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Performance Comparison of Pre-processing Techniques for Image Denoising

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Abstract*: The main objective of this survey is to compare different nonlinear filtering techniques for denoising and enhancing digital images for multiple noise environments. In this Survey, the various noise conditions are studied and some efficient nonlinear filters are designed to suppress bipolar fixed-valued impulse noise quite effectively. Efforts have been made to develop some noise removal techniques.*

Keywords: salt and pepper noise, random-valued impulse noise and multiple noise, Switching Mechanism

I. INTRODUCTION

Image Processing is a technique to enhance raw images received from cameras/sensors placed on satellites, space probes and aircrafts or pictures taken in normal day-to-day life for various applications. Various techniques have been developed in image processing during the last four to five decades. Most of the techniques are developed for enhancing images obtained from unmanned spacecrafts, space probes and military reconnaissance flights. For a meaningful and useful processing to have very good visual display in applications like television, photo-phone, etc., the acquired image signal must be denoising and made enhanced image. Image denoising (filtering) and enhancement come under a common class of image processing tasks known as image restoration.

The present day state-of-art technology offers very high quality photo sensors, high quality electronic circuitry, e.g., system on chip (SOC), and high quality channel as well. Therefore, the noise level has drastically reduced. In the last two decades, many researchers have attempted to develop filters to high density SPN. But the filters that are quite efficient at high noise levels don’t perform so well at low noise levels. Therefore, it is very important to design and develop highly efficient image filters that suppress low power noise as well as high power noise quite effectively. Further, it is essential to develop efficient filters to suppress multiple noise since the practical systems suffer from such a type of noise.

A linear filter is implemented using the weighted sum of the pixels in successive windows. Nonlinear digital filters for images are described by J. Astola and P. Kuosmanen and Ioannis Pitas, Anastasioa [1 & 2]. Recently some intelligent adaptive techniques are analyzed and implemented. Digital images are highly contaminated by impulse noise. Nonlinear filters are widely used for denoising digital images. For that use of local min max operation had been implemented by Yasuo nakagava et al [3]. **2**Alpha-trimmed means and their relationship to median filters had been implemented by Bednar.J et al [4]. This paper explains the relationship between α-trimmed means and median filters derives a simple straightforward and fast algorithm. An Improved Non-local Mean Filter for Image Denoising had been investigated by Mingyue Ding et al [5]. Due to the drawback that the similarity is computed based on the noisy image, the traditional NLM method easily generates the artifacts in case of high-level noise.

The objective of any nonlinear filtering technique is to eliminate the noise and preserve the edge structures without losing the fine details of the image. The properties of median filters had been analyzed by Neal. C et al [6-10]. In this paper, necessary and sufficient conditions for a signal to be invariant under a specific form of median filtering . A new impulse detector for switching median filters had been presented by Shuqun Zhang et al [11-17]. This impulse detector is based on the minimum absolute value of four convolutions obtained using one dimensional Laplacian operators. Adaptive Two-pass rank order filter to remove impulse noise in highly corrupted image had been implemented by

Xiaoyin Xu et al [18-28]. This adaptive process detects irregularities in the spatial distribution of the estimated impulse noise.

Here Edge Preserving Filter (EPF) is capable of preserving edge pixels; Decision Based Filter 2 (DBF 2) has an ability to preserve the original pixels in homogenous region and Decision Based Filter 3 (DBF 3) has used to preserve both edge pixels and pixels in the homogenous region of digital images. The rest of the paper is organized as follows. Section 2 explains about noise model. In section 3, different pre-processing techniques were discussed. Section 4 discusses results of the experiments conducted to evaluate the performance of various noise model as well as techniques and comparative discussion of these results is also presented. Conclusions and remarks present in the section 4.

II. NOISE MODEL

In this section, various types of noise corrupting an image signal are studied; the sources of noise are discussed, and mathematical models for the different types of noise are presented. An image signal gets corrupted with noise during acquisition, transmission, storage and retrieval processes. Acquisition noise is usually salt and pepper noise (SPN) and additive white Gaussian noise (AWGN) with very low variance. In many engineering applications, the acquisition noise is quite negligible. It is mainly due to very high quality sensors. In some applications like remote sensing, biomedical instrumentation, etc., the acquisition noise may be high enough. But in such a system, it is basically due to the fact that the image acquisition system itself comprises of a transmission channel.

The Salt & Pepper Noise

Salt and pepper noise [4] is an impulse type of noise, which is also called as intensity spikes. This is generally caused due to errors in transmission of data through the channel. It has only two possible values, “a” and “b“. The probability of each is less than 0.1. The corrupted or noised pixels are set alternatively to the minimum or to the maximum value, giving the image a “salt and pepper” like appearance. For an 8-bit image, the typical value for pepper noise is ‘0’ and for salt noise are ‘255’. The salt and pepper noise (impulsive noise) is generally caused by malfunctioning of pixel elements in the camera sensors, timing errors, or faulty memory location in the digitization process. The probability density function (PDF) for impulsive noise is shown below:-

$$F(g) = \begin{cases} p_a & g=a \\ p_b & g=b \\ 0 & otherwise \end{cases} \quad \dots\dots\dots\dots\dots (2)$$

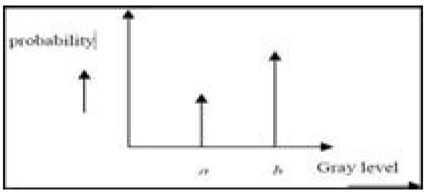

Fig. 1 Graphical Representation of Impulsive Noise

Random Valued Impulse Noise (RVIN)

The impulse noise occurs at random locations with a probability. The SPN and RVIN are substitutive in nature. The noise magnitude at any noisy pixel location is independent of the original pixel magnitude. Therefore, the RVIN is truly substitutive. A random noise has a bell-shaped symmetrical distribution of instantaneous power on two sides of its mean power. A fading noise does not have a symmetrical distribution. Rather its distribution has a longer tail on the far end of the low-power side of the mean. This tail represents the probability of finding the fading (extremely low power) instances.

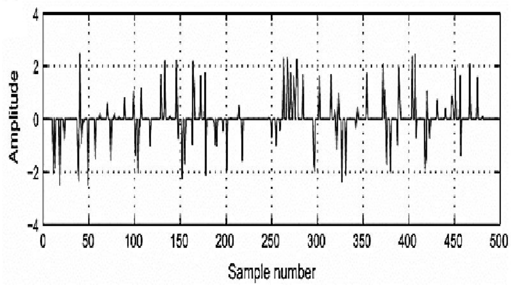

Fig. 2 Graphical Representation of Random Valued Impulse Noise

Gaussian Noise

Gaussian noise [4] is uniformly distributed over the signal. It means that each pixel in the noisy image is the sum of the true pixel value and a random value of Gaussian distributed noise. As the name shows, this type of noise has a Gaussian distribution, that has a bell shaped probability distribution function (PDF)given by:-

$$F(g) = \frac{1}{\sqrt{\sqrt{2\pi\sigma^2}}} e^{\frac{-(g-m)^2}{2\sigma^2}} \ldots\ldots\ldots(1)$$

Where g is represented AS gray level, m is mean or average of the function, σ^2 = variance of the noise.

It is graphically shown as:-

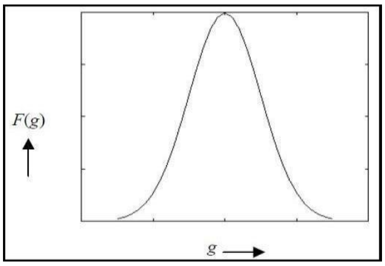

Fig. 3 Graphical Representation of Gaussian Noise

III. COMPARISON OF DENOISING TECHNIQUES

Already Existing filtering techniques are adaptive process detects irregularities in the spatial distribution of the estimated impulse noise. To overcome the above drawbacks appeared in median and their variance and switching filters, Decision Based filtering techniques (DBFT) are proposed. In existing decision based filter, the difference between the median value of pixels in the filtering window and the current pixel value is compared with a threshold to determine the presence of the impulse noise. If the current pixel is detected to have been corrupted by impulse noise then the pixel is subjected to filtering; otherwise, the pixel is left undisturbed. The following block diagram illustrates the impulse noise detection and elimination. This illustration is common for all decision based filters.

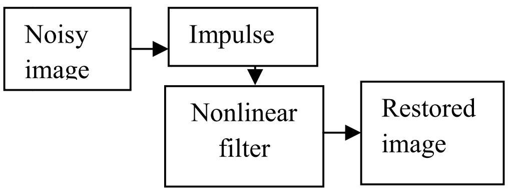

Fig. 4 Block diagram for impulse noise detection and elimination

In general, the decision-based filtering procedure consists of the following two steps: noise detector that classifies the input pixels as either noise-corrupted or noise-free, and a noise reduction filter that modifies only those pixels that are classified as noise-corrupted. In this chapter some new filter schemes are proposed to improve the performance of digital images.

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Proposed Decision Mechanism and Filtering Operation

The filtering technique proposed in this work employs a decision mechanism to detect the presence of impulse noise in the image. The pixels inside the sliding window are classified as corrupted and uncorrupted pixels by comparing their values with the maximum (255) and minimum (0) values. Consider an image of size M × N having 8-bit gray scale pixel resolution. The proposed filtering algorithm as applied on noisy image is described in steps as follows:

A two-dimensional square filtering window of size 3 x 3 is slid over the noisy image. As the window move over the noisy image, at each point the central pixel inside the window is checked whether it is a corrupted pixel or not. If the pixel is an uncorrupted one, it is left undisturbed and the window is moved to the next position. On the other hand, if the pixel is detected as a corrupted one, the filtering procedure is performed.

A Filtering Technique for Preserving Homogenous Region on Digital Images

In general, the main issue concerning the design of the decision-based median filter focuses on how to preserve features from the local information and establish the decision rule, in such a way to distinguish noise-free pixels from contaminated ones as precisely as possible. In this section, Filtering Technique for Preserving Homogeneous Region (FTPHR) is experimented for denoising the images contaminated by low levels of impulse noise.

Edge Preserving Filter (EPF)

The Impulse detection procedure is based on local measurements of impulse noise, which is referred to as impulse detection which is illustrated. This filtering operation is carried out in a way of detection of edge orientation to improve visual perception and filtering at the current pixel within the sliding window on digital image. The central pixel is identified as corrupted one; it is replaced by the proposed edge preserving method. Therefore, edges on the image is detected by computing gradient value in the direction of horizontal, vertical, left diagonal and right diagonal within the filtering window respectively

Decision Based Filter for Denoising Digital Images

The filtering technique proposed in this filter detects the impulse noise in the image using a decision mechanism. Consider an image of size M×N having 8-bit gray scale pixel resolution. A two dimensional square filtering window of size 3 x 3 is slid over a highly contaminated image. ***The pixels inside the window are sorted out in ascending order.*** Minimum, maximum and median of the pixel values in the processing window is determined. In this case, the minimum, maximum and median pixel values, respectively. If the central pixel lies between minimum and maximum values, then it is detected as an uncorrupted pixel and the pixel is left undisturbed. Otherwise, it is considered a corrupted pixel value. The corrupted central pixel is replaced by the median of the filtering window, if the median value is not an impulse. If the median value itself is an impulse then the central pixel is replaced by the already processed immediate top neighbouring pixel $A_{i-1,j}$ in the filtering window. ***This process is repeated until the last image pixel is processed.***

New Tristate Switching Median Filtering Operations

Decision based median filter, called new *tri-state median* (NTSM) filter, is proposed and discussed in this section. Impulse noise detection is realized by an impulse detector, which takes the outputs from the **FTPHR** and **EPF** filters and compares them with the origin or center pixel value within the filtering window on given contaminated digital image in order to make a tri-state decision. The switching logic as shown in Fig. 3.1 is controlled by a threshold T (T = 24; [0 - 255] for gray-scale images).

Multistate Switching Median Filter

In order to enhance the digital images, switching median filter is combined with Decision based filter to form the proposed Multistate switching median filter. Switching median filter has better edge preserving properties. Decision based filter has improved performance in retaining both the homogenous region of image as well as edge region of image satisfactorily. Therefore, these two filter outputs are integrated together to form the multistate switching median filter.

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IV RESULT AND DISCUSSION

In this work, some nonlinear filtering techniques for eliminating fixed impulse are investigated. Quantitative measures like PSNR, MSE and IEF on Lena image are being corrupted by noise have been estimated with respect to noise level. These estimated values are tabulated and given in Tables 3.60. Any filter having lower MSE value, higher PSNR and higher IEF values are considered to be superior filter in terms of noise elimination and restoration of image features. Qualitative performances of the proposed filters are evaluated on Lena image and are shown in Fig.5.

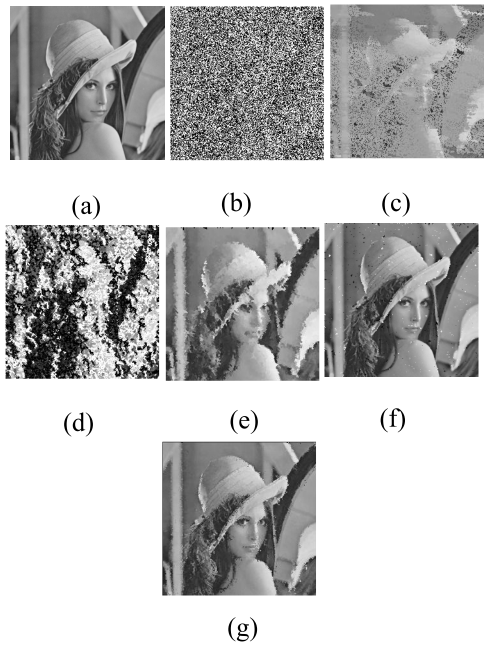

Fig. 5 Subjective performance comparison of proposed filter with other existing filters on Lena test image (a) Noise free images, (b) image corrupted by 70% impulse noise, (c) images restored by FTPHR, (d) images restored by EPF, (e) images restored by DBF, (f) images restored by NTSMF, (g) images restored by MSSMF

FTPHR filter is outperforming the other proposed filtering techniques when homogeneous region of the images are damaged. But it shows the poor performance when the images are highly damaged by impulse noise. Because, images are corrupted by higher level of impulse noise it should not preserve the edges and fine details at higher level of impulse noise on digital images. This filter shows good performance of preserving in both homogenous region as well as edge region of digital images up to 30% of impulse noise. EPF filter is outperforming the other proposed filtering techniques when edge region of the images are damaged. But it shows the poor performance when the images are highly damaged by impulse noise. This filter shows good performance of preserving edge and fine details of digital images up to 30% of impulse noise. Performance of decision based filtering (DBF) is superior when compared to the performance of FTPHR and EPF. This filter shows good performance of preserving edge and fine details of digital images up to 50% of impulse noise. New tristate switching median filter (NTSMF) is outperforming the above mentioned FTPHR, EPF and DBF up to 30% of impulse noise. But it shows the poor performance when the images are highly damaged by impulse noise. Multistate Switching Median Filter (MSSMF) has superior performance than the other decision based nonlinear filters for all the level of noise from 5% to 70%. It is worth to be noted that the MSSMF performs even better than the FTPHR, EPF, DBF and NTSMF for noise percentage ranging from 5% to 70%. The proposed multistate switching median filter has very good subjective improvements i.e. fine details preservation of the image.

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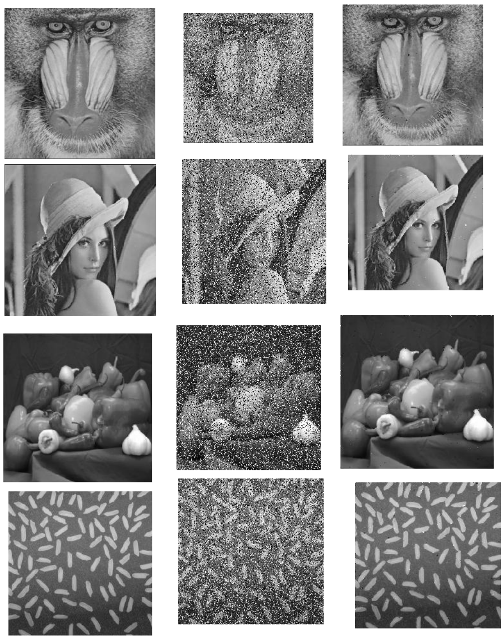

Fig.6 Subjective performance illustration of proposed MSSMF Technique for Baboon, Lena, Pepper and Rice images: noise free image in first row, images corrupted with 70% impulse noise in second row, Images restored by proposed Filtering Technique in third row

Therefore these filters perfromance are tested using different images namely; Baboon, Lena, Pepper and Boat corrupted with impulse noise of densities up to 90%. Qualitative performances are evaluated in Fig.6. The Multistate Switching Median Filter shows that good in visual perception for human eye as well as improved performance in objective measures while comparing to other existing nonlinear filtering schemes for the noise densities upto to 70%. The performance of Lena and Rice images are better than the other images for the noise levels ranging from 10% to 30%. But for higher noise levels, the Pepper image is better. The Baboon image seems to perform poorly for higher noise levels. Based on the intensity level or brightness level of the image, it is concluded that the performance of the stationary images like Baboon, Lena, Pepper and Rice will change. In addition to these, in this chapter decision based filtering algorithms are described for uniform noise and Gaussian and impulse noise. The proposed filters are seen to be quite effective in eliminating the Gaussian noise and impulse noise; in addition, the proposed filter preserves the image boundaries and fine de-tails satisfactorily. The efficacy of the proposed filter is illustrated by applying the filter on various test images contaminated by different levels of noise. Here, the conventional filters are integrated to form the multistate switching median filter which gives the proposed filter, so that the performance of conventional filter is improved. This proposed MSSMF appears to perform well for human visual perception when images are corrupted up to 70% of impulse noise.

V. CONCLUSION

In this article, there are eight decision based filtering techniques are investigated namely: Filtering Technique for Preserving Homogeous Region (FTPHR), Edge Preserving Filter (EPF), Decision Based Filter (DBF), New Tristate Switching Median Filter (NTSMF), Multistate Switching Median Filter (MSSMF), Random Valued Impulse Noise Elimination (RVINE), Multiple Noise Elimination method 1 (MNE1) and Multiple Noise Elimination 2 (MNE2). These filtering techniques are outperforms the existing filtering techniques for denoising and enhancing digital images while images are contaminated by SPN or AWGN, or RVIN or MN. FTPHR is investigated to preserve the homogeneous region. EPF is implemented for edge preservation of digital images. In order to preserve both homogeneous and edge region, DBF is investigated. A new tristate switching median filter is developed for edge and fine detail preservation. FTPHR and EPF are integrated to form a NTSMF. Performance of this filter is good up to 30% of impulse noise. A multistate switching median filter (MSSMF) is developed for edge and fine detail preservation. NTSMF and DBF are integrated to form a MSSMF. Performance of this filter is better upto 70% of impulse noise. ATMF is investigated for denoising random valued impulse noiseDecision Based Algorithm 1 (DBA1) is developed to eliminate uniform noise and impulse noise. Decision Based Algorithm 2 (DBA2) is developed to eliminate gaussian noise and impulse noise. In order to improve the fine detail preservation, artificial intelligent techniques may be utilized in real application.

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