AN IMPROVED VECTOR MEDIAN FILTER FOR IMPULSE NOISE REMOVAL FROM COLOR IMAGES

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Abstract— This paper presents an improved way in image processing for impulse noise removal from color images. In this method we adopt a new Vector median filter based on Non-causal Linear Prediction for detection of impulse noise .In the Proposed Method, error is detected at first and if the pixel is found to be corrupted, pixel is replaced by Vector Median using Vector median filter. Experimental results show how the proposed method improves the Noisy image, corrupted by two sided–fixed impulse noise model by both visually and quantitively at different densities.

Keywords— kernel, Two sided Impulse noise mode, Vector median filter, Non-causal Linear prediction.

I. INTRODUCTION

Digital Image restoration is an important operation in image Processing. Impulse Noise is specially an "On-Off" Noise which generates Short-duration, high-energy pulses which disturb the regular signals. Impulse noise mainly occurs during image transmission due to interference in the channel, atmospheric disturbances or during image acquisition due to switching. When an image is affected by such impulse noise, filtering of image is necessary for preserving image details. Non-linear filters are the best filters which exhibit better performance than to the Linear Filters when restoring images corrupted by impulse Noise.

Median Filter (Mainly Scalar filter) is the best choice among all nonlinear filters for removal of impulse noise from corrupted images. Median is widely used in statistical analysis and Tukey previously introduced it in time series analysis. Color Image is a multiple channel signal. According to RGB model(R=Red, G=Green, B=Blue), in color image every pixel consists of three components. So implementation of median filter in case of color image is not a direct one. The ordering of vector pixel data, which we have taken for the sake of calculation of Vector median filter is processed by a suitable distance measuring technique. This vector operation on each kernel tends to alter all the pixels irrespective of whether they are corrupted or not. As a result image may be suffered from distorted features or blurring affects which degrade quality of the image and which affects the color images severely.

That is why we need to modify vector median filter which can detect impulse noise prior to the further processing operation so that image details are preserved. In the proposed method we need not to operate Vector operation in each step. If the central pixel in a kernel is found to be corrupted, normal vector median filter operation will be processed within that kernel.

We have organized the next part of the paper in the following way: An impulse noise model is explained in section II. The vector median filter and the proposed VMF are formulated in section III. In section IV we discuss the experimental results. Conclusion is presented in section V.

II. IMPULSE NOISE MODEL

The two-sided fixed impulse noise model is also known as "Salt and pepper noise model". Impulse noise having very large value is called as the 'salt' noise or when it has a very small value, it is called the 'pepper' noise. Let it is considered that *'a'* gives the probability that a very low value error, occurs at a signal component and that *'b'* gives the probability that a very high value error, occurs at a signal component. Then $(a+b)$ gives the value of probability where error occurs (high or low valued error). If we consider B as the number of bits used per pixel component then the 'salt' noise is represented by $(2^B\text{-}1)$ or *'h'*, while 0 or *'l'* gives the 'pepper' noise. Let X_c, (where $c = 1$ for red, 2 for green or 3 for blue) be a pixel component of a vector pixel X in any one of the channels of a multichannel image. Then we represent Impulse Noise model in the following way:

$$X_c = \begin{cases} l, \text{ with probability } a \\ h, \text{ with probability } b \\ S_c, \text{ with probability } (1\text{-}a\text{-}b) \end{cases} \qquad (1)$$

S_c = noise free pixel component.

III. FORMULATION FOR VMF AND PROPOSED FILTER

A kernel (3×3) is considered for all the filtering operation since it allows faster convergence of the filters. So In a (3×3) kernel there are total 9 vector pixels. This scheme is chosen only for simplicity in operation. In a window the vector pixels are represented as X_i where i=1, 2... 9.

$$W=[X_1, X_2, \ldots X_9] \qquad (2)$$

A. Vector Median Filter (VMF):

Vector median filter [4]-[5] has proved to be very an effective tool for removing impulse noise from color images. The VMF may be viewed as a generalization of the median filter to the vector valued signals and images. In VMF for the ordering of the vectors in a particular kernel or mask a, we have to choose a suitable distance measuring technique (Euclidian distance or City block distance). The vector pixels in the kernel are ordered on the basis of sum of the distances between one pixel to the other pixels in the kernel or window. The sum of the distances is arranged in the ascending order. The vector pixel which has smallest sum of distance is considered as the vector median pixel. The operation of VMF is now followed:

$$Y_i = \sum_{j=1}^{N} (X_i - X_j), i = 1, \dots N \quad (3)$$

Where X_i is the i^{th} pixel in the window, and N=9 for a (3×3) kernel. The pixel which yields the minimum value of Y is selected as the vector median and used as the corresponding pixel position in the filtered image. $(X_i - X_j)$ is the City Block distance and is given by:

$$(X_i-X_j)=abs\ (R_i-R_j) + abs\ (G_i-G_j) + abs\ (B_i-B_j) \quad (4)$$

Here R_i is the red component of the pixel X_i and so on. Thus Y is simply the sum of the distances in RGB space from the pixel to all other pixels in the kernel.

Now the ordering of distance may be given by:

$$Y_1 \leq Y_2 \leq Y_3 \ldots\ldots \leq Y_N \quad (5)$$

And this implies the same ordering to the corresponding vector pixel i.e.

$$X_1 \leq X_2 \leq \ldots \leq X_9 \quad (6)$$

So here the vector pixel which has the smallest sum of distances is depicted as the Vector median. As a result the vector median will correspond to rank 1 which is shown in the previous equation written in terms of ordering of pixels, i.e.;

$$X_{VMF} = X_1 \quad (7)$$

B. Proposed Non-causal Linear Prediction based VMF (NCLPVMF):

The proposed VMF is based on non-causal linear prediction coefficient to find the predicted vector pixel value at the centre of the filter window or kernel in color images where prediction of error vector is tough being a multichannel operation. So, main aim of the proposed method is not only to remove impulse noise, but also to avoid unnecessary Vector filtering operation from color images where detection method is a challenging one.

Strong correlation which exists among image pixels over two-dimensional neighborhood makes the linear prediction model very natural for estimating pixel values at any location of the test image. Here we have implemented the system for color images in a very simple way. The Non-causal signifies that prediction of the centre vector pixel $(X_{m,n})$ depends on both past and future pixel values which are clearly shown in the following pictorial representation of a kernel:

$X_{m-1,n-1}$	$X_{m,n-1}$	$X_{m+1,n-1}$
$X_{m-1,n}$	$X_{m,n}$	$X_{m+1,n}$
$X_{m-1,n+1}$	$X_{m,n+1}$	$X_{m+1,n+1}$

Fig. 1. Pixel representation of a kernel

Here general representation of each pixel is given by:

$$X_{(m,n)} = [X_{R(m,n)}, X_{G(m,n)}, X_{\boldsymbol{B}(m,n)}] \quad (8)$$

So each pixel consists of R, G, B components .Here we will find the error coefficients separately to find the linear prediction error. Linear predicted central vector pixel is given by:

$$P_{m,n} = \sum_{(i,j)\in W} a_{(i,j)} X_{(m-i,n-j)} \quad (9)$$

W is the non-causal region of support for the linear Predictor.

Now a General Block diagram of non-causal linear prediction based VMF is shown below:

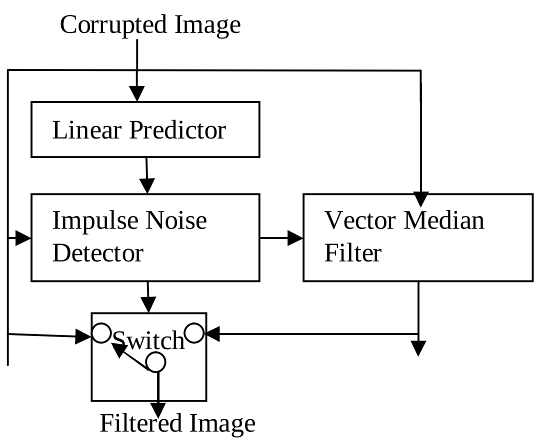

Fig 2: Block Diagram of Non-causal Linear prediction based VMF

Considering only R channel, we can write that the prediction vector pixel of R channel is given by:

$$P_{R(m,n)} = a_R X_{RN} \quad (10)$$

X_{RN} =Matrix in the non-causal region and a_R is the linear predicted co-efficient(R is used in subscript because we have shown only R channel). Total number of vector pixels surrounding the centre vector pixel to be predicted for a second-order non-causal system is 8.

After finding the a_{RN} we can easily find out the error vector between the vector pixel $X_{R(m,n)}$ and linear predicted centre vector pixel $P_{R(m,n)}$ given by:

$$e_r = X_{m,n} - P_{R(m,n)} \quad (11)$$

Using that way we can find error vector for *G* and B channel also. If e_g and e_b are the error vector for G and B channel respectively

Predicted error vector of the centre pixel e is given by

$$e = max(e_r, e_g, e_b) \quad (12)$$

So output of the non-causal linear prediction-based VMF is given by

$$X_{NCLPVMF} = \begin{cases} X_{VMF}, & if\ e > 0 \\ X_{m,n}, & otherwise \end{cases} \quad (13)$$

IV. EXPERIMENTAL RESULTS

Test images we have used here are Lena, Mandrill, Miramar, Everest etc. Each vector pixel consists of 24 bits, and every channel (R or G or B) has 8 bits. Two-sided fixed impulse noise model has been used for evaluation. We verify the performances by both visual observation and peak signal to noise ratio (PSNR) which is given by:

$$PNSR = 10\log_{10}\left(\frac{I^2{}_{MAX}}{MSE}\right) \quad (14)$$

Where I_{MAX} = maximum pixel value of the component of the vector pixel of the original image.MSE [Mean Square Error] [9], [10] between original image and the filtered image is given by:

$$MSE = \frac{1}{MNS}\sum_{p=1}^{M}\sum_{r=1}^{N}\sum_{t=1}^{S}(Y_{p,r,t} - Y'_{p,r,t})^2 \quad (15)$$

The image dimensions are represented by *M*, *N* and *S* is the number of channels present in the image[*S*=3 for color image]. $Y_{p,r,t}$ and $Y'_{p,r,t}$ stand for components of the original and filtered vector pixels respectively.

An image is corrupted by impulse noise generated as per the two sided fixed impulse noise model. The corruption is carried out at different noise percentages and the proposed filter is tested using these increasingly corrupted images.

TABLE. I

Performance Comparison of different filters on various images corrupted with 20 %(6.67% per channel) two-sided fixed impulse noise. The PSNR values in dB have been listed

Images/Filters	VMF		Proposed NCLPVMF	
	PSNR	*MSE*	*PSNR*	*MSE*
Lena	35.2091	19.5961	38.4312	9.3316
Mandrill	33.7718	27.2835	38.1435	9.9708
Miramar	31.9715	43.2414	37.7456	10.9278
Everest	36.3412	15.0994	44.1329	2.5106
Point Loma	33.2179	30.9949	38.1346	9.9912
Gold Hill	26.1709	157.0327	30.7823	54.3063

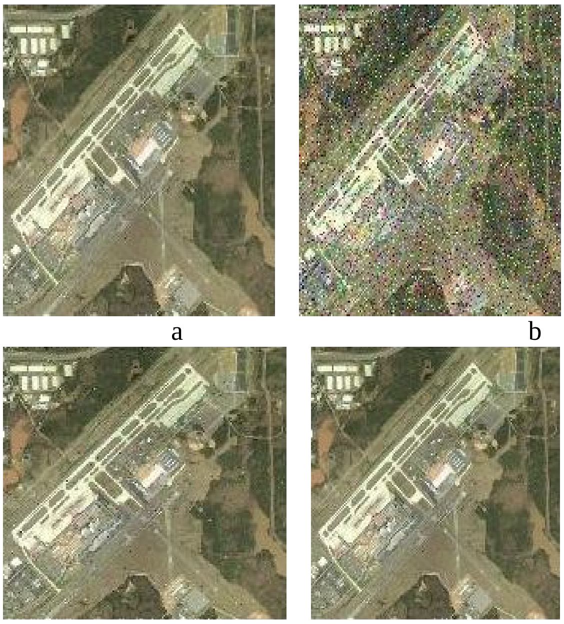

Fig. 3. (a) Original Miramar image (b) Image with 20% impulse noise (c) Filtered output of VMF (d) Filtered output of Proposed filter

In Fig .3 visual observations are presented where original Miramar image is corrupted with 20% two sided fixed impulse noise model. Here Proposed VMF preserves more image details than VMF.

We have made observations using a Miramar image and the graphs are plotted in Fig.4 where the noise percentages range from 0% to 60%. It is clear from the graph in Fig. 1 that the proposed filter improves results as compared to the VMF that has been mentioned in this paper, while color images are de-noised within that range. The improved performance, in terms of PSNR, is observed up to a corruption of about 44%.

In Fig. 5, We have carried out the comparison on the basis of execution time on Miramar image where image is corrupted by two sided fixed impulse noise . We have taken noise percentages from 0% to 60%. Here proposed filter shows lesser execution time than that of VMF drastically.

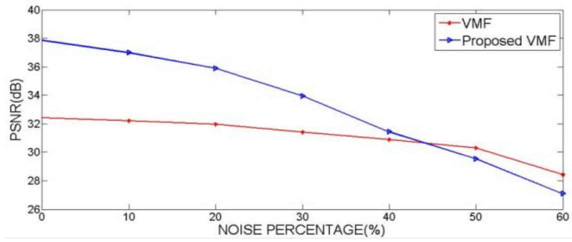

Fig. 4. Comparison of VMF and Proposed filter in terms of PSNR

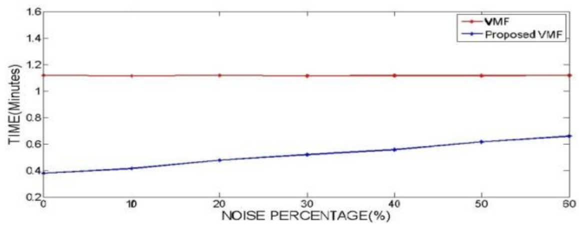

Fig .5 . Comparison of VMF and Proposed filter in terms of Execution time (minutes)

CONCLUSION

This work presents a vector median filter which is efficient for detecting impulse noise from color images prior to filtering. From the observation table, graphs and visual observation, it has been seen that the proposed filter works better for removal of impulse noises generated by two-sided fixed impulse noise model. Ability of the detection mechanism of the proposed filter to detect the corrupted pixels rightly makes the proposed NCLPVMF more accurate in terms of PSNR from color images. Moreover, limiting the distance calculation and ranking process to only the kernel which are affected by noise reduces execution time. Apart from that, the proposed filter gives a stable performance over wide variety of ranges.

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