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VLSI Architecture for Impulse noise Removal using Modified Conditional Median Filter

Femina Shereef [1], Ann Jose [2]

M.Tech Scholar, Dept. of ECE, Ilahia College of Engineering and Technology, MG University, Kerala, India[1]

Assistant Professor, Dept. of ECE, Ilahia College of Engineering and Technology, MG University, Kerala, India[2]

ABSTRACT: During transmission or acquisition images are corrupted by impulse noise .In this paper propose efficient denoising and VLSI architecture for removal of random valued impulse noise in an images .In order to achieve a low cost proposed a low-complexity VLSI architecture. Here a decision–tree-based impulse detector to detect a noisy pixel and a conditional median filter to reconstruct the noisy pixel value and preserve fine edge details .This method provide better performances in terms of visual quality and quantitative evaluation than other methods.few line memory and low computational complexity is the main advantages of this method.It is suitable to be applied to many real-time applications because its hardware cost is low**.**

KEYWORDS: Image denoising ,impulse noise, impulse detector ,median filter

I. INTRODUCTION

Image processing is used in many fields, such as face recognition, liscence plate recognition, medical imaging, scanning techniques etc. In general, During transmission or acquisition images are corrupted by impulse noise.The performance of the image processing techniques are may affected by the noisy pixels. So an efficient denoising scheme is necessary in image processing techniques .Impulse noise can be classified in to two categories according to the distribution of noisy pixel values They are fixed valued impulse noise also known as salt-and-pepper noise and random valued impulse noise.In fixed valued impulse noise its value is either maximum(255)or minimum (0) value in gray-scale images.But in the case of random valued impulse noise the noisy pixels are uniformly distributed in the range of [0,255] for gray-scale images .Many methods are available for the removal of fixed valued impulse noise [1],[2],[3],[4],[5].Due to the random distribution of noisy pixel values the removal of random-valued impulse noisy is very difficult .In this paper focused on removing the random –valued impulse noise.

The denoising methods are of two types: lower complexity techniques and higher complexity techniques.In denoising algorithms the complexity depends on memory buffer,local window size and number of itrations.The lower complexity technique have fixed window size,require a few line buffers and perform no itrations.So require low computational complexity,but the image quality is not good.For high quality images higher complexity techniques are used.1t uses high computational complexity arithemetic operations and enlarges the window size and perform iterations. The time requirement is long and also uses full line buffer.While purchasing a consumer electronic product cost is a very important consideration.Less memory and easier computation are indispensable to achieve the goal of low cost. In this paper focus lower complexity technique due to simplicity and easy implementation with the VLSI circuit.

II. RELATED WORK

There are many methods are available for the removal of fixed valued impulse noise. some of them employ the adaptive median filter[6],this approach blur the image ,since both noisy and noise-free pixels are modified .It removes both positive and negative impulse noise simultaneously. In progressive switching median filter for the removal of impulse noise from highly corrupted images[7] restore image corrupted by salt-and-pepper noise.The impulse detector detect the presence of noisy pixels .Impule detection and noise filtering procedures are applied progressively .A new efficient approach for the removal of impulse noise from highly corrupted images is presented in[8].VLSI implementation for removal of fixed valued impulse noise is presented in A low-cost VLSI implementation for efficient removal of impulse noise [9].Lien and Huang proposed a method for removal of random valued impulse noise [10].In

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this method have decision tree-based impulse detector and an edge preserving filter to reconstrut the noisy pixel values in an image.The edge preserving filter have mainly two components called an average generator and a mined generator.Its architecture is too complex and implementation is difficult.In order to avoid this difficulty,this paper propose a method in which edge-preserving filter is replaced by using a modified conditional median filter,it adopts a simple algorithm.

III. PROPOSED METHOD

The proposed method contains a decision tree-based impulse detector and a modified conditional median filter.

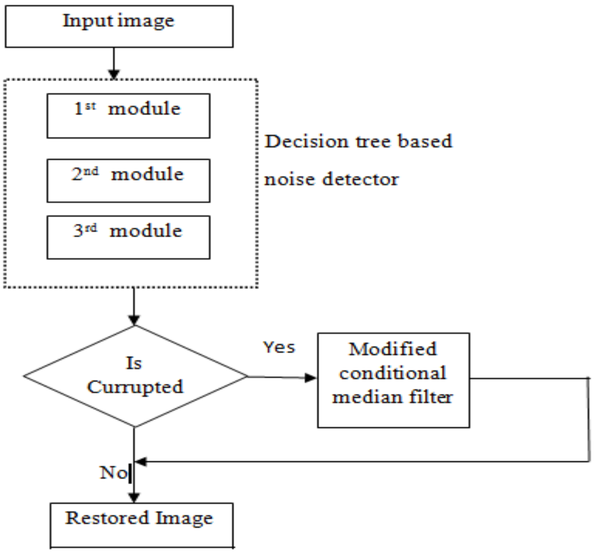

Fig 1. The dataflow of DTCDBM

Here the noise considered is random valued impulse noise with uniform distribution. For image denoising a 3x3 mask is adopted .Let $p_{i,j}$ is the pixel to be denoised. We can divide the other eight pixel in to two half's according to the input sequence of image.

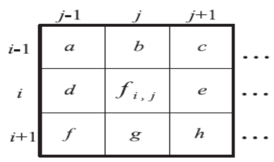

Fig.2: A 3x3 mask centered of a sampled image

$$\text{Mtophalf} = \{a,b,c,d\} \quad \text{eq. (1)}$$
$$\text{Mbottomhalf} = \{e,f,g,h\} \quad \text{eq.(2)}$$

In this the decision tree based impulse detector detect the noisy pixel and a modified conditional median filter reconstruct the pixel value.By using the correlation between $p_{i,j}$ and neighbouring pixel the detector determines the whether the pixel is noisy.If the result is positive the modified conditional median filter reconstruct the noisy pixel value.Otherwise the value will be kept unchanged.The dataflow of DTCDBM is shown in fig.1

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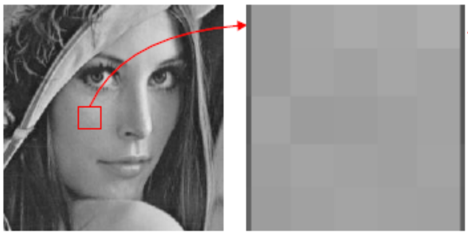
A. *DECISION TREE-BASED IMPULSE DETECTOR*

To determine the status of the pixel $p_{i,j}$,ie,it is noisy or noise free observe the correlation between the current pixel and neighboring pixel.we can obtain this by observing the degree of isolation of current pixel,check whether the current pixel is on fringe,or comparing the similarity between the current pixel and the neighboring pixel. By considering these three things decision-tree-based impulse detector is composed of three modules-isolation module (IM),fringe module(FM)and similarity module (SM).The combination of decision provided by these three mobules build a decision tree.It is a binary tree and by using a different equations in a different modules it can determine the status of the pixel $p_{i,j}$ .Isolaton module determines whether the current pixel is in smooth region or not.If the result is positive ,we can conclude that the current pixel is noisy or situated on an edge. Otherwise. it is noise free if the result is negative. In order to coform the result fringe module is used.If the result is negative current pixel is situated on an edge,otherwise the result will be positive. The similarity module is used to conform the result. In similarity module it compares the similarity between the current pixel and the neighboring pixel.If the result is negative,current pixel is a noise free pixel,otherwise it is a noisy.

(a) Isolation Module

In a smooth region the pixel value should be closely or locally slightly varying.There is a small difference in the neighboring pixel values.It is shown in Fig 3.



156	165	170	167	173
156	164	161	166	163
164	156	157	160	163
159	164	162	160	164
157	161	164	162	161

(a) original image (b) Region of red rectangle (c) Gray-scale value

Fig 3. A smooth region in an image.

The distribution of the pixel value is different if there are noisy values,blocks,or edges in this region.By observing the smoothness of the surrounding pixel ,we can determine whether current pixel is in an isolation point. It is called isolation point because, there is a low similarity with the neighboring pixel if the pixel with shadow suffering from noise. There is a large difference between it and its neighboring pixel.First detect the maximum and minimum luminance values in Mtophalf,named as *TopHalf_maxim*, *TopHalf_minim*,find out the difference between them,named as *MTopHalf_diff*.Apply the same idea to obtain *MBottom half_diff*. The two difference values are compared with a threshold *Th_IWa* to determine whether the surrounding region belongs to a smooth area.

$$IMTopHalf\_diff = TopHalf\_maxim - TopHalf\_mini \quad \text{eq. (3)}$$

$$IMBottomHalf\_diff=BottomHalf\_maxim-BottomHalf\_minim \quad \text{eq. (4)}$$

$$DecisionI = \begin{cases} true, if\ (MTopHalf_{diff} \geq Th\_IWa) \\ or\ (MBottomHalf_{diff} \geq Th\_IWa \\ false, otherwise \end{cases} \quad \text{eq. (5)}$$

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Then consider $p_{i,j}$ and calculate two values.first one is the difference between $f_{i,j}$ and *TopHalf _maxim* and second one is the difference between $f_{i,j}$ and *TopHalf_minim*. After subtraction Th_IWb is is used to compare these two differences.In the case of *Mbottomhalf* same method is used,The equations are

$$IM\_MTopHalf = \begin{cases} true, if\ (|f_{i,j} - TopHalf\_maxim| \geq Th\_IWb\ ) \\ or(|f_{i,j} - TopHalf\_minim| \geq Th\_IWb\ ) \\ false, otherwise \end{cases} \quad \text{eq. (6)}$$

$$IM\_MBottomHalf = \begin{cases} true, if\ (|f_{i,j} - BottomHalf_{maxim}\ | \geq Th_{IWb}) \\ or(|f_{i,j} - BottomHalf_{minim}\ | \geq Th_{IWb}) \\ false, otherwise \end{cases} \quad \text{eq. (7)}$$

$$Decision\ II = \begin{cases} true, if(IM\_MTophalf\ = true) \\ or\ (IM\_MBottomhalf\ = true) \\ false, otherwise \end{cases} \quad \text{eq. (8)}$$

This result provides a temporary decision whether $p_{i,j}$ belongs to a noisy pixel or noise free pixel

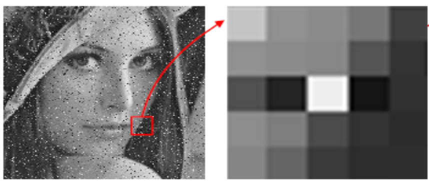
134	136	134	131	133
134	131	119	111	116
120	87	58	55	56
101	65	50	48	49
106	87	70	59	70

(a) original image (b) Region of red rectangle (c) Gray-scale value

Fig 4. A non smooth region in an image.

(b) Fringe Module

The pixel $p_{i,j}$ might be a noisy pixel or just situated on an edge ,if it has a great difference with neighboring pixels as shown in Fig.6



196	145	139	119	64
145	139	135	84	52
80	36	238	21	48
140	125	76	50	44
133	101	59	45	46

(a)Original image (b) Region of red rectangle (c) Gray scale value

Fig 6. The edge region in an image

It is a difficult process to conclude that the pixel is noisy or situated on an edge. In order to deal with this case, define four directions from D1 to D4. For example, consider D1,find absolute difference between $f_{i,j}$ and other pixels along the same direction.The equations from[11] are as follows

$$FM\_D1 = \begin{cases} false, if(|a - f_{i,j}| \geq Th_{FWa}) \\ or(|h - f_{i,j}| \geq Th_{FWa}) \\ or(|a - h| \geq Th_{FWb}) \\ true, otherwise \end{cases} \quad \text{eq. (9)}$$

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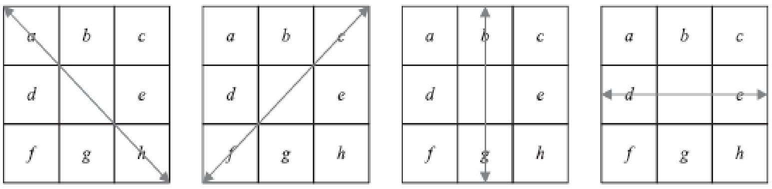
$$\text{FM\_D2} = \begin{cases} false, if\left(\left|c - f_{i,j}\right| \geq Th_{FWa}\right) \\ or\left(\left|f - f_{i,j}\right| \geq Th_{FWa}\right) \\ or\left(|c - f| \geq Th_{FWb}\right) \\ true, otherwise \end{cases} \quad \text{eq. (10)}$$

$$\text{FM\_D3} = \begin{cases} false, if\left(\left|b - f_{i,j}\right| \geq Th_{FWa}\right) \\ or\left(\left|g - f_{i,j}\right| \geq Th_{FWa}\right) \\ or\left(|b - g| \geq Th_{FWb}\right) \\ true, otherwise \end{cases} \quad \text{eq. (11)}$$

$$\text{FM\_D4} = \begin{cases} false, if\left(\left|d - f_{i,j}\right| \geq Th_{FWa}\right) \\ or\left(\left|e - f_{i,j}\right| \geq Th_{FWa}\right) \\ or\left(|d - e| \geq Th_{FWb}\right) \\ true, otherwise \end{cases} \quad \text{eq. (12)}$$

$$\text{Decision III} = \begin{cases} false, if\ (FM\_D1) or\ (FM\_D2) \\ or(FM_{D3}) or(FM\_D4) \\ true, otherwise \end{cases} \quad \text{eq.(13)}$$



D1 D2 D3 D4

Fig 7. Four directions in DTCDBM

(C) Similarity Module

Similarity module is the last module in DTBDM. In noise free area the luminance value might be close. The impulse impulse is llocated in one of the ends and median is located in center of the variational series. Hence,the possibility of noisy pixel is occurred if there is an extreme big or small values in the series .According to this concept sort nine values in ascending order and obtain fourth, fifth and sixth values which are close to median in mask M.The fourth, fifth and sixth values are represented as $4^{th} inM_{i,j}$,$MedianinM_{i,j}$ and $6^{th}\ inM_{i,j}$.Then from [11] define $Maxim_{i,j}$ and $Minim_{i,j}$ as follows

$$Maxim_{i,j} = 6^{th}\ inM_{i,j} + Th\_ISMa \quad \text{eq.(14)}$$

$$Minim_{i,j} = 4^{th} inM_{i,j} - Th\_ISMa \quad \text{eq. (15)}$$

The status of the pixel can be obtained from $Maxim_{i,j}$ and $Minim_{i,j}$ .For precise Decision do some modification as

$$Nmaxim = \begin{cases} Maxim_{i,j}\ , if\left(Maxim_{i,j} \leq MedianinM_{i,j} + Th\_ISMb \right) \\ MedianinM_{i,j} + Th\_ISMb\ , otherwise \end{cases} \quad \text{eq. (16)}$$

$$Nminim = \begin{cases} Minim_{i,j}\ , if\left(Minim_{i,j} \leq MedianinM_{i,j} - Th\_ISMb \right) \\ MedianinM_{i,j} - Th\_ISMb\ , otherwise \end{cases} \quad \text{eq. (17)}$$

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Finally,If $f_{i,j}$ isnin between $Nmaxim$ and $Nminim$,conclude that the pixel $p_{i,j}$ is noisefree,otherwise it is noisy pixel.Modified conditional median filter will be used to build the reconstructed value,otherwise,final $f_{i,j}$ will be the output.

$$\text{Decision IV} = \begin{Bmatrix} true, if\left(f_{i,j} \geq Nmaxim\right) or\left(f_{i,j} \leq Nminim\right) \\ false, otherwise \end{Bmatrix} \quad \text{eq.(18)}$$

In this method the quality of the denoised image is affected by the threshold. In order to achieve a better detection result more appropriate threshold is used. Fixed values of threshold make the algorithm suitable and simple for hardware implementation. According to extensive experiment result thresholds Th_IWa,Th_IWb,Th_FWa,Th_FWb,Th_ISMa,Th_ISMb are all predefined values and set as 20,25,40,80,15 and 60.

B .*MODIFIED CONDITIONAL MEDIAN FILTER*

It is used to reconstruct the noisy pixel value.From the similarity module,we can obtain $Nmaxim$ and $Nminim$.In order to determine the noisy pixel value sort nine pixel value in ascending order. The noisy pixel value has extreme big or small value.According to this concept check each pixel which value is in between $Nmaxim$ and $Nminim$ .If the value is not between them take it as a noisy pixel.Then replace $m_{i,j}$ by seventh pixel in the sorted pixel series.Seventh pixel is the largest pixel value close to median.The value of $f^\wedge_{i,j}$ is obtained by the sorted value of median of four neighboring pixels (b,d,e,and g).

$f^\wedge_{i,j}$ = Sorted Median($m_{i,j}, b, d, e, g$). From [11],we reach an algorithm.

Algorithm :Reconstruction of noisy pixel using conditional median filter
1. **If** dec1 = dec2 =dec3 = dec4 = true **then**
2. **If** sort(4) <= Nmax and sort(4) >= Nmin **then**
3. mat2(i,j) := Sort(4)
4. **Elseif** sort(5) <= Nmax and sort(5) >= Nmin **then**
5. mat2(i,j) := Sort(5)
6. **Elseif** sort(6) <= Nmax and sort(6) >= Nmin **then**
7. mat2(i,j) := Sort(6)
8. **Elseif** sort(3) <= Nmax and sort(3) >= Nmin **then**
9. mat2(i,j) := Sort(3)
10. **Elseif** sort(2) <= Nmax and sort(2) >= Nmin **then**
11. mat2(i,j) := Sort(2)
12. **Elseif** sort(1) <= Nmax and sort(1) >= Nmin **then**
13. mat2(i,j) := Sort(1)
14. Else
15. mat2(i,j) := Sort(7)
16. end if
17. end if

IV. VLSI IMPLIMENTATION OF DTCMBDM

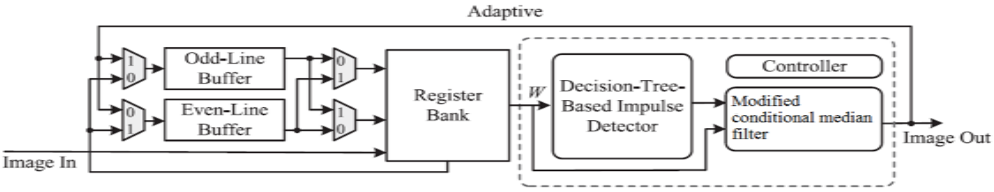

Fig.8 VLSI implementation of DTCMBDM

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In order obtain a better timing performance A pipelined architecture is used. Since it uses only two line , it has low implementation cost. SRAM is used to store the pixel values. Fig.8 shows block diagram for DTCMBDM. The architecture uses an adaptive technology and consists of five main blocks: line buffer, register bank (RB), decision-tree-based impulse detector, Conditional filter, and controller. Each of them is described briefly in the following sections

LINE BUFFERS

Since DTCMBDM uses 3x3 mask,three scanning lines are required . Three scanning lines with two line buffers are realize by four cross over mltipliers. To store the pixels at odd and even rows, Odd-Line Buffer Even-line Buffer are used respectively. To reduce cost and power consumption. the line buffer is implemented with a dual-port SRAM (one port for reading out data and other for writing back data concurrently) instead of a series of shift registers.

REGISTER BANK

Register bank consists of nine register, the 3 ×3 pixel values of the current mask W is stored in it . The data detector and noise filter for denoising are used nine values stored in RB are then used simultaneously, The reconstructed pixel value generated by the conditio1nal median filter is outputted and written into the line buffer, Once the denoising process for *pi,j* is completed. For denoising the odd or the even rows, the selection signals of the four multiplexers are all set to 1 or 0

DECISION TREE BASED IMPULSE DETECTOR

To detect the noisy pixels in an image, the decision tree based impulse detector is used The impulse detector is used to verify each pixel in rows and columns of the image and their relation with the neighboring pixels. It is also a complex decision making process. To finds solution for the multivariable problem by dividing the complex tasks into simpler problems and finds a unique solution for the problem the impulse detector is used. To determine the noisy pixel the impulse detector having three modules, Isolation Module, Fringe Module, Similarity Module

MODIFIED CONDITIONAL MEDIAN FILTER

One of the most suitable filter for removing impulse noise in an image is the median filter. By adding certain conditions to it ,it is possible to improve efficiency. Such type of filter is called conditional median filter. This can not only reduce computational complexity but also improves image quality also improves signal to noise ratio.

CONTROLLER

To control pipelining and timing statuses of the proposed circuits controller sends signals . It sends control signals to schedule reading and writing statuses of the data that are stored in register bank or in line buffers. The concept of finite state machine (FSM) is used to realize the controller. The proposed circuit can automatically receive stream-in data of original images and produce stream-out results of reconstructed image by the controller design.

V.SIMULATION RESULTS

The characteristics and performance of the denoising Algorithms can be test verified by taking an image . Consider the test image and by applying impulse noises of varying intensities in MATLAB Environment. Image is converted in to corresponding pixel value and fed in to denoising process because the digital gray scale image cannot process in VLSI.

Design summary	Proposed Method	Existing Method
Number of slices	2618	2223
Number of slice flipflops	528	567
Registers	518	565
Flipflops	518	565
Total time	4.04ns	4.04ns
PSNR	29.5461	29.5324

Table 1.Synthesis result

From the table it is clear that within same time the proposed method can reduce number of flipflops and registers. This will reduce the memory space and also reduces cost

VI.CONCLUSION

An efficient algorithm to remove high density random valued impulse noise using VLSI is proposed.. The conditional median filter not only reduce computation time but also improve the signal to noise ratio and also reduces number of slice flipflops in VLSI circuit. The algorithm preserves the edge and fine details and removes noise even at higher noise densities. When compared to the architecture of this type the performance of the algorithm is better. So this technique can be used directly in many real –time applications.

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BIOGRAPHY

Femina Shereef is an M.Tech scholar in Applied Electronics in the Electronics and Communication Engineering in Ilahia College of Engineering and Technology, MG University, Ernakulam, Kerala, India

Ann Jose is an Assistant Professor in Electronics and Communication Engineering in Ilahia College of Engineering and Technology, MG University, Ernakulam, Kerala, India