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# An Improved De-noising Algorithm for Highly Corrupted Color Videos Using FPGA Based Impulse Noise Detection and Correction Techniques

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## Abstract

**Objective:** This research focuses on design and implementation of FPGA hardware architecture based image de-noising algorithm with automatic detection and correction of impulse noise. With the proposed hardware, image or video camera can be interfaced with the implementing hardware for de-noising of salt and pepper noise called impulse noise. **Methods/Analysis:** The algorithms proposed in this research mainly work on images to identify the impulse noise affected pixel and correct only the corrupted pixel instead of uncorrupted. Also the novelty method modifies the existed features of various de-noising techniques using real time, low power FPGA architecture for the noise detection and correction. **Findings:** The proposed research is in two stages namely modified boundary discriminative noise detection and recursive median filter based correction technique. These two stages are tested for various noise densities and delivered better de-noising factor than the existing algorithms. The simulation results of the implemented algorithm prove efficiency of 98% noise reduction factor for 90% corrupted image or video.

**Keywords:** BDND, FGPA, Impulse Noise, Median Filters, MSE, Non Linear Filters

## 1. Introduction

Digital Image processing is a broad area with remarkable applications including our daily life such as image authentication, broadcastings, medicines, automatic control equipments, and military surveillance[1]. In the all above applications, the captured images by camera are affected during image acquisition and image transmission by different kinds of noises. It may severely degrade the quality of image and cause information loss in image[2,3]. According to the different types of disturbances or errors in image acquisition and image transmission process, the image noise may be classified as non-isotropic noise, Periodic noise, Shot noise, Speckle noise, Amplifier noise and Salt-and-pepper noise called impulse noise[4]. In recent decades there are different processes are available to remove or reduce the noise from digital images. For that, several linear filters have been utilized for de-noising the images[5]. But due to the image blurring, the non linear filters have been exploited widely because of the improved filtering performance.

## 2. Noise Models and Filtering Methods

In the noise model the impulse noise have the highest priority to be removed from an image before applying the image in to image processing tools[6]. The impulse noise is also called as the salt and pepper noise, spike noise and shot noise that mainly caused by malfunctioning pixel elements and faulty memory locations or by the timing errors at the time of digitization process[7]. In this research we mainly focus on removing impulse noise from the real time

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video images. There are two promising values exists in the impulse noise. They are 'a' and 'b'. The probability of each is below 0.2[8]. If the numbers 'a' and 'b' are greater than 0.2 the noise may swamp out the image. The typical value for salt noise of an 8 bit image is 255 and pepper noise is 0. The main reasons for Salt and Pepper Noise are as follows[9,10].

a. Memory cell failure.
b. Malfunctioning of camera's sensor cells.
c. Synchronization errors in image digitizing or transmission.

$$P(Z) = \begin{cases} Pa \ \ for \ z = a; \\ Pb \ \ for \ z = b; \\ 0 \ otherwise \end{cases}$$

Filtering the impulse noise is a primary process used to achieve noise estimation, noise reduction, re-sampling and interpolation[11]. All the filtering methods are of two stages. The first stage is to detect the noise and the second stage is to eliminate or remove the noise from digital image. In the first stage the pixels based on the intensity values are divided roughly into two types[12]. Noisy pixels and Noise free pixels are identified and the noisy pixels are changed to non noise pixel by the filter application. The noisy pixels in the image show different intensity values instead of true pixel values.

$$Y = \begin{cases} 0 \ to \ 255 & with \ probability \ p \\ X & with \ probability \ 1 - p \end{cases}$$

Here Y is the noisy pixel and X is the original value.

## 3. Related Works

Several filtering techniques have been proposed to remove the noises from the digital images. All the proposed filtering methods may include mean filter, average filter, median filter and etc[13]. All existing survey of various noise filtering techniques implies that non linear filter have high act on removing the noises than the linear filters. In the non linear filters, the median filter is most popular due to its simplicity in implementation and efficiency in noise suppression. The general median filter applies median operation to all the pixels unconditionally without checking whether the pixel is corrupted or uncorrupted. This unconditional operation is done by standard Median Filter (MF) and center weighted median filter[16].

Noise reduction methods were proposed by applying fine threshold method to each pixels present in the corrupted image using Center Weighted Median Filter (CWMF). In[14] proposed adaptive centers weighted median filter to remove salt and pepper noise. In [15] suggested various new non linear filtering techniques for image de-noising. Switching Median Filter (SMF), Adaptive Switching Median Filter (ASMF), and decision based algorithm, adaptive decision based robust statistics estimation filter are the popular noise reduction filters suggested by various researchers by including noise detection and correction methods. Hence there is a strong need of a novelty method to detect and correct the corrupted pixels from digital images.

## 4. Novelty Method for Impulse Noise Detection

This proposed research mainly focuses on detecting the noisy pixels from pixel set of an image. To detect the noisy pixels, the proposed method uses pixel intensity calculation technique and it includes three kinds of pixel set formation such as minimum intensity pixel set, medium intensity pixel set and maximum intensity pixel set. The salt and pepper noise has intensity level of 255 and 0 respectively. We can part intensities from 0 to 255 as minimum, medium, and maximum levels[9].

$$Intensity \ cluster \ set = \begin{cases} 0 < Pint < 10; & Minimum \ intensity \\ 10 < Pint < 245; & Medium \ intensity \\ 245 < Pint < 255; & Maximum \ intensity \end{cases}$$

The noise detection method consists of two different rules. The first rule is applied to find intensity cluster set. The second rule is applied followed by the first rule if and only if the processing pixel set lies in the minimum or maximum intensity level of cluster set. In order to find the intensity cluster set, let us consider an image window of 5*5 as below,

$$W5*5 = \begin{pmatrix} 255 & 255 & 42 & 255 & 32 \\ 48 & 255 & 255 & 0 & 0 \\ 0 & 0 & 212 & 230 & 204 \\ 60 & 255 & 0 & 0 & 255 \\ 255 & 75 & 86 & 0 & 182 \end{pmatrix}$$

In the above 5*5 window, the processing pixel is 212. Now the pixel 212 is applied to rule 1. In the rule 1, 5*5 window is sorted in the form of ascending order ($P_0$) to find median. The median in $P_0$ is 86. Then $P_{int}$ (intensity difference of each pixel) is calculated. Thus, the 3 intensity set are found out as depicted below. As already said, the second rule is applied if and only if the processing pixel lies on minimum or maximum intensity set level after the pixel intensity cluster calculation process. In our consideration the processing pixel 212 lies on maximum intensity level. Therefore the rule 2 is applied further.

*Rule* 1:

$$P0 = [0\ 0\ 0\ 0\ 0\ 0\ 0\ 32\ 42\ 48\ 60\ 75\ 86\ 182\ 204\ 230\ 255\ 255\ 255\ 255\ 255\ 255\ 255\ 255\ 2555]$$

$$Med = [86]$$

$$P_{int} = [0\ 0\ 0\ 0\ 0\ 0\ 32\ 42\ 48\ 60\ 75\ 86\ 182\ 204\ 230\ 255\ 255\ 255\ 255\ 255\ 255\ 255\ 255]$$

$$\textit{Maximum difference from } 0 \textit{ to Med in } P_{int} \textit{ is} => 32$$

$$\textit{Maximum difference from Med to } 255 \textit{ in } P_{int} \textit{ is} => 96$$

$$\textit{Minimum intensity cluster} = [0\ 0\ 0\ 0\ 0\ 0\ 0]$$

$$\textit{Medium intensity cluster} = [32\ 42\ 48\ 60\ 75]$$

$$\textit{Maximum intensity cluster} = [182\ 204\ 212\ 230\ 255\ 255\ 255\ 255\ 255\ 255\ 255\ 255]$$

Since the processing pixel is in maximum intensity cluster, the window size can be reduced to 3*3. Now the rule 2 processes starts with finding sorted pixel ($\mathbf{P}_{0/new}$) set and finding vector intensity set. Further minimum, medium and maximum intensities of 3*3 window is calculated.

*Rule* 2:

$$W\ 3*3 = \begin{pmatrix} 255 & 255 & 0 \\ 0 & 212 & 230 \\ 255 & 0 & 0 \end{pmatrix}$$

$$P0_{new} = [0\ 0\ 0\ 0\ 212\ 230\ 255\ 255\ 255]$$

$$P_{int}new = [0\ 0\ 0\ 212\ 18\ 25\ 0\ 0\ ]$$

$$1st \textit{ maximum difference} => 212$$

$$2nd \textit{ maximum difference} => 25$$

$$\textit{Minimum intensity cluster new} = [0\ 0\ 0\ 0]$$

$$\textit{Medium intensity cluster new} = [212\ 230]$$

$$\textit{Minimum intensity cluster new} = [255\ 255\ 255]$$

After rule 2, the processing pixel 212 lies on medium intensity cluster. Hence it is identified that the processing pixel is in uncorrupted pixel set. So there is no need of further filtering process.

The typical block diagram of the proposed research is shown in the Figure 1.

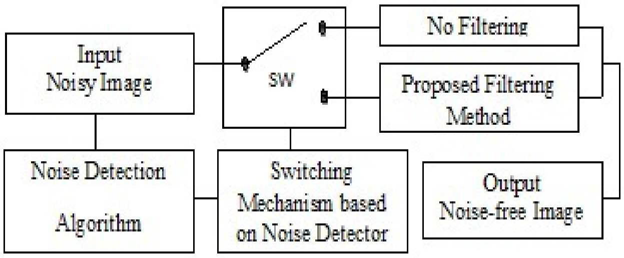


**Figure 1.** Block diagram for noise detection and correction.

## 5. Impulse Noise Reduction/ Correction Method

Let us consider an image window of 3*3 as below and now the processing pixel is 255. Now the pixel 255 is applied to rule 1 and rule 2. Finally it is also identified that 255 lies on maximum intensity cluster and it is identified as the salt noise. Thus it should be filtered in order to reduced noise as described below,

*Noise reduction method*

$$W\ 3*3 = \begin{pmatrix} 69 & 78 & 0 \\ 200 & 255 & 60 \\ 85 & 90 & 75 \end{pmatrix}$$

$$P_1D = [69\ 78\ 0\ 200\ 255\ 60\ 85\ 90\ 75]$$

$$\textit{Removing } 0 \textit{ and } 255, \textit{ we get}$$

$$P_{mod} = [60\ 69\ 75\ 78\ 85\ 90\ 200]$$

$$\textit{Median is } 78$$

*Now the processing pixel 255 is replaced by 78 and the modified matrix is formed as*

$$W\ 3*3 = \begin{pmatrix} 69 & 78 & 0 \\ 200 & 255 & 60 \\ 85 & 90 & 75 \end{pmatrix}$$

*The same process is repeated for all pixels in the image*

The above noise reduction process starts with finding one dimensional array ($\mathbf{P}_{1D}$) set and finding modified pixel set ($\mathbf{P}_{mod}$) by removing 0 and 255 in the one dimensional array ($\mathbf{P}_{1D}$). In the above work the median is 78 and it may lie on medium intensity pixel. Hence it is replaces the processing pixel 255 into 78. Thus the noise is detected and corrected successfully.

## 6. Data Flow Diagram of the Research

The data flow diagram shown in Figure 2 consists of three units. The first unit is the preprocessing unit, where all the video to frame conversion is done. The second unit is the impulse noise detection method[10]. The third unit concentrates on correcting the impulse noise from the image and delivering the final output video.

## 7. FPGA Hardware Implementation Details

Median filter is designed in FPGA platform using the following Figures x, y. It uses a mask that is applied to each pixel present in the input image[13]. The median value is found by placing the pixel values in ascending order and selecting the midpoint value. The implemented FPGA hardware is depicted in the Figure 3 and 4.

The proposed noise detector noise detecting and filtering algorithm and its FPGA hardware architecture is designed and verified on Spartan-3E family device using Model_sim 6.1 and Xilinx 12.1. Our proposed de-noising system is evaluated with Peak Signal to Noise ratio. Here the real time video capturing, noise adding and noise filtering is done using the hardware implemented in Figure 4. The noise density is varied and the result of proposed technique is compared and proved its originality than others as shown in Figure 4 and 5. The power consumption and performance analysis of the research is shown in Table 1 and 2.

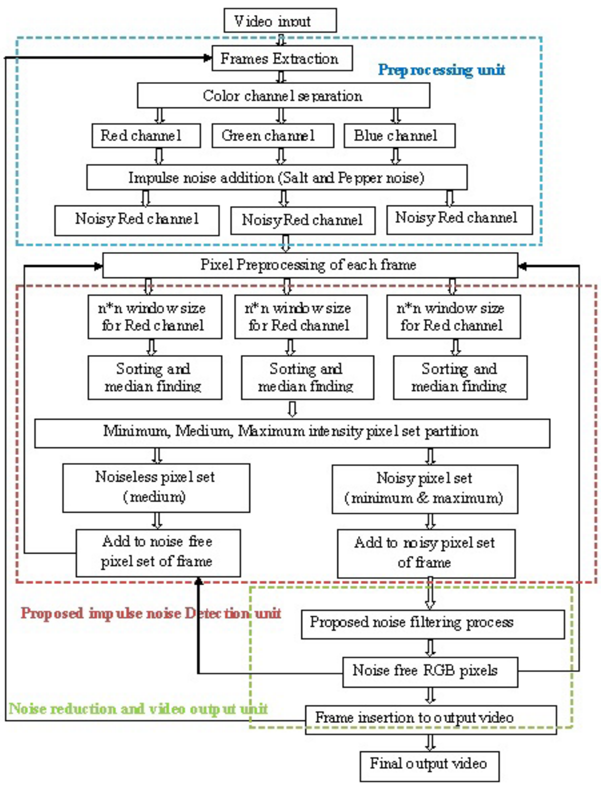


**Figure 2.** Proposed research flow diagram.

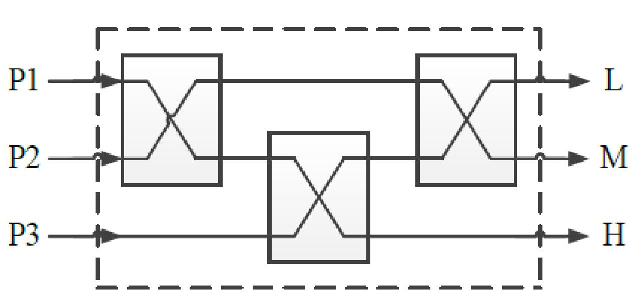


**Figure 3.** Pixel comparator design for FPGA architecture.

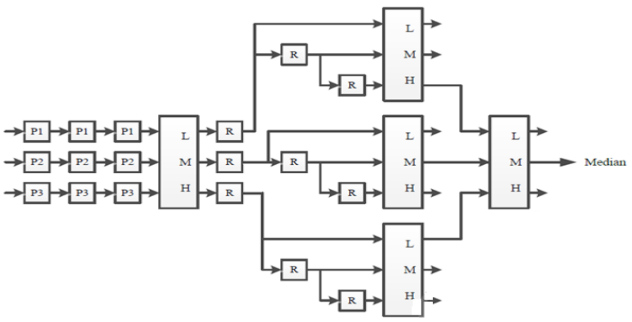


**Figure 4.** Median finding pixel comparator design for FPGA architecture.

**Table 1.** Comparison of power consumptions of spartan-3 family

| FPGA Family | Device specifications | Power consumption |
|---|---|---|
| Spartan-3E | Xc3s500E | 81.37 mW |
| Spartan-3E | Xc3s1200E | 158.95 mW |
| Spartan-3E | Xc3s1600E | 203.27 mW |

**Table 2.** Performance analysis of hardware utilization

| Performance parameters | Proposed architecture |
|---|---|
| Slices | 29 |
| LUTs | 48 |
| IOs | 45 |
| Bonded IOBs | 36 |

## 8. Simulation Results

The performance of our proposed impulse noise detection and correction method is tested with some color images are listed in the Figure 5 and 6. In the experimental simulation, the color image will be added with impulse noise (salt and pepper noise). Here the pixel value 255 represents the salt noise and pixel value 0 represents the pepper noise. For Noise correction capability, the addition of salt and pepper noise is varied from 10% to maximum (up to 90%). For each variation, our proposed algorithm has produced the good restoration level.

The peak signal to noise ratio and mean square error value are calculated with various noise variances and found greater restoration performances and illustrated in Table 3. The theory of PSNR is to make relationship between original images and resulted images and is defined as follows,

$$\mathrm{PSNR} = 10 \times \log_{10} \frac{255^2}{\mathrm{MSE}}$$

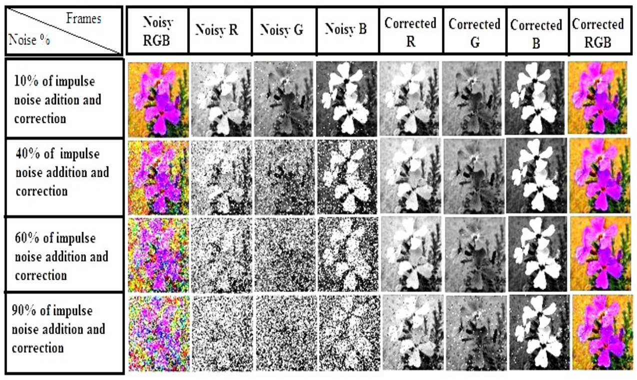


**Figure 5.** Impulse noise removing capability of the proposed system.

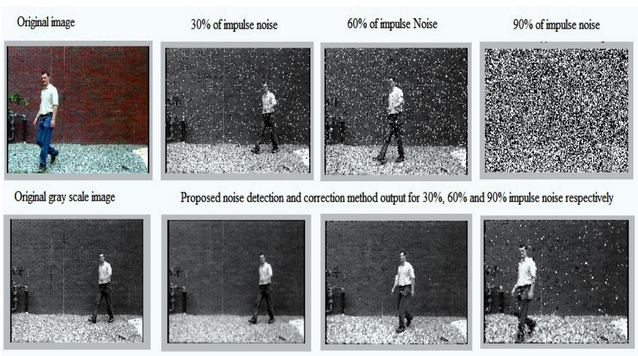


**Figure 6.** Real video Impulse noise removing capability of the proposed system.

**Table 3.** Peak signal to noise ratio

| ND | SMF | DBA | IDBA | PA |
|---|---|---|---|---|
| 10% | 33.12 | 41.58 | 41.39 | 42.29 |
| 20% | 28.76 | 37.44 | 37.32 | 38.91 |
| 30% | 23.64 | 34.69 | 34.50 | 36.54 |
| 40% | 19.08 | 32.18 | 32.22 | 34.18 |
| 50% | 15.29 | 30.18 | 29.72 | 31.12 |
| 60% | 12.35 | 27.92 | 27.18 | 30.03 |
| 70% | 10.0 | 25.69 | 24.46 | 28.97 |

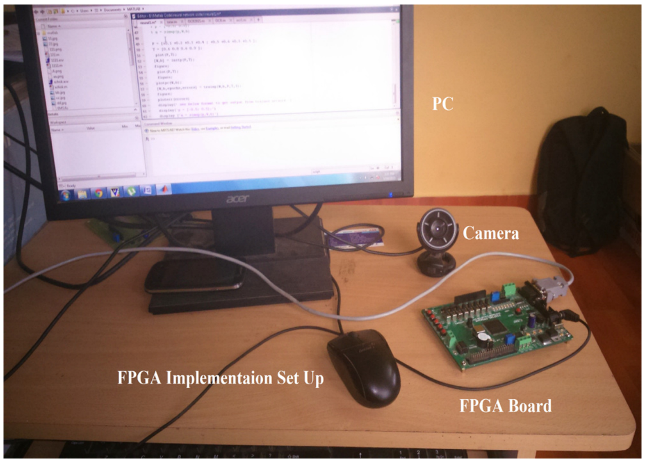


**Figure 7.** Proposed FPGA implementation Set Up.

$$\mathrm{MSE} = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} (S_{ij} - y_{ij})^2$$

Here $S_{ij}$ -> pixel of the original image

$y_{ij}$ -> pixel of the restored image

MSE -> mean square error,

PSNR -> Peak Signal to Noise Ratio.

## 9. Conclusion

As Salt and pepper noise has the highest priority to be removed from video and images, the de-noising algorithms that are being proposed should be effective in removing ratio than existing. As per the requirement the proposed FPGA hardware algorithm enhances and restores the image with high quality without salt and pepper noise. The peak signal to noise ratio and mean square error value are calculated with various noise variance and found greater restoration performances.

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