Multi Sensor Image Fusion For Impulse Noise Removal In Digital Images

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Abstract

The digital images are corrupted by impulse noise due to errors generated in camera sensors, analog-to-digital conversion and communication channels. Therefore it is necessary to remove impulse noise in-order to provide further processing such as edge detection, segmentation, pattern recognition etc. Filtering a noisy image, while preserving the image details is one of the most important issues in image processing. In this paper, we introduce an image fusion technique for impulse noise reduction, where the fused image will combine the uncorrupted pixels of the filtered noisy images obtained from different sensors. The image captured by different sensors undergoes iterative filtering algorithm, search for the noise-free pixels within a small neighborhood. The noisy pixel is then replaced with the value estimated from the noise-free pixels. The process continues iteratively until all noisy-pixels of the noisy image are filtered. The filtered images are fused in to a single image using a fusion algorithm by using the quality assessment of spatial domain. The experimental results show the proposed algorithm can perform significantly better in terms of noise suppression and detail preservation in images.

Keywords: Impulse Noise, Impulse Noise Removal, Image Processing.

1. INTRODUCTION

Digital images are often corrupted during acquisition, transmission or due to faulty memory locations in hardware [1]. The impulse noise can be caused by a camera due to the faulty nature of the sensor or during transmission of coded images in a noisy communication channel [2]. Consequently, some pixel intensities are altered while others remain noise free. The noise density (severity of the noise) varies depending on various factors

namely reflective surfaces, atmospheric variations, noisy communication channels and so on.In most image processing applications the images captured by different sensors are combined into a single image, which retains the important features of the Images from the individual sensors, this process is known as image fusion[3][4]. In this paper, the images captured by 'n' sensors are differently noised depending on the proximity to the object, environmental disturbances and sensor features. The noisy images are filtered using an iterative filtering algorithm, and finally the filtered images are fused into a single image using the quality assessment of spatial domain. The entire process of fusion is shown in figure 2.

Non-linear filters exhibit better performance as compared to linear filters [6][7][8] when restoring images corrupted by impulse noise. These techniques estimate noisy pixels taking into account all pixels within the window, without considering the status of (noisy/ noise-free) pixels. Consequently, the estimated noisy pixel value will not be accurate, degrading the quality of restored image.

In this paper, we use a new iterative filtering algorithm for removal of impulse noise in noisy images. The algorithm emphasis on the noise-free pixels within small neighborhood. First the pixels affected with noise are detected. If we did not find certain number of noise-free pixels within neighborhood, then the central pixel is left unchanged. Otherwise the noisy pixel is replaced with the value estimated from the noise-free pixels within neighborhood. The process iterates until all noisy pixels are estimated in the image. After that, the filtered images are fused into a single image. The main steps of the filtering algorithm are shown in figure 1.

The rest of the paper is organized as follows: Section 2 presents the impulse noise models in digital images, Section 3 presents the proposed iterative filtering algorithm, Section 4 presents Fusion using Quality Assessment of Spatial Domain, Section 5 presents the experimental results and finally Section 6 reports conclusion.

2. IMPULSE NOISE IN DIGITAL IMAGES

Impulse noise is independent and uncorrelated to the image pixels and is randomly distributed over the image. For an impulse noise corrupted image all the image pixels are not noisy, a number of image pixels will be noisy and the rest of pixels will be noise free. There are two types of impulse noise namely fixed value impulse noise and random valued impulse noise.

In salt and pepper type of noise, the noisy pixels takes either salt value (gray level -225) or pepper value (grey level -0) and it appears as black and white spots on the images [5]. In case of random valued impulse noise, noise can take any gray level value from zero to 225. Consider a corrupted image Y of size NxM, which containing the random valued / salt and pepper noise with probability p is mathematically represented in the form:

$$yij = \begin{cases} nij \text{ with probability } p \\ xij \text{ with probability } 1-p \end{cases}$$

$$y_{ij} = \begin{cases} n_{ij}\text{ ,zero or 255 with probability } p \\ x_{ij}\text{ ,with probability } 1-p \end{cases} \quad (1)$$

Where i=1,2,….,M and j=1,2,…..N and 0<p<1. y_{ij} represents the intensity of the pixel located at position (i, j). x_{ij} and n_{ij} denote the intensity of the pixel (i, j) in the original image and the noisy image respectively.

3. THE FILTERING ALGORITHM

The filtering algorithm is divided into three stages.

Stage 1: Construction Of Binary Image

[1] Let Y be the noisy image of size NXN of an object or scene captured by sensor.

[2] The noise boundaries of noisy image I are computed by spike detection technique [5]. Let L_1 and L_2 be the lower and upper noise boundaries for the noisy image.[3]The binary map (BM) of the noisy image is developed using the noise boundaries L_1 and L_2. If the image pixel 'y' lies within the noise boundaries, then it is uncorrupted and represented by a '0' in the binary map. The corrupted pixel is represented by a '1'in binary map.

$$BM = \begin{cases} \text{'0' if } L_1 < y < L_2 \\ \text{'1' if } y < L_1 \text{ or } y > L_2 \end{cases} \quad (2)$$

[3] Compute the noise density ND of the noisy image.

$$ND = \frac{\text{sum of '1's in BM}}{N*N} \quad (3)$$

The value of ND ranges from 0 to 1.

Stage 2: Noise Filtering Method

Consider a window of size q x q at each pixel location (i, j) of the noisy image Y and the binary image B. We prefer to use the value of q (=3), because the larger size window may not be too efficient and effective. Larger window may also remove the edges and fine image details. By applying small window of size 3x3, we obtain the noisy image patch $Y_{i,j}$ and the binary image path $B_{i,j}$.

For each iteration, we count the number of noisy pixels in the binary map B. If the value of count K is a positive integer and the central pixel y_{ij} within the 3X3 window is noisy, then the array R is populated with noise-free pixels. The maximum length of the array R is eight, indicating all the pixels are noise free. The minimum length is zero, shows that all the pixels in the window are noisy. Depending upon the noisy density in the window, the length of the array varies from zero to eight. We emphasize a constraint of minimum three noise-free pixels within the window, ie., the minimum length of the array R should be three. If this condition is satisfied, then we replace the central noisy pixel with the estimated value ie.,

$$g_{ij} = \begin{cases} e_s, \text{ if } b_{ij}=1 \text{ \&\& Length(R)} \geq 3 \\ y_{ij}\text{ , otherwise.} \end{cases} \quad (4)$$

Where e_s is the estimated value of the noisy pixel. Where e_s is the estimated value for the noisy pixel. Currently, we estimated the value of noisy pixels taking average from the noise-free pixels.

Stage 3: Update Noisy Image and Binary Image.

If the noisy pixel is estimated from the noise-free pixels within the window, the binary image B is also updated by changing the entries at the corresponding location of the image from "1" to "0". At the end of each iteration, we obtain a refined image G and updated binary image B. After a few iterations, depending upon the intensity of the salt-and-pepper noise, all entries in the binary image becomes zeros. The updating process terminated and we obtain a restored image G.

1. Take the initial noisy image Y.
2. Computation of binary map B
3. Compute the value of K that represent the noise-free
   pixels in B and assign Y→X
4. Check: If K=0, output resorted image X and stop.
   else
   i) Check if y_{ij} is noisy, then do
   ii) Fill the array R with noise-free pixels
   iii) Check if length of array R >3 , do
   iv) Update b_{ij} and x_{ij} using the value estimated from
   Noise-free pixels in R.
   v) Process each y_{ij} and get updated X and B
   vi) For the next iteration; assign X→Y and go to
   step 3.

Fig 1: Proposed Algorithm

4. IMAGE FUSION USING QUALITY ASSESSMENT OF SPATIAL DOMAIN

The algorithm for the multi-sensor image fusion using quality assessment of spatial domain is as follows:

The images captured by different sensors are filter using filtering algorithms. These filtered images are fused into a single image having all objects in focus without producing details that are non-existent in the given images. The algorithm consists of the following steps:

[1] Let I_1, I_2 ,......, I_n be the noisy images of an object or scene captured by sensors S_1,S_2 ,......,S_n respectively. Let Ii be of size NXN where i =1,2,…,n.

[2] Filter the noisy images using five different filtering algorithms. The filtered images are denoted as R_i .

[3] The recovered images R_i for i=1,2,..,n are divided into non-overlapping rectangular blocks (or regions) with size of mxn . The j^{th} image blocks of R_i are referred by R^i_j

[4] Quality assessment value (λ) of R^i_j is calculated and the results of R^i_j are denoted by λ^i_j.

Quality Assessment value λ is given by

$$\lambda=\lambda_1-\lambda_2$$

where

$$\lambda_1=\frac{1}{2}\left(trace(J)+\sqrt{trace(J)-4\det(J)}\right)$$

$$\lambda_2=\frac{1}{2}\left(trace(J)-\sqrt{trace(J)-4\det(J)}\right) \quad (5)$$

The covariance matrix of the gradient vectors for all b2 sites in this block is given by

$$J=\frac{1}{b^2}\sum_{s\in B} g_s^T g_s = \begin{bmatrix} j_{11} & j_{12} \\ j_{21} & j_{22} \end{bmatrix} \quad (6)$$

In order to determine the sharper image block, the quality assessment value of image blocks from 5 recovered images are sorted in descending order and the same ordering is associated with image blocks. The block with the maximum quality assessment is kept in the fused image. The fusion mechanism is represented as follows:

If λij is the quality assessment value of block R^i_j , the ordering of assessment values is given by

$$\lambda_{(1)} > \lambda_{(2)} > \ldots\ldots > \lambda_{(n)} \quad (7)$$

and this implies the same ordering to the corresponding blocks

$$R_{(1)} > R_{(2)} > \ldots > R_{(n)}$$

W here the subscripts are the ranks of the image blocks. Since the block with the largest quality assessment value is in the fused image, it will correspond to rank 1 of the ordered blocks ie;

$$\text{Fused Block} = R_{(1)} \quad (8)$$

5. EXPERIMENTAL RESULTS

The performance evaluation of filtering using image fusion method is tested on the true color remote sensing image with 290x290 pixels. The impulse noise is added into the image with different noise densities. Here we are assuming, n=2, ie; 2 sensors. The noisy image is processed using a iterative filtering algorithm based on the noise density in the image. These filtered images are fused into a single image using Quality Assessment of Spatial Domain. The experimental results are shown in Figure 3. Table (1) shows the results of PSNR values of fused image with different noise densities. We used the image quality metric, peak signal-to-noise ratio (PSNR), to measure the quality of the restored image. The PSNR measure is defined as

$PSNR=10\log10\frac{(255)^2}{MSE}$, Where MSE is the mean squared error between the original noise-free image and the restored image.

CONCLUSION

In this work, we propose a fusion algorithm for removal of impulse noise in digital images. The noisy images captured by 'n' sensors undergo filtering iteratively by replacing the noisy pixel with the value estimated from the noise-free pixels within the small neighborhood for the entire image. The filtered images are fused into a single image using the quality assessment of spatial domain .This scheme provides superior performance in removing the noise, while preserving the fine image details and edges.

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TABLE 1: Performance Comparison Corrupted With Various Noise Densities

ND(in percentage)	ND(in percentage)	Filtering and Fusion
10	14	29.9
20	24	28.3
30	32	28.1
40	46	27.6
50	54	27.5
60	67	27
70	78	26.7
80	84	25.8

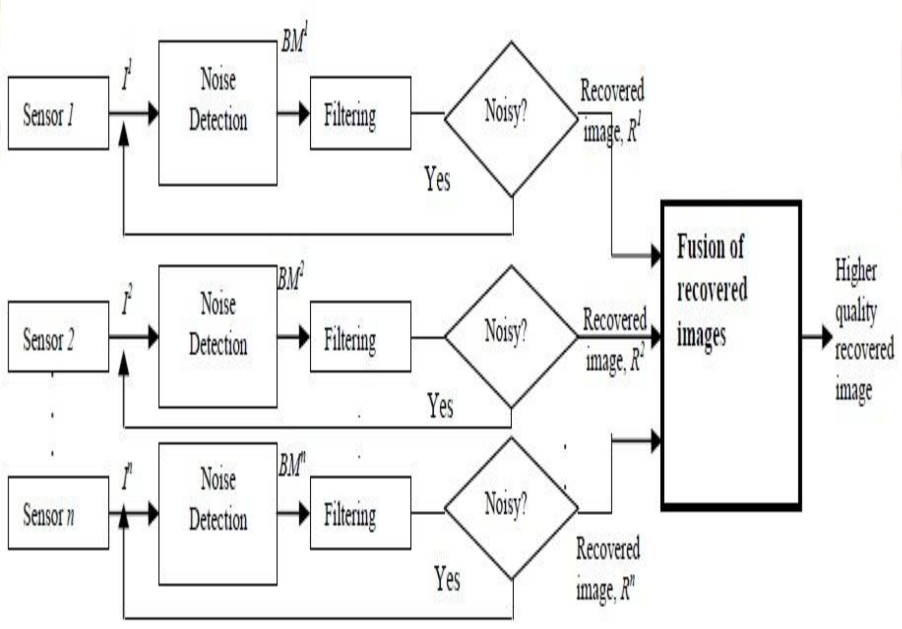


Fig.2. Block diagram of impulse denoising

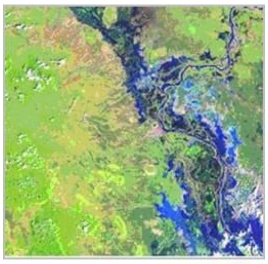
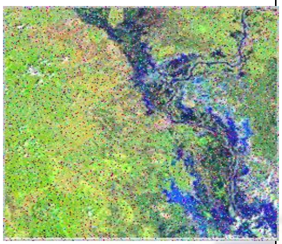
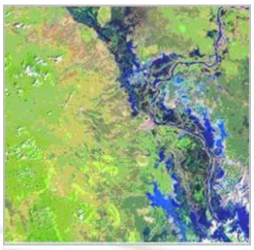
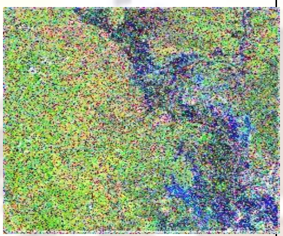
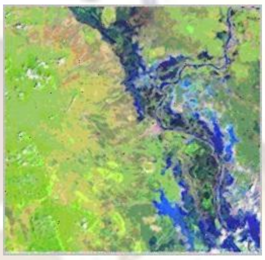
Original Image	20% Noisy Image	Filtered Image	Fused image
			
	40% Noisy Image	Filtered Image	
			

Fig3: Experimental results of proposed Image Fusion algorithm