Improved Fuzzy Certainty Degree Filter for Image Restoration

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ABSTRACT

The removal of impulse noise in images is an important research problem in image processing. In this paper, we propose a Fuzzy filter in two steps to restore corrupted images by salt and pepper noise. In the first step of the algorithm identifies the noise using the fuzzy certainty degree with the directional weighted difference, in the second step the noise pixel can be replaced by a weighted average of uncorrupted pixels. Experimental results show that the proposed algorithm is superior to the state of the art filters. The proposed method also shows to be robust to noise levels up to 90% while maintaining the main image details.

Keywords

Weighted average, certainty degree, fuzzy directional weighted difference, impulse noise.

1. INTRODUCTION

A digital image is an image having discrete amounts of intensity values. Images play the most important role in many aspects of human life including ultrasound, electron microscopy, television, computer tomography, astronomy, computer generated images, etc., where vision for humans is limited. It is well known that when the transmission and compression some aberration get introduced within images, as noisy which lead to bad results in the image processing. To maintain the originality of the given image, it must submit to the preprocessing.

Preprocessing methods are broadly divided into two categories: linear and nonlinear filters. Thus, the known linear filters are average filters, linear filters are acceptable if the noise is smaller than the smallest region of interest in an image, but the blurring of sharp edges is a serious drawback of these filters. To overcome the blurring effect of sharp edges in images nonlinear filters are introduced. Well, known nonlinear filters are the median filters.

The idea of a median filter is to replace the window pixel given by the median of the brightness in the window. After the weighted median change (WM) [Brovik, 2000] and central weighted median (CWM) [Ko and Lee, 1991] came into existence in which only the central pixel of the filter window has a weighting factor. These filters remove impulse noise well and do not blur the edges so much noise levels are 10% of the pixels of the image. The main disadvantage of the median filter is detrimental to fine lines, sharp corners in the image. All traditional median filtering approaches disturb image qualities because of following median filtering method i.e. to change pixel value whether it is corrupted or uncorrupted. To avoid this, noise detection mechanism was applied before filtering. For this, the switching median filters [Wang and Zhang, 1999] [Zhang and Karim, 2002] [eng and Ma, 2001] [Ng My 2006] included noise identification method that has been diagnosed corrupted pixel and replaced by Median while uncorrupted pixels remain unchanged. Non-linear filters with AMF [Hwang and Haddad 1995] were utilized for recognizing corrupted and uncorrupted pixels next the filtering approach was applied to avoid it a noise adaptive soft-switching median (NASM) filter was proposed in [Eng and Ma, 2001] was better than other techniques as it consists of the switching mechanism. Its performance achieves the result equivalent to ideal-switching median filter even in a wide range of noise densities from 10% to 70%. For noise density above that range recovered image significantly degraded. To overcome the performance degradation, an effective new method called boundary discriminative noise detection (BDND) [Ng and Ma, 2006] was presented and showed effects. BDND algorithm first classifies the pixels of a localized window of length 21x21, centering on the current pixel, and group the pixels into three different groups, lower intensity impulse noise, uncorrupted pixels, and higher intensity impulse noise. The second round is done on a window length is reduced by 3 × 3 with the same set of steps to reduce the pixel classification error. Steps to be taken more time than other algorithms, miss detection rate and false alarm rate were exhibited in a high noise density. For high noise density, it causes less correlation between the values of pixels corrupted and changed the median pixel values. Since it does not take into account local characteristics or patterns such as pixel edges, corners and edge detail were not recovered in case of high noise density noise. And also increased the computation time for implementation. [Srinivasan and Ebenezer 2007] recommended an efficient decision-based algorithm (EDBA) for impulse noise removal, it removes only corrupted pixel by the median value or by its neighboring pixel value. A 3x3 sized window is taken, if the pixel value is between 0 to 255 pixels then remains unchanged, but if the value is 0 or 255 and surrounding elements have the same value, that is the information, otherwise it is taken for the corruption of a pixel. The repeated replacement of neighborhood pixels produces the streaking effect. To address the problem of BDND cloud model filter was introduced [15].CM filter mainly used cloud model to identify corrupted pixels and replace it with the center weighted mean value. The main advantage of this filter is that it gives better performance than other switching filters in the image de-noising a wide range of noise levels. However, it is not preserving edge detail at the highest sound level. Recent progress in fuzzy systems allows different possibilities for developing the new image noise reduction methods. Under the classical fuzzy filters, we have a fuzzy median filter, the weighted fuzzy mean filter, the type-1 adaptive weighted fuzzy mean filter, and type-2 weighted fuzzy mean filters were introduced, these filters well suited for low-density impulse noise, however, they failed at high-density impulse noise. So as to triumph over the drawbacks of the above filters, a new fuzzy-based soft computing method with certainty degree (IFCDF) is introduced for disposing of impulse noise at a huge range of noise densities, especially for excessive impulse noise. The proposed technique reconstructs the image with less computational time and maintaining edge information examine with different existing filters.

2. IMPULSE NOISE MODELS

Two impulse noise models are used for the review of the implementation of the proposed method. Each model is described in detail below. Noise is demonstrated that salt and pepper noise where pixels arbitrarily reduced using the constant excessive values, 0 and 255 (for 8-bit image in gray scale) with the same possibility. That is, for each image pixel (i, j) with brightness $X(i, j)$, The relative brightness of the image will be noise, $Y(i, j)$ Wherein the probability density function of $Y(i, j)$ is

$$Y(i,j)=\begin{cases}\frac{P}{2}\ , for\ \ X(i,j)=0\\ 1-P,\ for\ X(i,j)\\ \frac{P}{2}\ , for\ \ X(i,j)=255\end{cases}$$

When the P is the noise probability density

Model 2: Noise Model 2 is as model 1, except that each pixel is probably called for help from the other noise "Pepper" (0) or "salt" noise unequal probabilities. It is

$$Y(i,j)=\begin{cases}\mathrm{P1}\ , for\ \ X(i,j)=0\\ 1-P,\ for\ X(i,j)\\ \mathrm{P2}\ , for\ \ X(i,j)=255\end{cases}$$

P = p1 + p2 is the noise density p1 and p2 ≠.

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3. IMPROVED FUZZY CERTAINTY DEGREE FILTER FOR IMAGE RESTORATION (IFCDF)

To conquer the disadvantage of traditional filters and advanced filters indicated in the introduction a new fuzzy-based soft computing method with certainty degree (IFCDF) has been proposed for high-density salt and pepper noise elimination. IFCDF is a fuzzy logic based filter that selects most effective pixels in the window integrates decided for the filtering process. The choice of uncorrupted pixels in a window is made based on Fuzzy Certainty Degree, therefore, the power of each noise detection and removal of corrupted pixels at the same stage in the filtering process has been included in IFCDF. It had been found from an experimental examination that the IFCDF filter is better than AMF, EDBA, and BDND and also offers higher results to both noise models discussed in phase 2.

BDND filter is one of the today's and superior switching median filters which outperform many of the existing noise removal strategies together with soft computing based strategies.

A major drawback of BDND filter is that the interior of the first noise detection step, it makes use of a filter size of 21 × 21 to identify whether a pixel is corrupted or not. The same detection technique is repeated in the 2nd level the new version, the use of a filter size 3 × 3 to bypass the misclassification of pixels, after these two levels, the filtering method can be implemented for the pixel corruption. This time consumption of BDND makes it less attractive.

The anticipated IFCDF is a significantly faster filter than BDND filter because it uses only one iteration step for detecting whether a pixel is corrupted or not, and it makes use of a fixed mask length of 7 × 7 for each detection and filtering section.

In IFCDF the first step is to choose whether a pixel is damaged or not. For this IFCDF makes use of the fuzzy certainty degree, fuzzy certainty degree define as

$$\mu\ (x_{i,j}) \leftarrow e^{-\frac{\left(x_{(i,j)}-\bar{X}\right)^2}{2\sigma^2}} \tag{1}$$

Where σ and $\bar{X}$ define as

$$\sigma\ \leftarrow \sqrt{\frac{\pi}{2}} \times \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}\left|x(i,j)-\bar{X}\right| \tag{2}$$

$$\bar{X} \leftarrow \frac{1}{mn}\sum_{i=1}^{m}\sum_{j}^{n}x(i,j) \tag{3}$$

The method gives the best results up to 50% noise levels. Noise levels above 60, it will give more false alarms and performance decreases. The execution is enhanced by applying the condition of the directionality on the filtering mask W along with fuzzy certainty degree. The proposed method focuses on the four main windows directions as shown in figure1.

Allow Dk (k = 1 to 4) represents the set of coordinates aligned with the direction centered at (0,0) on the size of filtering window 7.

D1 = [(- 3,3), (- 2,2), (- 1,1), (0,0), (1, -1), (2, -2), (3, -3)]
D2 = [(- 3.0) (- 2.0), (- 1,0), (0,0), (1,0), (2,0), (3,0)]
D3 = [(- 3, -3), (- 2, -2), (- 1, -1), (0,0), (1,1), (2,2), (3,3)]
D4 = [(0, -3), (0, -2), (0, -1), (0,0), (0,1), (0,2), (0,3)]

The Weighted difference of central pixel with other six pixels calculated in four directions as shown in the figure by giving the 2 power 2 and 2 power1 and 2 power 0 weights are assigned to four neighbors, 8-neighbours and for the reaming pixels.

1. *For every pixel* $x_{i,j}$ *image do*
2. *Get region R for image pixel* $x_{i,j}$ *by taking* $M = 4$

   $R_{i,j}^{M} = \left\{ r_{i+a,\, j+b} \;\middle|\; -M \le a,b \le M \right\}$
3. *Calculate the sample mean of the Region R, i.e.,*

   $\bar{X} = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} x(i,j)$
4. *Calculate the Entropy of the Region R, i.e.,*

   $\sigma = \sqrt{\frac{\pi}{2}} \times \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} \left| x(i,j) - \bar{X} \right|$
5. *Calculate the fuzzy membership of the processing pixel* $x_{i,j}$, *i.e.,*

   $\mu(x_{i,j}) \leftarrow e^{-\frac{\left(x_{(i,j)} - \bar{X}\right)^2}{2\sigma^2}}$
6. *if* $\mu(x_{i,j}) > T$ *then*

   $x_{i,j} = x_{i,j}$, *continue*
7. *else*
8. $x_{i,j}$ *is corrupted with impulse*

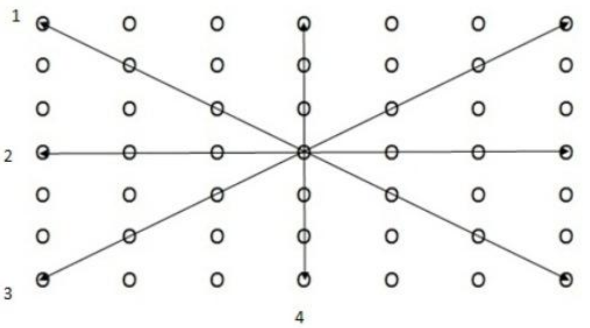

Fig.1an example of four directions for filtering the size of window 7.

And calculate the minimum directional weighted difference, calculate the maximum directional weighted difference and

R1 = minimum DWDI j = 1-4
R2 = maximum DWDI j = 1-4
R3 = R2-R1

The fuzzy rule can be defined for finding the central pixel is corrupted or not

If $\mu(r_{i,j}) > T1$ && *R3 > T 2* Then central pixel is not corrupted else corrupted.

Where T1 is the alpha value which is second minimum degree of certainty of R. T2 is the threshold valued defines as specified the 5[].Step 2 In IFCDF replaces the corrupted pixel with the weighted average of pixels not corrupted in the window. Certainty degree of each uncorrupted pixels is considered as a weight and averaged.

4. RESULTS AND DISCUSSION

The algorithm 1 apply alone it leads missed detections and false alarms in the following cases

Case1: If there is no noise in the window and the central pixel value is a minimum of the 49 then algorithm 1 leads to false alarm

Case2: If there is no noise in the window and the central pixel value is a second minimum value 49 Lena image Then algorithm 1 leads to false alarm

Case3: If the window containing the maximum number of zeros=9 and non-zero and 255s =2 and remaining 255 and central pixel is also 255 it may lead to missed detection

Case4: If the window containing the maximum number of zeros=9 and non-zero and 255s =2 and remaining 255 and central pixel is a non-impulse then it may lead to false alarm

Case5: If the window containing the maximum number of 255=9 and non-zero and 255s =2 and remaining 0 and central pixel is also 0 it may lead to missed detection

Case6: If the window containing the maximum number of 255=9 and non-zero and 255s =2 and remaining 0 and central pixel is a non impulse then it may lead to false alarm.

To overcome the above problems the weighted difference of central pixel with other six pixels calculated in four directions as shown in the figure by giving the 2^2, 2^1 and 2^0 weights are assigned to 4-neighbors, 8-neighbours and for the reaming pixels. And calculate the minimum directional weighted difference. To express the productivity of IFCDF on identifying impulse noise, we contrast our outcomes and three of the most illustrative strategies BDND, CM and AM [7, 11, and 15]. Expansive recreations are carried on two test images Lena, Mandrill. The bits per pixel of these images are 8 and the determination of them is the 256 x 256.In the relationship with different strategies "salt-and-pepper" noise show in which brightness value 0 speaks to "pepper" and 255 speaks to "salt", these noises are uniformly scattered over the entire image [11].To make IFCDF have the capacity to execute all in all image area, we amplify each of the four sides of the image through padding by ten pixels. Two thresholds T1 and T2 are individually set to second minimum certainty degree and 5 (expecting the force of the image has been normalized). The costing records we considered are the number of miss detections that indicates the quantity of noise being miss-distinguished and the number of false alarms that means the quantity of noise free pixels that are miss- distinguished noise pixel. To make the detection results more objective and more accurate, we repeat the noise adding and detection procedures 10 times independently for each noise density and take the average as the final results. From Table I and Table II we can notice that our proposed method generates very promising ZERO miss detection rates while maintaining a rather low false alarm rate. Repeat filtering procedure ten times and take the average of ten results to get more accurate results for each noise density. From Table I and Table II we can see that our proposed technique creates exceptionally encouraging ZERO miss location rates while keeping up a fairly low false alert rate. IFCDF filter a greater efficiency to determine impulse noise and corrupted pixels have much less chance to be omitted. It isn't always difficult to deduce that in the context of impulse noise containment false alarm detections are greater harmful than missed detections. The motive is living within the fact that if the noise pixels are omit-detected, they'll lose the chance of being restored. And by means of adopting right filtering scheme, those false detected pixels might not be drastically affected. From this point of view, our proposed approach has extraordinary superiority over the contemporary techniques and undoubtedly will offer a strong basis for next filtering stage. The PSNR values of the proposed method, CM, and BDND and AM filters for different images (“Lena”, “Mandrill) across 10% to 90% noise levels are shown in Table 3 and Table 4 and subjective visual comparison of the noise removal and perception of the image details for the test images “Lena”” are presented in Fig.1

METHODS | 70% DE-NOISED IMAGE | 80% DE-NOISED IMAGE | 90% DE-NOISED IMAGE

AM

CM

BDND

IFCDF

Fig 2: Different filters restoration Details . row1.row2,row3.and row4 are restored images of AM,CM,BDNDand IFCDF filters for the 70%,80%,90% corrupted Lena image respectively.

Table 1: Number of false alarms and detection Miss Lena free

	Missed detection (MD)			False alarm (FA)		
% Noise	BDND	CM	IFCDF	BDND	CM	IFCDF
20	0	0	0	8	0	0
40	0	0	0	15	0	0
60	0	0	0	12	0	0
80	120	0	0	20	0	0
90	224	0	0	13	0	0

Table 2: Number of false alarms and detection miss for mandrill picture

	Missed detection (MD)			False alarm (FA)		
% Noise	BDND	CM	IFCDF	BDND	CM	IFCDF
20	0	0	0	65	78	12
40	0	0	0	39	20	8
60	4	0	0	67	14	7
80	24	0	0	84	5	7
90	258	0	0	15	0	19

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Table 3. Comparison Restored Table Image Lena PSNR (in decibels)

FILTER/ NOISE%	10%	20%	30 %	40%	50%	60%	70%	80%	90%
IFCDF	40.47068	37.26748	34.85038	33.01774	31.42794	29.76594	28.07401	26.23267	23.9652
BDND	40.4991	37.9514	36.4084	34.9038	34.2485	32.4312	30.6886	28.6686	28.4377
CM FILTER	43.4523	41.5863	37.5493	36.8482	36.0495	35.1729	33.9073	32.4917	30.6802
AM	38.76	38.1838	37.4731	36.7071	35.7315	35.0049	34.1155	33.0138	31.2476

Table 4. Comparison Table Mandrel To The Restored Image PSNR (in decibels)

FILTER\ NOISE%	10%	20%	30 %	40%	50%	60%	70%	80%	90%
IFCDF	34.6923	31.7177	29.78307	28.09233	26.72251	25.31329	24.00687	22.66035	21.18229
BDND	34.185	33.8565	32.9203	32.4064	30.8991	29.1471	28.7744	28.1055	27.8875
CM FILTER	33.2353	32.8841	32.5419	32.0834	31.7522	31.2915	30.7103	30.0861	29.2608
AM	35.539	34.8771	34.1117	33.2632	32.5249	31.7346	30.943	30.2487	29.5419

5. CONCLUSION

In this article, precise and highly productive strategy for the recognition of impulse noise is proposed. Experimental results demonstrate that our technique is extraordinary ability to distinguish impulse noise and achieve zero Miss Detection rate while false discovery rate at a low level. Since the results of the discovery will be used to direct filtering conduction, which is the most important step in the switching filter system. IFCDF method is turned out to be better than existing methods. Widespread simulation effects show that the proposed detector's false alarm charge and miss detection rate are both amazingly low even when noise density is up to 90% and considerably outperforms current modern-day algorithms.

In future the algorithm may extend to the medical image processing and color image processing.

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