for those noisy ones.

V. ADAPTIVE FUZZY SWITCHING MEDIAN FILTER

1. Determine the number of noise-free pixels G(i,j) by computing the number of '1s' in B(t)(i,j):

$$G(i,j) = \Sigma_{p.q\epsilon\{-Lf, Lf\}} B^{(t)}(i+p, j+q)$$

2. Expand $W_f(i,j)$ by one pixel at each of its four sides (i.e., $L_f \leftarrow L_f + 1$) if $G(i,j) < 1$. Repeat Steps 1 and 2 until the criterion $G(i,j) \le 1$ is satisfied.

3. Compute the median pixel M(i,j) using all noise-free pixels in the current $W_f(i,j)$. The median pixel $M(i,j)$ is given as:

$$M(i,j) = \text{median}\{ x(i+p, j+q) \} \ \forall \ p,q \text{ with } B^{(t)}(i+p, j+q) = 1$$

4. Extract the local information $D_l(i,j)$ from $W_f(i,j)$ according to:

$$D_l(i,j) = \max\{D^l(m)\} = D_S((2L_d+1)^2 - 1)$$

5. Compute the fuzzy membership value $F(i,j)$ based on the local information $DI(i,j)$:

$$F(i,j) = \begin{cases} 0 & : DI(i,j) < T1 \\ \dfrac{DI(i,j) - T1}{T2 - T1} & : T1 \le DI(i,j) < T2 \\ 1 & : DI(i,j) \ge T1 \end{cases}$$

Where $T1$ and $T2$ are two predefined thresholds.

6. Compute the restoration term $y(i,j)$ as follows:

$$y(i,j) = F(i,j).M(i,j) + [1 - F(i,j)].x(i,j)$$

VI. VLSI IMPLEMENTATION

For real-time embedded applications, the VLSI implementation of switching median filter for impulse noise removal is necessary and should be considered. For customers, cost is usually the most important issue while choosing consumer electronic products. We hope to focus on low-cost denoising implementation in this paper. The cost of VLSI implementation depends mainly on the required memory and computational complexity. Hence, less memory and few operations are necessary for a low-cost denoising implementation. Based on these two factors, we propose a CAFSM filter and its VLSI implementation for removing fixed-value impulse noise. Compared with previous VLSI implementations in image processing, our design achieves better image quality and also less area is occupied. This architecture work can also

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be extended to RGB colour images from monochrome image.

VII. SIMULATION RESULTS

Simulation results for the noisy cameraman image using various filters is given below.

Noise Densities

Methods	0.1	0.2	0.3	0.4	0.5
Corruped	15.07	12.08	10.29	9.024	8.088
Sam Filter	26.02	23.73	20.52	17.32	14.26
FuzzyFilter	34.27	30.69	27.96	25.91	24.13
NAFSM Filter	34.26	30.67	28.18	26.25	24.44
CAFSM Filter	40	33.98	30.46	27.96	26.02


a)


b)


c)


d)


e)


f)


g)

a) original cameraman image, b) noisy cameraman image with 50% noise, simulation results using c) weighted median filter, d) partition filter, e) SAM filter, f) NAFSM filter, g) CAFSM filter.

VIII.CONCLUSION AND FUTURE WORK

In this paper, a CAFSM filter for effective removal of impulse noise is presented. This filter is able to suppress high density of impulse noise, at the same time preserving fine details, textures and edges. Further, it does not requires any training or tuning of parameters once optimized. Future work, in authors opinion could be removal of impulse noise from colour images using the same algorithm.

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