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Recovery of Image Destructed by Impulsive Noise Using Threshold Value and Fuzzy Rules

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Abstract. Spotting and removing noise is of high importance in image processing. This paper presents a two-step noise spotting method, at first step of which one filter with two threshold values are applied to spot and remove the noise. At the next step, a directional adaptive median filter is introduced, which has been designed based on fuzzy rules.This filter is effective for removing the impulsive noise above 20%. In fuzzy filter, fuzzy rules are used to define the difference between the examined pixel and the adjacent pixels available in four directions. Using this distinction, the examined pixel may be categorized into noise pixels, detailed pixels and pixels without noises. The results of the simulation show that the recommended filter has the best performance in removing impulsive noise compared to other well-known filters.

Keywords—image processing, impulsive noise, two-threshold noise-removing filter, fuzzy logic, noise removing

I. INTRODUCTION

Destructed image made by impulsive noise results from errors in noise sensors and communication channels [1]. In the case of noised input image, the processing quality for items like edge recognition, partitioning, tracking and recognizing objects dramatically worsens. Therefore, spotting noised pixels and replacing them with appropriate values is considered a basic point in image processing.

Impulsive noise may be divided to two known types: impulsive noise with fixed value (Salt & Pepper) and impulsive noise with random value. In a destructed image by Salt & Pepper noise, the intensity values of the noised pixels are either zero or one [1]. This paper examines the more general impulsive noise (the impulsive noise with random value). The intensity of noised pixels in the image which includes this type of noise is a random value in the dynamic range of the image [2-7].

In the recent decades, various types of non-linear filters have been presented for removing noise and recovery of image. Standard Median Filter is the most well-known and practical non-linear filter with high efficiency in removing impulsive noise and doing calculations. Yet, in conditions where the density of impulsive noise is less than 20%, it is more efficient. This filter, like other location filters, is in the form of a window which scans the noised image from left to right and up to down. Then, it replaces the value of each pixel by the medianintensity level adjacent to the pixels. However, the use of this filter at high densities of noise, damages the details of the image, which is of high risk, especially in medical images [8].

In conditions where the location density of impulsive noise exceeds 20%, the use of Adaptive Median Filter is preferred (AMF) to that of Standard Median Filter (SMF).In AMF, some features such as the size of filter window change proportionate to the statistical characteristics of the image in the area under examination. The very feature distinguishes between this filter and SMF. AMF too, like SMF, removes the details of the image by removing the impulsive noise [9].

To maintain details of image while using AMF, many methods have been offered, the basis of which stands on the separation of noised pixels from the ones without noises in the destructed image.Filtering is done only on noised pixels, and those without noises are maintained unchanged via the typical use of switching strategy [10].

Through recent years, fuzzy systems received attention due to holding the capability to separate noised pixels from those with no noise. Such applications use fuzzy rules to model uncertainty for the noise degree of pixels [11].

In the second part of the paper, the noise-removing algorithm with two threshold extent, basic definitions of filtering technique and noise recognition for the directional median filter are posed. Third part introduces a directional median filter based on fuzzy rules, and the fourth part presents the results of simulations while the final part concludes the discussion.

II. SUGGESTED METHOD

In this suggested method, a two-step solution is used to remove the noise.Through the first step, a two-threshold noise-removing algorithm is used, and in the next step, noise removing is done with the help of fuzzy rules. This method works better than other methods for Salt & Pepper noise higher than 20%.

In the suggested method, first, the noise-removing filter with two thresholds is applied on the image covered by Salt & Pepper noise. Then, the noise-removing filter with fuzzy rules is applied on the resulted image to obtain the final free-of-noise image.

As for noise removing with one threshold, as the central pixel is controlled to a known amount of noise, any amount less than that is considered noised pixel. Therefore, a two-threshold filter is used.

In this method, first, a 3*3 or 5*5 window is moved on the image such that the examined pixel is put on the center of the window. Then, the means of rows and columns of the filtering window are calculated to obtain threshold values, and by each movement of the window, the minimum and maximum threshold values are obtained.

To this end, first, the mean of elements in each row of the filtering window is calculated. Also, the mean amounts proportionate to each column are calculated, and the lowest and highest of them are respectively chosen as the minimum and maximum thresholds. Then, the central pixel (cp) is compared to these two values. If th_{min}<cp<th_{max}, then the pixel is considered without noise; otherwise, it will be noised. If the central pixel is noised, the noise-removing algorithm is applied, and the median value of means of rows and columns of the filtering window will replace the central pixel, and then the window will move on the next pixels. The above steps are repeated until the final assessment of all the pixels of the image.

First, it should be mentioned that all image-filtering techniques have two hypotheses: The first hypothesis is that an image without noise must be locally smooth so that the distinction of areas in it is done using edges [8]. The second hypothesis states that the grey intensity of a noised pixel is larger or smaller than its adjacent pixels [16]. Edges are only considered in the four directions shown in Figure 1.

The slide window$W = \{X_{i-2}, X_{i-1,j-1}, \ldots, X_{i+1,J+1}, X_{i+2,J+2}\}$ contains 25 pixels. The central pixel, $X_{i,j}$, shows the pixel located in (i,j). By putting $X_{i,j}$ aside, the four directions shown in Figure 1 are defined using S_K groups (K=1,2,3,4) as follows:

$S_1 = \{X_{i-2,j-2}, X_{i-1,j-1}, X_{i+1,J+1}, X_{i+2,J+2}\}$. (1)

$S_2 = \{X_{i,j-2}, X_{i,j-1}, X_{i,J+1}, X_{i,J+2}\}$. (2)

$S_3 = \left\{X_{i+2,j-2}, X_{i+1,j-1}, X_{i-1,J+1}, X_{i-2,J+2}\right\}$. (3)

$S_4 = \left\{X_{i-2,j}, X_{i-1,j}, X_{i+1,J}, X_{i+2,J}\right\}$. (4)

To determine the existence or non-existence of edge or line in the pixel under examination, the four-direction elements are defined as follow:

$D_k = \sum_{x \in S_k} |x - x_{i,j}|$, $k = 1,2,3,4$ (5)

In a directional weighted median filter (DWMF), the value of r is defined as:

$r = \min\{D_1, D_2, D_3, D_4\}$ (6)

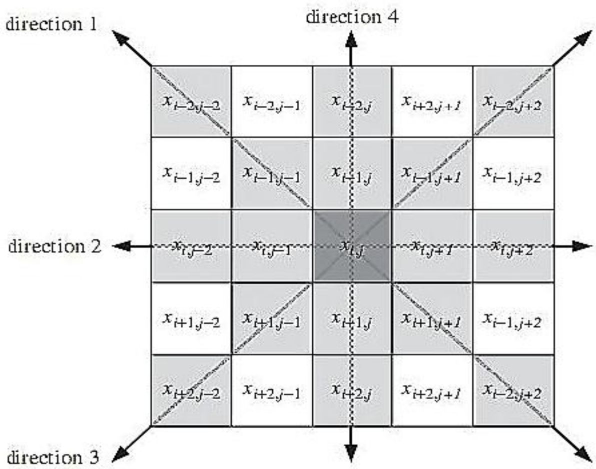

Figure 1. Sliding window (W) and four defined directions

Based on the below reasons, using the value of r, the noised and without-noise pixels can be distinguished:

- In the case of a without-noise pixel in a homogenous region, the value of r is low because for each of D_k, the value of r is low.
- In the case of an edged pixel, the value of r is low because at least on D_k is low.
- In the case of a noised pixel, the value of r is high because for each of D_k, the value of r is high.

Therefore, it could be stated that, if r>T, then $X_{i,j}$ is a noised pixel; otherwise$X_{i,j}$ is without noise.

This paper introduces a method for spotting impulsive noise in images. This method is grounded on fuzzy rules. First, Relation 5 is changed as follows:

$D_k = \frac{1}{4} \sum_{x \in S_k} |x - x_{i,j}|$, $k = 1,2,3,4.$ (7)

D_l (l=1,2,3,4) is allocated to the input of fuzzy systems. To obtain the values ofD_l, D_k has to be put in ascending order, i.e. there is:

$D_1 \leq D_2 \leq D_3 \leq D_4$. Also, (D_1) is allocated to the direction ofD_1.

The following 5 fuzzy rules are used to determine the pixel type in a noised image.

Rule 1. If D^1 is BIG, D^2 is BIG, D^3 is BIG and D^4 is BIG then $x_{i,j}$ is possibly a noise in the smooth region.

Rule 2. If D^1 is SMALL, D^2 is BIG, D^3 is BIG and D^4 is BIG then $x_{i,j}$ is an edge detail.
Rule 3. If D^1 is SMALL, D^2 is SMALL, D^3 is BIG and D^4 is BIG then $x_{i,j}$ is possibly a noise detail.
Rule 4. If D^1 is BIG, D^2 is BIG, D^3 is SMALL and D^4 is BIG then $x_{i,j}$ is possibly a noise detail.
Rule 5. If D^1 is SMALL, D^2 is SMALL, D^3 is SMALL and D^4 is SMALL then $x_{i,j}$ is a noise-free smooth-region pixel
BIG (u) and SMALL (u) are fuzzy functions defined by Relations 8 and 9. Both these fuzzy functions are trapezoidal, and are shown in Figure 2.

$$BIG(u) = \begin{cases} 0, & u < s \\ \frac{u-s}{b-s}, & s \le u < b \\ 1, & u \ge b \end{cases} \quad (8)$$

$$SMALL(u) = \begin{cases} 1, & u < s \\ \frac{u-s}{b-s}, & s \le u < b \\ 0, & u \ge b \end{cases} \quad (9)$$

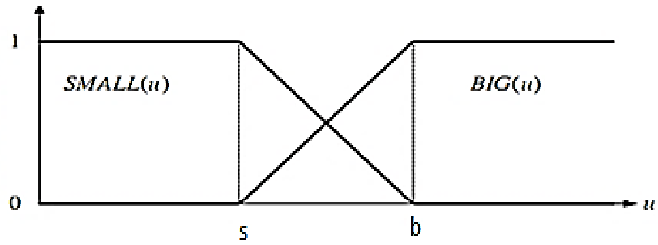

Figure 2. Fuzzy trapezoidal functions BIG (u) &SMALL (u)

Five rules of Frame defined as the following (m is the number of the rule):
$F_1 = BIG(D^1).BIG(D^2).BIG(D^3).BIG(D^4)$ (10)
$F_2 = SMALL(D^1).BIG(D^2).BIG(D^3).BIG(D^4)$ (11)
$F_3 = SMALL(D^1).SMALL(D^2).BIG(D^3).BIG(D^4)$ (12)
$F_4 = SMALL(D^1).SMALL(D^2).SMALL(D^3).BIG(D^4)$ (13)
$F_5 = SMALL(D^1).SMALL(D^2).SMALL(D^3).SMALL(D^4)$ (14)
To calculate F_m, the product inference engine is used [16]. After the calculation of F_m, the following items are considered:
First, ifmax$\{F_1, F_2, F_3, F_4, F_5\} = F_1$, then probably $x_{i,j}$ is a noised pixel in the smooth region. To replace this pixel, SMF is directly used: $y_{i,j} = MED\{x\}, \quad (x \in W)$. (15)
Second, Ifmax$\{F_1, F_2, F_3, F_4, F_5\} = F_2$, then $x_{i,j}$ is a pixel belonging to the edge which must be kept unchanged. In other words, there is:

$$y_{i,j} = x_{i,j}.$$

Third, if max$\{F_1, F_2, F_3, F_4, F_5\} = F_3 \text{ or } F_4$, $x_{i,j}$ may be a noised pixel in an area with details.
In such a case, the suggested median filter, after spotting the direction of the edge, removes the noise from the image. Since D_l is ranked, the edge would be in one of directions D_1or D_4. Checking values$|D^3 - D^4|$&$|D^1 - D^2|$ is enough for the determination of outside locating of D_1or D_4.
If $|D^1 - D^2| \ge |D^3 - D^4|$, then $D_1$is outside located, and the impulsive noise is in$\Gamma(D^1)$ direction; otherwise, $D_1$is outside located, and the impulsive noise is in $\Gamma(D^4)$direction.
Fourth, ifmax$\{F_1, F_2, F_3, F_4, F_5\} = F_5$, $x_{i,j}$is a pixel without noise in the smooth region which must be kept unchanged. In other words, there is $y_{i,j}=x_{i,j}$.

III. RESULT

Simulation has been performed on known images “Lenna”, “building”, “baboon”, “peppers” and “mri”, which have been destructed by 40% impulsive noise. Images “Lenna” and “peppers” are smoother and have 512*512 dimensions, but images “building”, “baboon”, and “mri” are more complex and have 256*256 dimensions. The ratio of peak signal to noise (PSNR) [1] and the mean of absolute values of errors (MAE) [1] between the main and recovered image are selected as standards for assessing the efficiency of the used methods. These criteria are defined by the following relations:

$$PSNR = 10.log\frac{255^2}{(\frac{1}{I.J})\sum_{i=1}^{I}\sum_{j=1}^{J}(y_{i,j}-s_{i,j})^2} (16)$$

$$MAE = \frac{1}{I.J}\sum_{i=1}^{I}\sum_{j=1}^{J}|y_{i,j} - s_{i,j}| (17)$$

In Relation 17, I*J is the size of image dimensions. $y_{i,j}$ and$S_{i,j}$ are respectively the amounts of intensity for the pixels of recovered images and main ones which have been located in (i,j).

First, an initial value is allocated to s and b parameters. To assess the efficiency of the suggested method for various values of s and b, PSNR is calculated for all four images, and the mean of them is calculated. By trial and error, the best efficiency is shown for ranges $b\epsilon[60,80]$& $s\epsilon[10,30]$. Especially when s=20 and b=70, the efficiency is maximum. Therefore, s=20 and b=70 are selected as parameters of fuzzy functions. Figure 3 shows the capability of the suggested method in noise removing of ranges $b\epsilon[60,80]$& $s\epsilon[10,30]$.

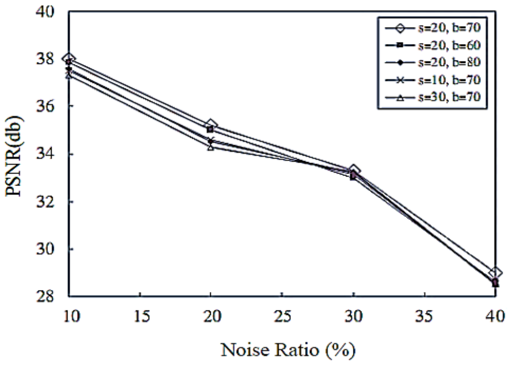

Figure 3. The PSNR of recovered images using the suggested method and various values of parameters in fuzzy functions (s,b)

To test the efficiency of the suggested filter for removing noise, the simulation results have been compared to the results concerning filters [8]SWM, [1]CWM ,[1]MED,[12]SAWMF ,[11]DRID ,[11]ERID, [10]MSM, [9]TSM, the suggested filter of Chen and Wu [13], the suggested filter of Zhang and Karim [14] and DWM [15].The amounts of PSNR and MAE are shown for the recovered images using these filters in Table 1.

Figure 4 shows the image destructed by the impulsive noise of p=40% density and the recovered images using various methods. Given the results, it can be concluded that the suggested method brings about the highest amount of PSNR for various noise densities.

Table1. The results of the recovery of images destructed by 40% impulsive noise (the amounts of PSNR (MAEs))

Method	Camera-man	Lenna	Building	Bridge
Noised image	13.43(28.52)	13.22(29.17)	12.68(30.92)	13.15(29.47)
MED	23.35(6.95)	24.94(6.28)	22.46(8.65)	21.33(9.03)
CWM	22.61(8.01)	22.37(7.96)	22.04(9.03)	21.55(9.07)
SWM-I	23.32(7.90)	22.84(8.61)	22.64(7.15)	21.99(8.33)
SWM-II	21.33(7.74)	21.73(8.68)	21.43(9.66)	19.48(10.65)
TSM	14.49(5.98)	23.91(6.32)	23.49(9.66)	22.58(8.61)
MSM	23.71(6.35)	22.86(6.34)	21.63(8.40)	21.46(8.42)
ERID	22.68(6.78)	21.24(7.91)	20.61(8.62)	20.53(9.12)
DRID	21.62(7.67)	20.28(9.76)	20.16(8.34)	19.93(9.36)
SAWMF	21.97(7.44)	23.96(6.82)	21.95(8.31)	20.63(8.72)
Chen and Wu	25.04(6.18)	24.75(7.49)	24.15(7.65)	22.88(8.38)
Zhang and Karim	22.76(6.95)	22.15(8.62)	22.04(8.10)	21.39(8.65)
DWM	26.20(4.74)	28.44(4.56)	25.01(7.37)	23.62(7.56)
Suggested method	27.49(4.56)	30.31(4.14)	25.89(7.17)	25.19(7.54)

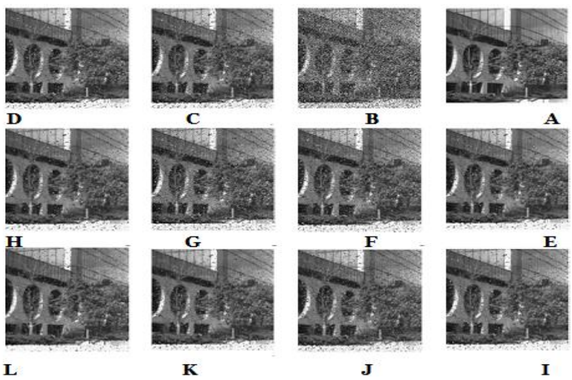

Figure 4. A) Main image of building B) image destructed by 40 % impulsive noise C) result of recovery using MED filter D) TSM E)MSM F) ERID G) DRID H) SAWMF I) Chen and Wu J)Zhang and Karim K)DWM L)suggested method

IV. CONCLUSIONS

This paper uses a two-step noise-removing method, at pre-processing step of which, the impulsive noise utilizes one noise-removing filter with two thresholds, and at the next step of which it utilizes one filter based on fuzzy rules. In this method, the central pixel can be a kind of noised, without noise, or edge-bound. If the central pixel is one without noise or edge-bound, it must be kept unchanged. However, if it is a noised pixel in a homogenous area, standard median filter replaces it. The other is a form wherein the noised pixel is in a detailed spot. This study presents a new method for the determination of line or edge direction. By use of this method, the impulsive noise may be removed from the image while at the same time the details of the image are maintained. Also, for future works, random directions can be figured out by this filter in a specific manner as only four directions have been defined for it. Therefore, it cannot be stated that random directions are kept unchanged in the suggested method.

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