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Noise Reduction and Removal using Fuzzy based Median Filter and Matrix Algorithm

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Abstract—
This project presents a filter for restoration of images that are highly corrupted by salt and pepper noise. By incorporating fuzzy logic after detecting and correcting the noisy pixel, the proposed filter is able to suppress noise and preserve details across a wide range of salt and pepper noise corruption, ranging from 1% to 60%. The proposed filter is tested on different images and is found to produce better results than the Traditional Median Filter.

Keywords— Noise, fuzzy logic, TMF, Matrix Algorithm

I. INTRODUCTION

Digital images are often distorted by impulse noise during data acquisition, transmission and storage. Noise can enter through image acquisition by a camera, scanner, and recording and/or when the image is transmitted over a noisy channel. Salt-and-pepper noise is a special case of impulse noise, where a certain percentage of individual pixels are randomly digitized into two extreme, intensities, maximum and minimum. The need to remove salt-and-pepper noise is very important before subsequent image processing tasks are carried out because the contamination of image by salt-and-pepper noise is caused in great amount and the occurrence of noise can severely damage the information or data contained in the original image. The simplest and the traditional way to remove salt-and-pepper noise is by windowing the noisy image with a conventional median filter.

Median filters are the most popular nonlinear filters, are extensively applied to eliminate salt and pepper noise due to its outstanding computational efficiency. Pratt was the first to use median filters in image processing. Since the discovery of the Standard Median Filter (SMF) by Tukey who applied it to the smoothing of statistical data, filters of this class have been subject to growing interest. The median filter and its modifications are generally implemented to all pixels in an image. Hence the noiseless pixels also get affected. As a result, their effectiveness in noise suppression is often at the expense of blurred and distorted image features and is effective only at low noise densities. A better way to circumvent this drawback is to incorporate some decision-making process to discriminate between uncorrupted and corrupted pixels.

Adaptive Median Filter have been proposed in which the noisy pixels are identified and replaced by using median value or its variant while leaving uncorrupted pixels unchanged. The performance of AMF is good at low noise density. At higher noise densities, the number of replacements of corrupted pixels increases. Also, the corrupted pixel values and replaced pixel values are less correlated. Therefore, edges are smeared. Modified median based filter proposed by Shrinivasan and Ebenezer incorporated a decision based technique in which the corrupted pixels are replaced by either the median pixel or neighbourhood pixel. At higher noise densities, the median value may also be a noisy pixel, in that case neighbourhood pixels are used for replacement.

This provides good correlation between the corrupted pixel and neighbourhood pixel which in turn gives rise to better edge preservation. To remove any sort of Greyness' ambiguity and Geometrical uncertainty present in an image and/or to modify the pixels in an image without distorting the original details, a Fuzzy Rule based approach is used. With the growing appeal of fuzzy logic, employing fuzzy theories as an extension to the modified median filters can be used as an effective technique in the domain of noise removal in Image Processing. The fuzzy inference rules by else action (FIRE) filter introduced by Russo suggests that effective removal of salt and pepper noise can be achieved by using a fuzzy rule base and employing fuzzy sets, although FIRE filter suffered from a drawback that it was not able to remove noise

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present at the edges. In recent years, many fuzzy rules based filters have been designed which provide better results than the traditional median filters. Fuzzy filters are capable of removing the noise efficiently without distorting the edges and hence keeping the details of the image intact.

Haixiang Xu designed a fuzzy switching filter in which the noisy pixel value is replaced by an estimation value which is based on the median and average values of the selected window. Kenny Kal Vin Toh designed a fuzzy switching median filter in which the value of noisy pixel is replaced by an estimation value which in turn depends upon the luminance difference between the neighbouring pixel and the centre pixel and employing a linear membership function In this paper, modifications to work of along with the Fuzzy Rule based approach has been proposed to improve the filter performance in salt-and-pepper noise detection and cancellation. The proposed filter is composed of three subunits.

The first subunit aims at detecting impulse noise by considering gray scale distribution among neighbouring pixels. The detection of noisy and noise free pixels is decided by checking whether the value of a processed pixel lies between min (0) and max (255) value that occurs inside the selected window. If the value of the proposed pixel lies within the max-min range, then it is an uncorrupted pixel, hence the same value is retained. If the value does not lie within the max-min range, then it is a noisy pixel and is replaced by the median value of selected window or by its neighbourhood values. A possibility also arises that the median value is also a noise value. In this case, the pixel processed is replaced by the previously processed adjacent neighbourhood pixel value in place of the median value. Output from first subunit still contains some traces of salt-and-pepper noise.

Therefore, in the second subunit, the need of fuzzy logic arises which modifies the value of pixel obtained from the first subunit in order to remove noise, if present, and to improve the preservation of image details by fuzzy switching. The third subunit is basically a post-processing unit which aims at preserving the details of the image by border correction and by increasing contrast and sharpness.

II. PROPOSED FUZZY MEDIAN FILTER

An Consider a gray scale image ‗x' defined as an MxN matrix, where x(i,j) represents the intensity of the pixel at the ith row and the jth column. The intensity is stored in an 8-bit integer, giving 256 possible gray levels in the interval [0 255]. In this interval, a salt-and-pepper noise takes minimum and maximum intensity and appears in digital image with equal probabilities. The noise can be positive or negative [10]. Positive impulse appears as white (salt) points with intensity 255 and negative impulse appears as black (pepper) points with intensity 0 respectively.

A. Impulse Detection & Correction

A 2-Dimentional window ‗Sxy' of size 3x3 is selected and is denoted as S(1), S(2), ... , S(9) as shown in fig 1. Let the pixel to be processed is Y(x,y). Next, the pixel values inside the window are sorted by arranging the rows, columns and the right diagonal in the ascending order. Hence, the first element of the window, S(1) so obtained is the minimum value Y min, the last element of the window, S(9), is the maximum value Y max and the middle element of the window, S(5), is the median value Y med. Now, three cases are considered:

S (1)	S (2)	S (3)
S (4)	S (5)	S(6)
S (7)	S (8)	S (9)

Fig. 1:- 3x3 window

Case 1**:** Y(i,j) is noiseless pixel if it lies in the max-min range i.e. $Y\ min < Y(i,j) < Y\ max$, Also, $Y\ min > 0$, $Y\ max < 255$, then the value of the pixel is not changed. Otherwise, Y(i,j) is a noisy pixel.

Case 2: If Y(i,j) is a noisy pixel, it is replaced by its median value. For this, the median value must lie in the max-min range i.e. $Ymin < Ymed < Ymax$ and $0 < Ymed < 255$.

Case 3**:** If $Ymin < Ymed < Ymax$ is not satisfied or $255 < Ymed$ or Ymed=0, then Ymed is a noisy pixel. In this case, Y(i,j) is replaced by the value of the neighbourhood pixel value. Above process is repeated until the processing is completed for the entire image.

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B. Modification of Current Pixel based on Fuzzy Switching

Image obtained from first subunit still contains some amount of noise. To obtain a noiseless image, the pixels of image are fuzzy field by a membership function and values of pixels are modified according to a correction factor. [11] If μ[Y(i,j)] ϵ [0,1] is the membership function of Y(i,j) that indicates how much a pixel looks like salt and pepper noise, Following fuzzy rules can be given :- [Rule 1] If Y(i,j) is large, then μ[Y(i,j)] is large [Rule 2] If Y(i,j) is small, then μ[Y(i,j)] is small According to the above rules, S-function (fig. 2) is used to describe the membership function of the impulse noise corruption extent of the pixel:

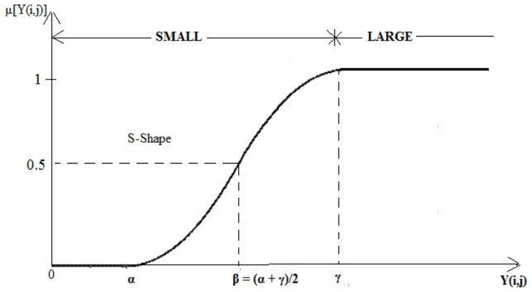


Fig 2:- S-shape Membership Function

$$\mu[Y(i,j)] = \begin{cases} 0 & \text{if } Y(i,j) \leq \alpha \\ 2\,[(Y(i,j)-\alpha)/(\gamma-\alpha)]^2 & \text{if } \alpha \leq Y(i,j) \leq \beta \\ 1-2\,[(Y(i,j)-\gamma)/(\gamma-\alpha)]^2 & \text{if } \beta \leq Y(i,j) \leq \gamma \\ 1 & \text{if } Y(i,j) \geq \gamma \end{cases}$$

Y(i,j) =(1- μ[Y(i,j)])*x(i,j) + μ[Y(i,j)] * M(i,j) (1) = x(i,j) +μ[Y(i,j)] * [M (i,j) – x(i,j)]

The correction term Y(i,j) for replacing the current pixel x(i,j) is taken from and is given in equation (1) Y(i,j) =(1- μ[Y(i,j)])*x(i,j) + μ[Y(i,j)] * M(i,j) (1) = x(i,j) +μ[Y(i,j)] * [M (i,j) – x(i,j)] where M(i,j) is the median of pixels in the 3x3 window given by, M(i,j) = median {S(1) .... S(9)}

If the membership function μ[Y(i,j)] = 0, it means that the current pixel Y(i,j) is a noise free pixel and there is no need of filtering the image. The filter will output the original pixel and preserve the image detail. If the membership function μ[Y(i,j)] = 1, it means that the current pixel Y(i,j) has been corrupted absolutely by impulse noise and needs to filter. If the membership function 0 < μ[Y(i,j)] < 1,it means that the current pixel is corrupted somewhat by impulse noise. The output of the filter in this case will be described by equation (1). The corrected pixel Y(i,j) depends on a linear combination between x(i,j) and Median M(i,j). The Fuzzy membership value μ[Y(i,j)] lends a weight on whether more of pixel x(i,j) or median pixel M(i,j) would be restored as the corrected pixel.

C. Post Processing

At this stage, the noise from the pixels is detected, corrected and the modification of pixels on the basis of fuzzy rules have also been applied. The image obtained is free from impulsive noise but to make it suitable for its use in various fields of Image Processing, further processing is done. Some of the techniques used in this paper are : Border Correction; the edges of the image are modified so that the border of the image is also free from noise and Contrast Enhancement; which is done to make the image clear and sharp for visual perception. Although, the post processing techniques may vary from image to image according to its future requirement. The proposed method is tested on various test images with Noise Density varying from 10% to 60%. Till 20%, both Traditional method and proposed method works well. But as the Noise Density is increased above 20%, the traditional method fails to remove noise from the image while the proposed method works well. When the Noise Density is increased above 40%, some noise is seen in the image.

To remove this noise, image is again passed through the whole process to obtain a noiseless image. At Noise Density 50%, when the salt and pepper noise completely dominates over the image, a noiseless image can still be obtained by performing two iterations of the method discussed above. Similarly at 60% noise, four iterations are sufficient to remove the noise completely from the image. Another advantage of this method is that while performing iterations the originality of image is not lost. The image becomes noiseless and the details are preserved after required number of iterations has been performed. While in case of Traditional Median, when the image is passed through iterations, image still contains noise and at the same originality of the image is lost. Hence, the proposed method is a better approach to remove salt and pepper noise while preserving the details of the image.

III. IMPROVED ADAPTIVE GENERALIZED MORPHOLOGICAL FILTER

The adaptive generalized morphological filter makes the output signal $y(n)$ approach the ideal signal closer by adjusting the weighting coefficient [a_1 (n), a_2 (n)] based on LMS algorithm. The filter itself doesn't adjust the output $y1$ (n), y $2(n)$ of generalized open - closing and close – opening filters. Moreover, for the morphological open – closing filter, the opening operation progressing firstly enhanced the negative impulse noise while filtering positive impulse noise. If the closing operation is done by reusing the structural element of same length, the negative impulse noise can not be filtered effectively. But if the structural element adopted in closing operation has longer length, the enhanced negative impulse noise will be eliminated effectively. It is the same principle to close-opening filter. Therefore, in order to filter the enhanced positive and negative impulse noise effectively, the choice of the length of structural element must experience repeated experiments, which will make the filtering process become slow and aggravate burdens. Hence this paper presents an improved adaptive generalized morphological filter, which is shown in figure 3.2.

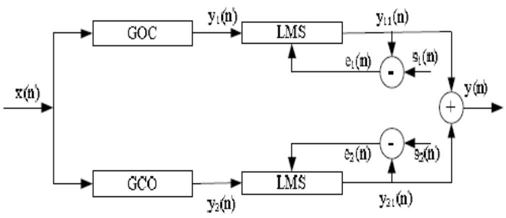


Fig 3 The block diagram of the improved adaptive morphological filter [2]

In figure 3, $x_0(n) = s(n) + d(n)$ is the input signal;

$y_1(n)$, $y_2(n)$ are the outputs of generalized open - closing and close – opening filters respectively;

$y_{11}(n)$, $y_{21}(n)$ are the outputs of $y_{12}(n)$, $y_{21}(n)$ based on LMS algorithm;

$s1(n)$, $s2(n)$ are the expectation responses, which are replaced by $y1(n+1)$, $y2(n+1)$ in this paper;

$e1(n)$,$e2(n)$ are the error signals.

$$e_1(n) = s_1(n) - y_{11}(n)$$
$$e_2(n) = s_2(n) - y_{21}(n)$$

Finally, the output of the improved adaptive generalized morphological filter will equal to the sum of the operational results $y_{11}(n)$, $y_{21}(n)$, that is:

$$y(n) = y_{11}(n) + y_{21}(n)$$

The improved adaptive generalized morphological filter can effectively suppress various noises in power system sampling signal. The filter consumes shorter time than adaptive generalized morphological filter and the filtering effects are better. So, the improved adaptive generalized morphological filter is effective and practical.

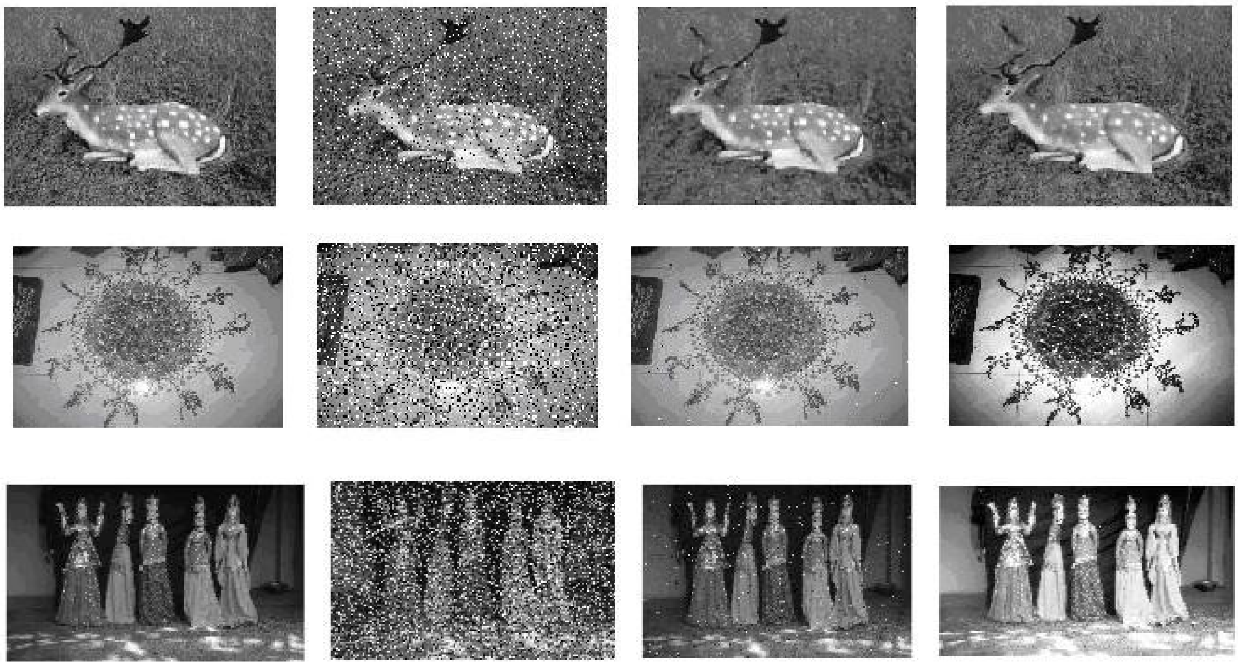
IV. EXPERIMENTAL RESULTS

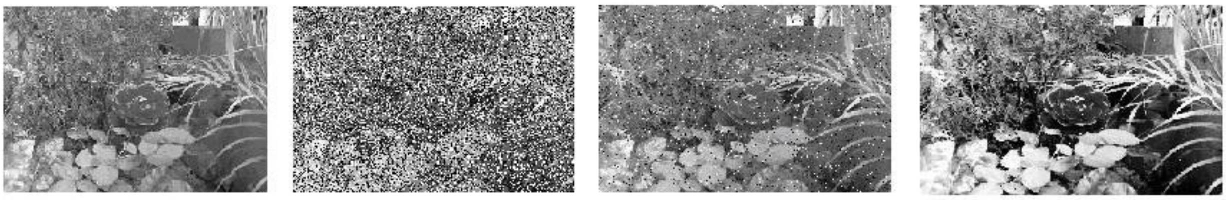
The performance of the proposed filter has been evaluated and compared with different gray scale images with their dynamic range of values [0 255]. The noise levels are varied from 10% to 60% and performances are quantitatively measured by Mean Square Error (MSE) and Peak Signal-to-noise ratio (PSNR) respectively.

$$PSNR = 10\log 10\left(255^2 / MSE\right)$$

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(r_{ij} - x_{ij}\right)^2$$

Where r original image, x restored image, MxN size of image





(a) (b) (c) (d) Fig 3. Various test images.

(a) Original Image

(b) Noisy corrupted image

(c) Output for Traditional Median

(d) Output for Proposed Method. Row 1 shows dear image corrupted by 10% noise. Row 2 shows design image corrupted by 20% noise. Row 3 shows puppet image corrupted by 30% noise. Row 4 shows flower image corrupted by 60% noise.

V. Conclusions

In this paper, a fuzzy based median filter is introduced which removes salt-and-pepper noise effectively while preserving details of the image under both low and high noise densities. As shown by examples of various test images, the performance of the proposed filter is better than that of the traditional median filter. The proposed filter can be used as a pre processor which can be combined with other image processing techniques to enhance the robustness to salt-and-pepper noise.

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