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A New Method of Image Fusion Technique for Impulse Noise Removal in Digital Images

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A NEW METHOD OF IMAGE FUSION TECHNIQUE FOR IMPULSE NOISE REMOVAL IN DIGITAL IMAGES

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A New Method of Image Fusion Technique for Impulse Noise Removal in Digital Images

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Abstract: Image fusion is the process of combining two or more images into a single image while retaining the important features of each image. Multiple image fusion is an important technique used in military, remote sensing and medical applications. This paper presents a new method of image fusion for impulse noise removal in digital images. The images are captured by five sensors and undergo filtering by five different filtering algorithms. These five de-noised images from five different filters are combined into a single image to obtain a high quality image compared to individually de-noised image. The performance of the Image Fusion is evaluated by using a reference image quality metric, Structural similarity Index (SSIM), to estimate how well the important information in the de-noised images is represented by the fused image. Experimental results show that the fused image has more quality than other filtered images.

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I. 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. The images captured by multiple sensors are differently noised depending on the proximity to the object, environmental disturbances and sensor features. In this paper, the images captured by five different sensors are filtered using five different non-linear filtering algorithms such as Standard Median Filter (SMF), Component Median Filter (CMF), Vector Median Filter (VMF), Spatial Median Filter (SMF) and Modified Spatial Median Filter (MSF), producing five de-noised images. These de-noised images are fused using our fusion technique, thus obtaining a high quality image.

This paper is organized as follows, Section II presents the impulse noise in images, Section III presents five different filtering algorithms, Section IV presents Image Fusion technique, Section V presents experimental results and the paper is concluded in Section VI.

II. Impulse Noise in Images

Impulse noise [3] corruption is very common in digital images. Impulse noise is always independent and uncorrelated to the image pixels and is randomly distributed over the image. There are different types of impulse noise namely salt and pepper type of 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. In case of random valued impulse noise, noise can take any gray level value from zero to 225. In this case also noise is randomly distributed over the entire image and probability of occurrence of any gray level value as noise will be same.

III. Filtering Algorithms

Order-static filters are nonlinear filters whose response is based on the ordering (ranking) the pixels contained in the image area encompassed by the filter, and then replacing the value of the center pixel with the value determined by the ranking result.

The **Median Filter** [8] as the name implies, replaces the value of the pixel by the median of the intensity values in the neighborhood of that pixel defined in (1). The pixel with the median magnitude is used to replace the pixel in the signal studied.

$$MEDIANFILTER(x_1,x_2,\ldots\ldots x_N) = MEDIAN(x_1,x_2,\ldots\ldots x_N) \qquad (1)$$

The median filter is more robust with respect to the presence of noise.

The **Component Median Filter** (CMF) [5], defined in (2), also relies on the statistical median concept. In the Simple Median Filter, each point in the

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signal is converted to a single magnitude. In the Component Median Filter, each scalar component is treated independently. A filter mask is placed over a point in the signal. For each component of each point under the mask, a single median component is determined. These components are then combined to form a new point, which is then used to represent the point in the signal studied.

$$CMF(x_1,x_2,\ldots x_N) = \begin{cases} MEDIAN(x_{1r},\ldots\ldots x_{Nr}) \\ MEDIAN(x_{1g},\ldots\ldots x_{Ng}) \\ MEDIAN(x_{1b},\ldots\ldots x_{Nb}) \end{cases} \quad (2)$$

In the **Vector Median Filter** (VMF) [6] for the ordering of the vectors in a particular kernel or mask a suitable distance measure is chosen. The vector pixels in the window are ordered on the basis of the sum of the distances between each vector pixel and the other vector pixels in the window.

The sum of the distances is arranged in the ascending order and then the same ordering is associated with the vector pixels. The vector pixel with the smallest sum of distances is the vector median pixel. The vector median filter is represented as

$$X_{VMF} = \text{vectormedian (window)} \quad (3)$$

If δ_i is the sum of the distances of the i^{th} vector pixel with all the other vectors in the kernel, then

$$\delta_i = \sum_{j=1}^{N} \Delta(X_i, X_j) \quad (4)$$

where ($1 \le i \le N$) and X_i and X_j are the vectors, N=9. $\Delta(X_i, X_j)$ is the distance measure given by the L_1 norm or the city block distance which is more suited to non correlated noise. The ordering may be illustrated as

$$\delta_1 \le \delta_2 \le \delta_3 \le, \ldots, \le \delta_9 \quad (5)$$

and this implies the same ordering to the corresponding vector pixels i.e.

$$X_{(1)} \le X_{(2)} \le, \ldots, \le X_{(9)} \quad (6)$$

where the subscripts are the ranks. Since the vector pixel with the smallest sum of distances is the vector median pixel, it will correspond to rank 1 of the ordered pixels, i.e,

$$X_{VMF} = X_{(1)} \quad (7)$$

The **Spatial Median Filter** (SMF) [5] is a uniform smoothing algorithm with the purpose of removing noise and fine points of image data while maintaining edges around larger shapes. The SMF is based on the spatial median quantile function which is a L_1 norm metric that measures the difference between two vectors. The spatial depth between a point and a set of points is defined by

$$S_{depth}(X,x_1,x_2,\ldots\ldots x_N) = 1 - \frac{1}{N-1}\left\|\sum_{i=1}^{N}\frac{X-xi}{\|X-xi\|}\right\| \quad (8)$$

Let $r_1,r_2,\ldots.r_N$ represent $x_1,x_2,\ldots..x_N$ in rank order such that

$$\begin{aligned} &\ge S_{depth}(r_1,x_1,x_2,\ldots\ldots x_N) \\ &\ge S_{depth}(r_2,x_1,x_2,\ldots\ldots x_N) \\ &\ge S_{depth}(r_N,x_1,x_2,\ldots\ldots x_N) \end{aligned} \quad (9)$$

and let r_c represent the center pixel under the mask. Then

$$SMF(x_1,x_2,\ldots\ldots x_N) = r_1 \quad (10)$$

In the **Modified Spatial Median Filter** (MSMF) [5], we first calculate the spatial depth of every point within the mask and then sort these spatial depths in descending order. After the spatial depth of each point within the mask is computed, an attempt is made to use this information to first decide if the mask's center point is an uncorrupted point. If the determination is made that a point is not corrupted, then the point will not be changed. If the point is corrupted, then the point is replaced with the point with the largest spatial depth.

We can prevent some of the smoothing by looking for the position of the center point in the spatial order statistic. Let us consider a parameter P (where $1 \le P \le N$, where N represents numbers of points in the mask), which represents the estimated number of original points under a mask of points. If the position of the center mask point appears within the first P ranks of the spatial order statistic, then we can argue that while the center point is not the best representative point of the mask, it is likely to be original data and should not be replaced. The MSMF is defined by

$$MSMF(T,x_1,x_2,\ldots\ldots x_N) = \begin{cases} r_c & c \le P \\ r_1 & c > P \end{cases} \quad (11)$$

IV. Image Fusion

Given five de-noised images, it is required to combine the images into a single one that has all objects without producing details that are non-existent in the given images. Here R^1 is median filtered image, R^2 is CMF filtered image, R^3 is the VMF filtered image, R^4 is the SMF filtered image, R^5 is the MSMF filtered image. The fusion algorithm consists of the following steps:

a. Input images R^i for i=1,2,..,5 are divided into non-overlapping rectangular blocks with size of mxn (10x10 blocks). The j^{th} image blocks of R^i are referred by R^i_j .
b. Variance (*VAR*) of R^i_j are calculated for determining the sharpness values of the

corresponding blocks and the results of R^i_j are denoted by VAR^i_j. *VAR* is defined as:

$$VAR = \frac{1}{m \times n} \sum_x \sum_y (f(x,y) - \bar{f}) \qquad (12)$$

Where $\bar{f}$ is the average grey level over the image.

$$\bar{f} = \frac{1}{m \times n} \sum_x \sum_y f(x,y) \qquad (13)$$

c. In order to determine the sharper image block, the variances of image blocks from five images are sorted in descending order and the same ordering is associated with image blocks. The block with the maximum variance is kept in the fused image. The fusion mechanism is represented as follows:
If $VAR_{(k)}$ is the variance of block R^i_j, where k denotes the rank, the ordering of variances is given by

$$VAR_{(1)} > VAR_{(2)} > VAR_{(3)} > VAR_{(4)} > VAR_{(5)} \qquad (14)$$

and this implies the same ordering to the corresponding blocks

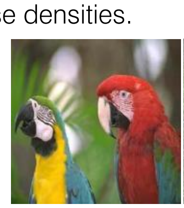
$$R_{(1)} > R_{(2)} > R_{(3)} > R_{(4)} > R_{(5)} \qquad (15)$$

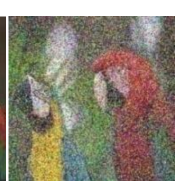
Where the subscripts are the ranks of the image blocks. Since the block with the smallest variance is in the fused image, it will correspond to rank 1 of the ordered blocks ie;

$$Fused\ Block = R_{(1)} \qquad (16)$$

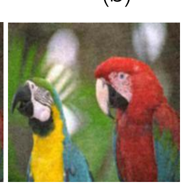
V. Experimental Results

The proposed method of image fusion for impulse noise reduction in images was tested on the true color parrot image with 290x290 pixels. The impulse noise is added into the image with noise density 0.4. The noisy image is processed using Median, CMF, VMF, SMF and MSMF filtering algorithms. The filtered images are fused into a single image using the Image fusion method. The experimental results are shown in Figure 1. Table (1) shows the results SSIM [7] values of individual de-noised images and fused image with different noise densities.


(a)


(b)


(c)


(d)


(e)


(f)


(g)


(h)

Figure 1 a) original image, b) impulse noise image corrupted by noise density 0.4, c) Median Filter d) component median filter e)VMF filtered image f) SMF filtered image, g) MSMF h) Fused image

Table 1: Performance Evaluation of Fusion Method

	ND 0.2 SSIM	ND 0.4 SSIM	ND 0.6 SSIM	ND 0.8 SSIM
VMF	0.821	0.714	0.586	0.4068
SMF	0.886	0.764	0.602	0.4324
Fused Image	0.9023	0.8109	0.6434	0.4671

ND-Noise Density

VI. Conclusion

This paper presents a new method of image fusion technique for removal of impulse noise in images. The images captured by sensors undergo filtering using VMF and SMF, and then the two individual de-noised images are fused to obtain a high quality image. The Quality of the images is evaluated using Structural Similarity Index (SSIM) with different noise densities. The proposed techniques are algorithmically simple and can be used for real time imaging applications.

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