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FPGA Based Approach for Impulse Noise Suppression using Adaptive Median Filter Architecture

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Abstract:

It is important to remove or minimize the degradations noises in valuable blurred color images. The traditional available filtering methodologies are applicable for fixed window dimensions only these are not applicable for varying scale images. In our project, we propose a new technique for digital image restoration, in this the noise free and noisy pixels are classified based on empirical multiple threshold values. Then the median filtering technique is applied. So, that noise free pixels are getting preserved and only noisy pixels get restored. In this paper, an Adaptive median filter, called the Decision based filter (MDBUT) filter, is proposed to restore images corrupted by salt-pepper impulse noise.

The filter is based on a detection-estimation strategy. The impulse detection algorithm is used before the filtering process, and therefore only the noise-corrupted pixels are replaced with the estimated central noise-free ordered mean value in the current filter window. The new impulse detector, which uses multiple thresholds with multiple neighborhood information of the signal in the filter window, is very precise, while avoiding an undue increase in computational complexity. For impulse noise suppression without smearing fine details and edges in the image, extensive experimental results demonstrate that our scheme performs significantly better than many existing, well-accepted decision-based methods. Simulation is done using Xilinx ISE software of XILINX platform studio where the implementations utilize on Spartan 3EDK FPGA board of XC3S200E device family.

Keywords:

Adaptive Median Filter, Median Filter, Real-time Filtering, Salt-and-pepper noise, Impulse Noise, Field programmable gate array (FPGA).

1. INTRODUCTION:

The field of Digital Image Processing refers to processing digital images by means of a digital computer. Digital images play a very important part both in applications such as television magnetic resonance imaging computer tomography as well as in field of science and technology such as geographical information system and astronomy. Sets of data collected by image sensors and other devices are generally contaminated by noise. Also, noise can introduce due to transmission errors and compression. Hence denoising is often a necessary and first step to be performed before image data is analysed and processed. An efficient denoising technique must be applied to compensate for such data corruption [1][2]. Noise is generally modeled as Gaussian noise (Normal), Uniform noise and Impulse noise (salt and pepper noise). The impulse noise is of two types, Fixed valued and random valued. The fixed valued impulse noise is also known as salt and pepper noise which can have value either 0 or 255. Here 0 represent complete black and 255 represent complete white on gray scale image. The random valued impulse noise can have any value between 0 and 255; hence its removal is very important and difficult. Image de-noising is an important pre-processing step for image analysis. It refers to the task of recovering a good estimate of the true image from a degraded observation without altering and changing useful structure in the image such as discontinuities and edges. Image denoising still remains an important challenge for researchers because denoising process removes noise but introduces artefacts and also causes blurring [3]. Several nonlinear filters have been proposed for restoration of images contaminated by salt and pepper noise. Among these standard median filters has been established as reliable method to remove the salt and pepper noise without damaging the edge details. However, the major drawback of standard Median Filter (MF) is that the filter is effective only at low noise densities [4]. When the noise level is over 50% the edge details of the original image will not be preserved by standard median filter. Adaptive Median Filter (AMF) performs well at low noise densities. But at high noise densities the window size has to be increased which may lead to blurring the image. In switching median filter, the decision is based on a pre-defined threshold value. The major drawback of this method is that defining a robust decision is difficult. Also, these filters will not take into account the local features. As a result of which details and edges may not be recovered satisfactorily, especially when the noise level is high.

To overcome the above drawback, Decision Based Algorithm (DBA) is proposed [5]. In this, image is denoised by using a 3×3 window. If the processing pixel value is 0 or 255 it is processed or else, it is left unchanged. At high noise density, the median value will be 0 or 255 which is noisy. In such case, neighbouring pixel is used for replacement. This repeated replacement of neighbouring pixel produces streaking effect. In order to avoid this drawback, Decision Based Unsymmetrical Trimmed Median Filter (DBUTMF) is proposed [6]. The proposed Modified Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF) algorithm processes the corrupted images by first detecting the impulse noise [7]. The processing pixel is checked whether it is noisy or noisy free. That is, if the processing pixel lies between maximum and minimum gray level values then it is noise free pixel, it is left unchanged. If the processing pixel takes the maximum or minimum gray level, then it is noisy pixel which is processed by MDBUTMF. Keeping these points in view, the authors have used the mean deviation parameter in deciding the noise pixel and replaced the central pixel by its mean deviation instead of its mean. The steps in the proposed MDBUTMF algorithm are given below.

2. LITERATURE SURVEY:

In this section, we have gone through detail literature reviews of impulse noise removal on the reported recent articles and critically studied their performances through computer simulation. In traditional median filtering called standard median filter (SMF), the filtering operation is performed across to each pixel without considering whether it is uncorrupted. So, the image details, contributed by the uncorrupted pixels are also subjected to filtering and as a result the image details are lost in the restored version. To overcome this problem, an impulse noise detection mechanism is applied prior to the image filtering. A Dynamic Adaptive Median Filter (DAMF) was proposed for removing high density salt and pepper noise [5]-[7]. The filter is dynamic in nature as it decides the window size for the test pixel locally before filtering during run time and is adaptive due to the selection of a proper window size.

The progressive switching median filter (PSMF) was proposed which achieves the detection and removal of impulse noise in two separate stages [9]. In first stage, it applies impulse detector and then the noise filter is applied progressively in iterative manners in second stage. In this method, impulse pixels located in the middle of large noise blotches can also be properly detected and filtered. The performance of this method is not good for very highly corrupted image. Nonlinear filters such as adaptive median filter (AMF) can be used for discriminating corrupted and uncorrupted pixels and then apply the filtering technique [12]. Noisy pixels will be replaced by the median value, and uncorrupted pixels will be left unchanged.

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An efficient decision-based algorithm (DBA) was proposed using a fixed window size of 3 × 3, where the corrupted pixels are replaced byeither the median pixel or neighborhood pixels. It shows promising results, a smooth transition between the pixels islost with lower processing time which degrades the visual quality of the image. A novel improved median filtering (NIMF) algorithm is proposed for removal of highly corrupted with salt-and-pepper noise from images [11]. Firstly, all the pixels are classified into signal pixels and noisy pixels by using the Max-Min noise detector. The noisy pixels are then separated into three classes, which are low-density, moderate density, and high-density noises, based on the local statistic information.

Finally, the weighted 8-neighborhoodsimilarity function filter, the 5 × 5 median filter and the 4-neighborhood mean filter are adopted to remove the noises for the low, moderate and high level cases, respectively A Tolerance based Arithmetic Mean Filtering Technique (TSAMFT) is proposed to remove salt and pepper noise from corrupted images [13]. Arithmetic Mean filtering technique is modified by the introduction of two additional features. In the first phase, to calculate the Arithmetic Mean, only the unaffected pixels are considered. In the second phase, a Tolerance value has been used for the replacement of the pixels. This proposed technique provides much better results than that of the existing mean and median filtering techniques.

A modified decision based unsymmetrical trimmed median filter (MDBUTMF) algorithm is proposed for the restoration of gray scale, and color images that are highly corrupted by salt and pepper noise. The proposed algorithm replaces the noisy pixel by trimmed median value when other pixel values, 0's and 255's are present in the selected window and when all the pixel values are 0's and 255's then the noise pixel is replaced by mean value of all the elements present in the selected window.

When this algorithm tested against different gray scale and color images, it gives better Peak Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF).

3.OVERVIEW OF FILTERS:

What is noise? Noise is any undesirable signal. Noise is everywhere and thus we have to learn to live with it. Noise gets introduced into the data via any electrical system used for storage, transmission, and/or processing. In addition, nature will always play a "noisy" trick or two with the data under observation. When encountering, an image corrupted with noise you will want to improve its appearance for a specific application. The techniques applied are application-oriented. Also, the different procedures are related to the types of noise introduced to the image. Some examples of noise are: Gaussian or White, Rayleigh, Shot or Impulse, periodic, sinusoidal or coherent, uncorrelated, and granular. When performing median filtering, each pixel is determined by the median value of all pixels in a selected neighborhood (window) [12] [13]. Median filtering is a simple and very effective noise removal filtering process

A. Median Filter:

The median filter is normally used to reduce noise in an image, somewhat like the mean filter. However, it often does a better job than the mean filter of preserving useful detail in the image [15].

How It Works:

Like the mean filter, the median filter considers each pixel in the image in turn and looks at its nearby neighbours to decide whether or not it is representative of its surroundings. Instead of simply replacing the pixel value with the mean of neighbouring pixel values, it replaces it with the median of those values. The median is calculated 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. (If the neighbourhood under consideration contains an even number of pixels, the average of the two middle pixel

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values is used). [17] Figure 3.1 illustrates an example calculation of median value.

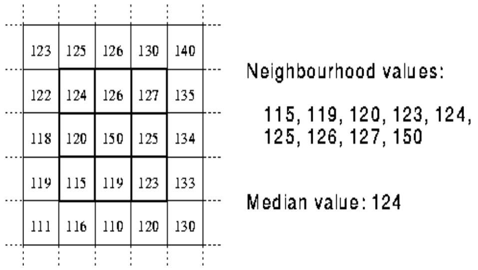

Figure 3.1. Calculating the median value of a pixel neighbourhood.

As can be seen the central pixel value of 150 is rather unrepresentative of the surrounding pixels and is replaced with the median value: 124. A 3×3 square neighbourhood is used here larger neighbourhoods will produce more severe smoothing

B. Adaptive Median Filter:

Comparing with Standard median filtering the Adaptive median filtering is an advanced method. Which pixels in an image have been affected by impulse noise can be determined by using spatial processing. AMF performs in the image by comparing each pixel with its surrounding neighbor pixels to classify pixels as noise. The neighborhood pixel of the size is adjustable, as well as for the comparison the threshold is adjustable [16-18]. The median pixel value of the pixels in the neighborhood can be replaced in the place of noise pixels that have passed the noise labeling test.

4. MODIFIED DECISION BASED UNSYMMETRICAL TRIMMED MEDIAN FLITER:

The proposed Modified Decision Based Unsymmetrical Trimmed Median Filter (MDBUTMF) algorithm processes the Corrupted images by first detecting the impulse noise. The processing pixel is checked whether it is noisy or noisy free. That is, if the processing pixel lies between maximum and minimum gray level values then it is noise free pixel, it is left unchanged.

If the processing pixel takes the maximum or minimum gray level, then it is noisy pixel which is processed by MDBUTMF.

MDBUT Algorithm

Step 1: The MDBUTM Filter selects a 2D-window of size 3×3. The center pixel in the selected window is the processing pixel and it is denoted as P_{ij}. It is given in Fig.4.1. The neighboring pixels of the processing pixel P_{ij} are present in the directions NW, N, NE, W, E, SW, S, and SE. The positions of these directions are (i-1, j-1), (i-1, j), (i-1, j+1), (i, j-1), (i, j+1), (i+1, j-1), (i+1, j) and (i+1, j+1) respectively. The directions are clearly mentioned in the following Fig.4.1. The X-axis is considered for ‘i’ and Y-axis is considered for ‘j’.

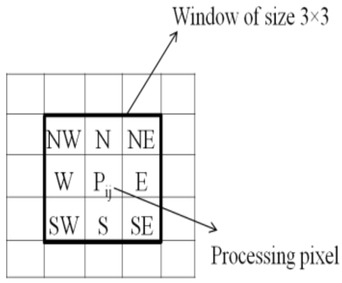

Figure 4.1. 2-D window of size 3×3

Step 2: If $0 < P_{ij} < 255$then $P_{ij}$is an uncorrupted pixeland its value is left unchanged. **Step3:** If$P_{ij} = 0$ or $P_{ij} = 255$then $P_{ij}$is a corruptedpixel then two cases are possible as given in Case i) and ii).

Case i): If the selected window contains all the elements as 0’s and 255’s. Then replace$P_{ij}$with the mean of the element of window.

Case ii): If the selected window contains not all elements as 0’s and 255’s. Then eliminate255’s and0’s and find the median value of the remaining elements. Replace $P_{ij}$with themedian value.

Step 4: Repeat steps 1 to 3 until all the pixels in the entire image is processed. The pictorial representation of each case of the proposed algorithm is shown in figure 4.2

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Each and every pixel of the image is checked for the presence of salt and pepper noise. Different cases are illustrated below. If the processing pixel is noisy and all other pixel values are either 0's or 255's is illustrated in Case i). If the processing pixel is noisy pixel that is 0 or 255 is illustrated in Case ii). If the processing pixel is not noisy pixel and its value lies between 0 and 255 is illustrated in Case iii).

Case i): If the selected window contains salt/pepper noise as processing pixel (i.e., 255/0-pixel value) and neighboring pixel values contains all pixels that adds salt and pepper noise to the image:

$$\begin{bmatrix} 0 & 255 & 0 \\ 0 & 255 & 255 \\ 255 & 0 & 255 \end{bmatrix}$$ where "255" is processing pixel, i.e., P_{ij}.

Since all the elements surrounding P_{ij} are 0's and 255's. If one takes the median value it will be either 0 or 255 whichis again noisy. To solve this problem, the mean of the selected window is found and the processing pixel is replaced by the mean value. Here the mean value is 170. Replace the processing pixel by 170.

Case ii): If the selected window contains salt or pepper noise as processing pixel (i.e., 255/0-pixel value) and neighboring pixel values contains some pixels that adds salt (i.e., 255-pixel value) and pepper noise to the image:

$$\begin{bmatrix} 78 & 90 & 0 \\ 120 & 0 & 255 \\ 97 & 255 & 73 \end{bmatrix}$$ where "0" is processing pixel, i.e., P_{ij}.

Now eliminate the salt and pepper noise from the selected window. That is, elimination of 0's and 255's. The 1-D array of the above matrix is [78 90 0 120 0 255 97 255 73]. After elimination of 0's and 255's the pixel values in the selected window will be [78 90 120 97 73]. Here the median value is 90. Hence, replace the processing pixel P_{ij} by 90.

Case iii): If the selected window contains a noise free pixel as a processing pixel, it does not require further processing. For example, if the processing pixel is 90 then it is noise free pixel:

$$\begin{bmatrix} 43 & 67 & 70 \\ 55 & 90 & 79 \\ 85 & 81 & 66 \end{bmatrix}$$ where "90" is processing pixel, i.e., P_{ij}.

Since "90" is a noise free pixel it does not require further processing.

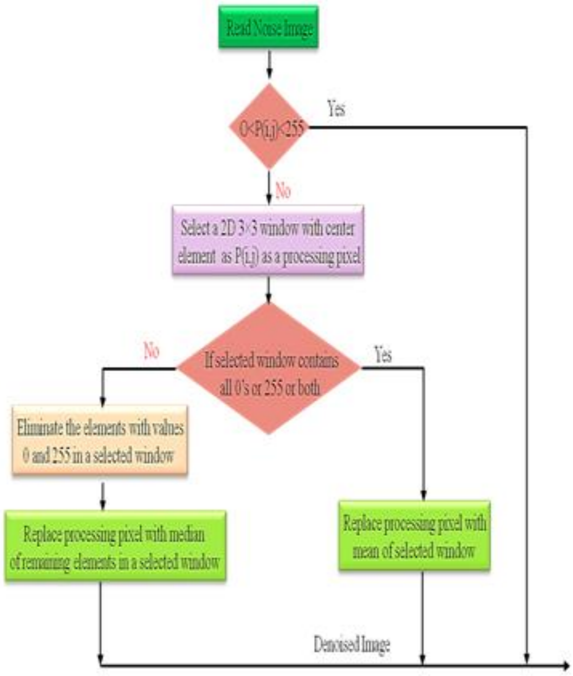

Figure 4.2.Flow chart of MDBUTMF

5.IMPLEMENTATION DETAILS:

The proposed adaptive median filter structure is designed, compiled and simulated using Xilinx ISE (v.10.1) software of XILINX. For flexibility and advantageous characteristics of FPGA, the hardware implementation has been done intoit. FPGAs are now a mainstream logic technology and provide a way of obtaining high performance on digital system design at an economical price. The FPGA used for the proposed design is the Spartan 3EDK board of the XC3S200E TQ144 device provides 200K System Gates, 5,508 number of Logic Cells,612 number of Total CLBs, 2,448 number of total Slices ,38K of Distributed RAM bits(1) ,216K of Block RAM bits, 12 number of Dedicated Multipliers, 3840 number of Flip Flops,256 shift registers is suitable for different kinds of memory functions and large number of complex logic

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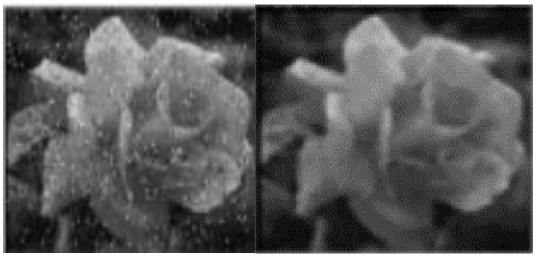
functions. The typical maximum operating clock frequency of the proposed designs is estimated by the timing analyzer using system generator of Xilinx ISE software. The proposed designs are successfully simulated with simulator of Xilinx (10.1) software.

6.RESULTS AND ANALYSIS:

Experiments are performed on gray level images to verify the proposed method. These images are represented by 8 bits/pixel and size is 128 x 128.Image used for experiments are shown in below figure.

Input: A 128 * 128 Gray Scale Noise Images
Output: It generates 128 * 128 Noise Removable Image through VB

In Figure 6.1, Figure 6.2, and Figure 6.3, the results of the application of median filter and adaptive median filter are presented on 8bit grey scale “Flower”, “Lena”, and “Pepper” images.



(a) (b)

Figure 6.1. (a) Corrupted image of “flower”. (b) Result of AMF

(a) (b)

Figure 6.2. (a) Corrupted image of “Lena”. (b) Result of AMF

(a) (b)

Figure 6.3. (a) Corrupted image of “Pepper”. (b) Result of AMF

When the executable file was dumped into the FPGA then it starts the execution of algorithm on the pixel values in the FPGA will be started. Then it returns the pixel values to the PC using RS232 cable. The pixel values reached to the PC are read and shown like Image format using Visual Basic Application Form.VB is responsible for reading the image pixel values and shows like an image, First the input Image will be printed in the VB screen, then after the pixel values are applied it Sobel operator and generates the edge pixels.

Table 1: Design summary of proposed Modified Decision Based Unsymmetrical Trimmed Median Filter in terms of their Chip Utilizations

Summary of Slice Utilization	MDBUTMF (3×3)
Number of Slices	89
Number of LUTs	132
Number of Flip Flops	119
Number of IOBs	498

These Edge pixels again they are transmitted to PC and shown like image, that image was the EDGE DETECTED image

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8.CONCLUSION AND FUTURE SCOPE:

In this paper, a new algorithm (MDBUTMF) is proposed which gives better performance in comparison with MF, AMF and other existing noise removal algorithms in terms of Peak signal to noise ratio (PSNR) and Image Enhancement Factor (IEF). The performance of the algorithm has been tested at low, medium and high noise densities on both gray-scale and colour images. Even at high noise density levels the MDBUTMF gives better results in comparison with other existing algorithms. Both visual and quantitative results are demonstrated. The proposed algorithm is effective for salt and pepper noise removal in images at high noise densities. This allows for a flexible window-size that can change from one calculation to another and we finally presented the results which are implemented on the Image using Spartan 3 EDK kit using System C coding and developed the architecture which shown as synthesis report as above which may useful for preparing the ASIC IC development for Edge detection. In the Transmission of Videos over channel, Video frames are corrupted by salt and pepper noise (Impulse Noise), due to faulty communication systems. With this project, we can implement a better filtering technique that makes the noisy video frames to noise free video frames. Median filters are the best known nonlinear digital filters based on order statistics to solve the present problem in videos. Median filters are known for their capability to remove salt and pepper noise and preserves the shape.

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