Iterative Filtering Algorithm For Impulse Noise Removal In Digital Images

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Abstract: Any real world sensor is affected by a certain degree of noise. Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. There are different types of noises like Gaussian noise, impulse noise, uniform noise, Rayleigh noise etc. are added to the images when they captured by sensors or camera.. Impulse noise corruption is one of common problem in image processing. This noise causes dark pixels in bright regions and bright pixels in dark regions. Noise represents unwanted information which deteriorates image quality. 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 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. 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.

A wide variety of data acquisition devices are available present, and hence image fusion has become an Important sub-area of image processing. There are sensors which cannot generate images of all objects at various instances (from the sensor) with equal clarity (e.g. camera with finite depth of field, light optical microscope, etc.).has several images of a scene are captured, with focus on different parts of it. The acquired images are complementary in many ways and a single one of them is lot sufficient in terms of their respective information content. However, viewing a series of such image separately and individually is not very useful and convenient. The advantages of multi-focus data can be fully exploited by integrating the sharply focused regions been in the different images [1].

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.

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:

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

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

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 SPIKE DETECTION TECHNIQUE

1. Obtain the image histogram H of the corrupted image, X.
2. Compute the vector D which is the difference between adjacent locations in the histogram array H.
   $D_i = H_{i+1}-H_i$ for all i=0,1….255
3. Determine the index values in D corresponding to which positive and negative spikes occur in D. Lower index value (NLI) indicates the pixel level up to which the image is noised, and upper index value (NLII) indicates the pixel level from which the image is noised. Plot of vector D for Lena image corrupted with 95% (noise density(%)=impulse noise corrupted pixels/total number of pixels*100%) random impulse noise with dynamic range 0-44 and 211-255 is shown in figure. We can observe positive and negative peaks in this plot corresponding to the noise boundaries 44 (NLI) and 211 (NLII).

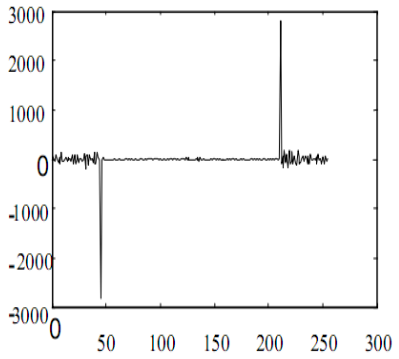

Figure 1: plot vector D

4. ITERATIVE FILTERING ALGORITHM

The filtering algorithm is as follows

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.

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

4. Compute the noise density ND of the noisy image.

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

The value of ND ranges from 0 to 1.

5. 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 $B_{i,j}$.

6. 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.

7. 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.,

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

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.

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8. 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.

5. IMAGE FUSION ALGORITHM

Given two (or more) images of a stationary camera, it is required to combine the images into a single one that has all objects in focus without producing details that are non-existent in the given images. Although the fusion algorithm can be extended straightforwardly to handle more than two source images, we only consider the fusing of two source images for simplicity. The algorithm consists of the following steps:

A. Partition the source images A and B into lattice of blocks of size b× b.Denote the ith blocks of A_i and B_i by and , respectively.

B. Compute the quality assessment value of each block in spatial domain, denote the quality assessment value of of A_i and B_i by λ_{Ai} and λ_{Bi} respectively.

C. Compare the quality assessment value of two corresponding blocks of A_i and B_i

If $\lambda_{Ai} > \lambda_{Bi}$, , then R_{Ai}=1 else R_{Bi}=1 , note that R_{Ai}=1 means the corresponding block in image B.

D. An alternative sequential filter formed by concatenating opening and closing with a small structuring element is applied on then R_{Ai} and R_{Bi}=1 to get the large connected regions. And the shape and size of structuring element depend on image content to some extent.

E. Construct the ith block of the fused image.

6. EXPERIMENTAL RESULTS

The performance evaluation of filtering using image fusion method is tested on the true color remote sensing image. 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 fusion algorithm. 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

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

7. CONCLUSION

In this work, we propose an fusion algorithm for removal of impulse noise in digital images. The noisy images captured by 2 or ‘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.

8. REFERENCES

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TABLE 1: Performance Comparison Corrupted With Various Noise Densities

Noise density added To image 1	Noise density added To image 2	PSNR VALUE
0.12	0.18	32.56
0.24	0.28	29.2
0.3	0.37	28.4
0.4	0.42	26.62
0.50	0.54	24.36
0.7	0.71	19.28

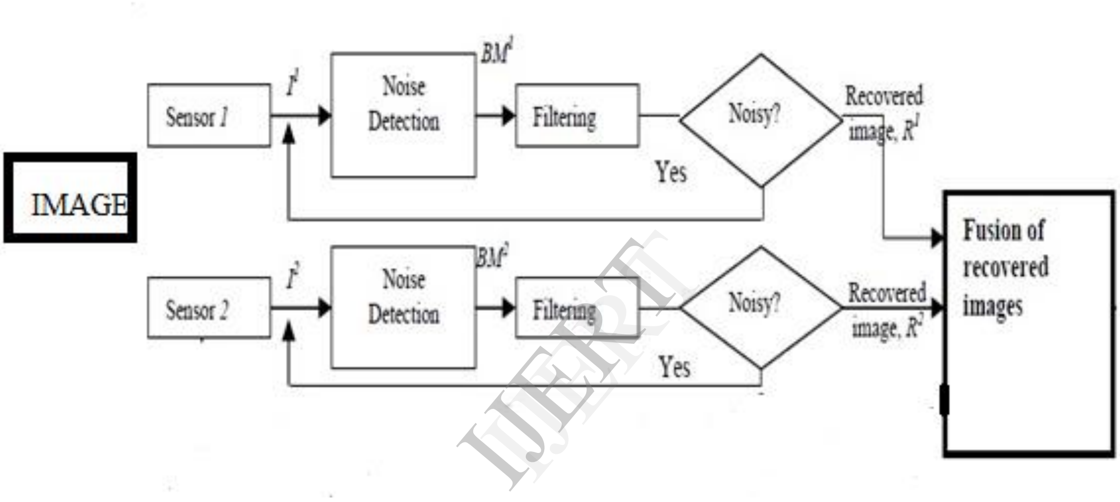

Figure 2: Iterative filtering algorithm