# Reliable Filters for Impulse Noise Suppression Methods Implementation and Experimental Analysis

**Geeta Hanji, M.V. Latte**

***Abstract—Improving the quaity of the noisy digital images is an important concern and a fundamental problem in the field of image processing. For the noisy images, quality improvement via noise suppression (or denoising) can be achieved with linear and nonlinear filters. Nonlinear filters being the winners in the list of denoising filters are more concerned about preserving the edge and other fine details of an image and are popularly used in the field of image restoration applications. In this paper, a simple and effective approach to suppress salt and pepper impulse noise from highly noised digital image is reviewed and implemented. Better modifications are suggested and incorporated to enhance its denoising capability. The presented work is based on X-ray filtering scheme used in Videoclient3, one of popular image processing algorithms used in PITZ applications. X-ray filter in videoclient 3 compares the central (suspected to be noisy) pixel with neighbors to see if the central pixel needs replacement, and has a percentage to control how intensive the filtering process is. The estimation of the noisy pixels is obtained by local mean. The essential advantage of applying X-ray filter is to effectively suppress the heavy noise and preserve sharp details of the original image. The simulation results on standard test images demonstrate the filter's simplicity and better denoising capability compared to state of art filters.***

***Index Terms—** X-ray filter, Videoclient3, PITZ applications, noise suppression.*

## I. INTRODUCTION

Detail preserving noise cleaning and image quality improvement has been an important concern in the field of image processing. Various types of Noise such as impulsive, Gaussian, speckle etc. affect the image during transit, storage, acquisition, and retrieval [1].Noisy image presents itself with an ugly look and renders useless for subsequent image processing operations such as segmentation, classification etc. in the image processing operations such as segmentation, classification etc. in the image processing chain. Thus, one of the important domains of image restoration is noise cleaning of corrupted and spoiled images. Image restoration aims at suppressing noise by

Discarding noisy pixels, while preserving edge and other fine information of the original image. Noise filtering can be viewed as replacing every noisy pixel in the image with a new value depending on the neighborhood region. The filtering algorithm varies from one algorithm to another by the approximation accuracy for the noisy pixel from its surrounding pixels [2,3]. The algorithm presented in this paper is based on X-ray filtering scheme used Videoclient3 [4,5,6,7] and focuses on a simple and effective means of detection and correction of salt and pepper noise in order to efficiently restore the noisy digital image. Three modifications have been suggested and incorporated to enhance its performance measures, namely the 'Peak Signal to Noise Ratio (PSNR)' and the 'run time' or the 'computational speed'. The work presented in this paper is organized as follows: Section 1 deals with the introduction and a brief review of literature. Section 2 describes the impulse noise models. Section 3 explains the details of X-ray filtering along with the suitable illustrations. Section 4 deals with the suggested modifications with suitable illustrations. Section 5 deals with the results and discussions. Conclusions and scope for the future work are discussed in section 6.

## II. A BRIEF REVIEW OF LITERATURE

A variety of image filtering methods have been proposed for noise reduction. A detailed literature survey of several linear and nonlinear filters is found in [8,9] and [19]. Several median-based methods for removing impulse noise from digital images have been used in the literature due to their simplicity [8,9]. However, the median filter should be applied only on the noisy pixels of the image in order to prevent unnecessary blurring due to filtering of noise free pixels. Therefore, a switching median filter approaches are popularly used in which the filtering is preceded by impulse detection [9,19].The concept of switching median filter has been used in a number of other ways also. For example, the weighted median filter and center-weighted median filter (CWMF) [8,9] are modified median filters which offer the trade–off between the noise suppression and image detail preservation by giving higher weight to some pixels of the filtering window. The task of impulse detection and removal is accomplished in an iterative manner in progressive switching median filter [9,19]. Some other filtering schemes such as BDND [13] and ABDND [14] achieve impulse detection by exploiting window statistics. The max-min excusive median filter impulse detector [8,9,19] and NASMBF [15] are proposed for detection and correction of salt and pepper noise from highly noised images. Detection schemes used in these filters tend to perform with poor performances when impulse occurs with values other than those on the extreme ends of the allowed intensity range. Another limitation of these schemes is

**Manuscript Received on December, 2014.**
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that they fail to distinguish noisy pixels from noise free ones when image pixels have identical intensity levels.

## III. IMPULSE NOISE MODELS

Impulsive type of noise can be modeled in four different types [19]. Description of all four models is as follows:

### *A. Noise Model 1*

This noise is a fixed valued impulsive type, also known as salt-and-pepper impulse noise. Here, pixels are randomly affected by two fixed extreme values, ‘0’ and ‘255’ (for gray level image), generated with the equal probability. That is, if ‘N’ is the noise density, then the noise density of salt (N1) is ‘N/2’ and pepper (N2) is ‘N/2.’

### *B. Noise Model 2*

This type of noise is similar to Noise Model 1 except that each pixel may be polluted by either salt or pepper noise with unequal probabilities, i.e. P1 ≠ P2.

### *C. Noise Model 3*

Instead of representing with two fixed values, impulse noise could be more realistically modeled by two fixed ranges that appear at both extreme ends with a length of ‘q’ each respectively. i.e., [0, q] denotes ‘salt’ and [255-q, 255] denotes ‘pepper.’ Here for noise density ‘P’ is P1= P2= P/2. This noise is also known as ‘random valued impulse noise’ or ‘uniform noise.

### *D. Noise Model 4*

This noise is similar to Noise Model 3. However the intensity of impulse noise is different, which means P1 and P2 are not equal i.e. P1 ≠ P2.

Many techniques have been proposed to eliminate impulse noise removal from gray scale images. Some of these methods work only for either low-density noisy images or high-density noisy images. Some other techniques are specifically designed for certain noise models. Some techniques use complicated formulations or require deep knowledge about the image noise factors. The proposed method, which is explained in section 2, is a method which removes any level of impulse noise, is applicable for almost all noise models, does not use complicated formulations and does not require deep knowledge about image noise factors.

## IV. DESCRIPTION OF X-RAY FILTERING (X1 ALGORITHM)

| | | |
|---|---|---|
| 7 | 12 | 25 |
| 36 | 252 | 40 |
| 22 | 70 | 220 |

**Fig 1: A small portion of noisy ‘Lena’ image is shown within 3x3 window.**

AwayAboveSurroundings: [1.0, 3.0] //Default:1.5//

(Alternative input: Percentage= AwayAboveSurroundings -1

Default Percentage: 0.5)

ALevelNumSurroundings: Maximum allowed counted number of surrounding pixels

//Default aLevelNumSurroundings: 4// cmp =central pixel× (1/ AwayAboveSurroundings)

Amount=0

For all surrounded pixles:

If value (surrounding pixel) < cmp

Amount+=1

End

If Amount >= aLevelNumSurroundings

Central pixel=Average (surrounding pixels)

**Fig 2. program used by Videoclient3 for X-ray filtering in PITZ applications.**

In this case, cmp=252× (1/1.5) =168. Only 1 surrounding pixel value is larger than 166, i.e. Amount=7 > ALevelNumSurroundings.

Thus, central pixel= Average (surrounding pixels) = Average (7,12, 25, 36, 40, 22, 70, 220) =54

From the above illustration it is seen that X-ray filter in videoclient 3 is to compare the central, suspected pixel with surrounding pixels to find if the central, suspected pixel needs to be replaced, with a variable percentage to control how intensive the filtering process is to be.

## V. PROPOSED WORK (WITH SUGGESTED VARIANTS OF X-RAY FILTERING SCHEME)

There are some issues related to the filtering step in the X-ray filtering algorithm that may cause degradation in its performance. Three proposed variants presented in this article incorporate three different feasible modifications to the filtering step of X-ray filtering algorithm to address these issues. Experimental evaluation shows the effectiveness of the proposed modifications in producing much clear images than the original X-ray filtering algorithm.

### *5.1 Modified Algorithm I (X2 algorithm)*

The standard median filter, which is a nonlinear order-statistic filter, is one of the most popular filters that is used in the removal of impulse noise. Since the ‘median’ is a robust estimator than the ‘mean’ or ‘average’, the development of several algorithms that are built on the standard median filter have



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assured the guaranteed performance [1,2]. Hence the first proposed work presented here is a modified version of the X-ray filtering scheme in which the restoration of the suspected noisy pixel is performed with the median of the surrounding pixels, say 'Xmed', where Xmed = med of the sorted array 7,12,22,25,36, 40,70,220 = Mean (or 'Average') of middle pixels 25 and 36. Thus, central pixel = Xmed = Median (surrounding pixels) =Average (25, 36,) = 30.5 ≈ 32.

Compared with the X-ray filtering algorithm, our suggested method has an advantage of using a robust estimator (i.e. 'median') than a non-robust estimator, namely a 'Mean' or 'Average'. However this method is computationally complex as it requires sorting operation.

### *B. Modified Algorithm 2 (X3 algorithm)*

In this proposal, a feasible modification is included in the filtering step of X-ray filtering algorithm is to restore the noisy central pixel of the working window by replacing its luminance value with the average of already processed pixel intensities. Thus, central pixel= Average (already processed pixels) = Average (7, 12, 25, 36) =20.
This method is computationally simple as it doesn't require sorting operation.

### *C. Modified Algorithm 3 (X4 algorithm)*

Another feasible modification incorporated in the filtering step of X-ray filtering algorithm is to restore the noisy central pixel of the working window by replacing its luminance value with the just processed pixel intensity. Thus, central pixel= Just processed pixel = 36.
This method is very simple as it neither require sorting operation for computing the 'median' value nor 'average' computation operations.

## VI. RESULTS AND DISCUSSIONS

We compare the performance of X-ray filtering and the suggested variants (modified filters) with the methods proposed in [12,16,18,21] by evaluating the objective parameter, Peak Signal to Noise Ratio (i.e. PSNR) given by

$$\mathrm{PSNR} = 10 \times \log_{10}\left(\frac{255^2}{\mathrm{MSE}}\right) \quad (1)$$

where 'MSE' is mean square error given by,

$$\mathrm{MSE} = \frac{1}{MXN}\sum_{i=1}^{M}\sum_{j=1}^{N}(X_{i,j} - Y_{i,j})^2 \quad (2)$$

In the above equation, '$X_{i,j}$' and '$Y_{i,j}$' are original noise free image and the denoised images respectively.

We also compared the performance of X-ray filtering and the modified filters suggested in this paper by evaluating the runtime consumed. Among the commonly used 256× 256, 8-bit gray-scale test images, the image 'LENA" is selected for simulations.

**Table 1. Run time (seconds) comparison for 'LENA' image corrupted with 90% Salt and Pepper noise density.**

| T | SMF | AMF | DBA | X1 | X2 | X3 | X4 |
|---|---|---|---|---|---|---|---|
| **PSNR** | 6.4 | 22 | 19.77 | 26.89 | 27.12 | 26.97 | 25.88 |
| **Run Time** | 3.13 | 54.35 | 27.31 | 18.9 | 30.5 | 17.54 | 10.56 |

In our simulations original images are corrupted by salt-and-pepper noise with equal and unequal probabilities as given by the noise model 1 and noise model 2 respectively. Simulations are carried under a wide range of noise-density levels (i.e. ranging from 10% to 90%) on a MATLAB plat form AMD Athlon 2.71 GHZ Processor, 2GB 800,Fsb RAM, 250GB HDD. Run time results of the algorithms presented are tabulated in Table (1) and the comparative PSNR results are tabulated in Table (2).

Although there has been as many attempts as there have been denoising algorithms, as yet, no universally accepted standard algorithm has emerged for denoising heavily noised images. Our work is to implement X-ray filter algorithm, propose feasible modifications to determine their performance levels in main aspects of image restoration, i.e denoised image quality by perception and the PSNR measure. For real time implementations, execution time of the algorithm plays an important role, hence we have attempted to obtain the run time and the PSNR values for all the implemented algorithms and a comparison is made among the competitive algorithms.

Simulation results reveal that the X-ray filter performed better than the competitive algorithms [12, 15, 16, 18 and 21] even under very high noise conditions. Among the proposed variants, X-ray filter with median based restoration worked very well in providing better PSNR values, but its performance with respect to run time is not much encouraging.

## V. SCOPE FOR FUTURE WORK

There are several interesting directions worth pursuing. This technique can further be worked with different types of noises (specially the Gaussian noise) and the mixed noise in grey scale and color images and also to restore images corrupted by artifacts such as blotches, strip lines etc along with the noise.

**Table 2. PSNR(dB) Performance Comparision for 'LENA' Grey- Scale Image.**

| % ND | SMF | PSMF | AMF | DBA | A1 | A2 | A3 | A4 | X1 | X2 | X3 | X4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|


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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 33.4 | 35.94 | 38.14 | 41.60 | 40.97 | 43.10 | 40.82 | 41.38 | 41.67 | 41.87 | 41.72 | 40.61 |
| 20 | 29.0 | 32.38 | 35.94 | 37.48 | 38.31 | 38.51 | 39.25 | 40.52 | 40.84 | 40.99 | 40.91 | 39.54 |
| 30 | 23.4 | 28.69 | 33.84 | 34.61 | 35.12 | 36.67 | 36.41 | 37.23 | 37.57 | 37.78 | 37.65 | 36.39 |
| 40 | 18.9 | 25.10 | 31.97 | 32.30 | 33.47 | 34.83 | 33.72 | 34.15 | 34.48 | 34.63 | 34.52 | 33.27 |
| 50 | 15.0 | 21.00 | 30.32 | 30.25 | 32.01 | 33.25 | 31.86 | 32.41 | 32.75 | 32.98 | 32.84 | 31.51 |
| 60 | 12.2 | 16.71 | 28.58 | 28.11 | 30.78 | 31.87 | 30.41 | 31.04 | 31.39 | 31.58 | 31.44 | 30.46 |
| 70 | 9.8 | 9.88 | 26.71 | 25.74 | 29.41 | 30.37 | 29.42 | 30.15 | 30.48 | 30.69 | 30.54 | 29.41 |
| 80 | 7.9 | 7.98 | 25.13 | 22.94 | 26.12 | 28.49 | 27.13 | 28.11 | 28.47 | 28.68 | 28.59 | 27.32 |
| 90 | 6.4 | 6.48 | 22.00 | 19.77 | 24.83 | 25.81 | 25.92 | 26.56 | 26.89 | 27.12 | 26.97 | 25.88 |

In the above table algorithms A1,A2,A3 and A4 are the algorithms presented by us, detailed in the references [12,18,21 and 22]

**Figure 3. LENA Test Image**

**Figure 4. a) Noisy image with 80% Noise Density & PSNR of 5.98.Restration results obtained for b) 'X1' with PSNR of 28.47 c) 'X3' with PSNR of 28.5 d) X4 with PSNR of 27.32 e) X4 with PSNR 26.26**

**Figure 5. a) Noisy image with 70% Noise Density & PSNR of 6.99. Restration results obtained for b) 'X1' with PSNR of 24.46 c) 'X2' with PSNR of 25.69 d) 'X3' with PSNR of 23.29 e) 'X4' with PSNR of 22.47**

**Figure 6. a) Noisy image with 0% Salt ,70% Pepper Noise & PSNR of 7.20. Restoration results obtained for b) 'X1' with PSNR of 10.95 c) 'X2' with PSNR of 13.24 d)'X3' with PSNR of 11.25 e)'X4' with PSNR of 10.02.**

**Figure 7. a) Noisy image with 70% Salt, 0% Pepper Noise & PSNR of 8.79. Restration results obtained for b) ‘X1’ with PSNR of 10.56 c) ‘X2’ with PSNR of 16.73 d) ‘X3’ with PSNR of 8.25 e) ‘X4’ with PSNR of 7.55.**

**Figure 8. a) Noisy image with 30% Salt, 40% Pepper Noise & PSNR of 7.02. Restration results obtained for : b)’X1’ with PSNR of 20.47 c) ‘X2’ with PSNR of 25.74 d) ‘X3’ with PSNR of 23.99 e)’X4’ with PSNR of 22.0**

| a | b | c | d | e |
|---|---|---|---|---|

In the above mentioned results, X1 is original X-ray filter algorithm, X2 is the modified version-I, X3 is modified version II and X4 is modified version III of the original X-ray filter used in Videoclient 3 for PITZ applications.

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