Multi-Sensor Image Fusion for Impulse Noise Reduction in Digital Images

By M.Premakumar, N.Sowjanya, Dr.P.RajeshKumar

Andhra University

Abstract - This paper introduces the concept of Multi-sensor image fusion technique for impulse noise reduction in digital images. Image fusion is the process of combining two or more images into a single image while retaining the important features of each image. Multiple sensor image fusion is an important technique used in military, remote sensing and medical applications. The images captured by five different sensors undergo filtering using five different vector median filtering algorithms and the filtered images are fused into a single image, which combines the uncorrupted pixels from each one of the filtered image. The fusion algorithm is based on quality assessment of the spatial domain from the individual de-noised images. The performance evaluation of our algorithm is evaluated using PSNR between original image and individually filtered and the fused image. Experimental results show that this fusion algorithm produce a high quality image compared to individually de-noised images.

Keywords : *Image Fusion, Image Restoration, Image Processing, Impulse Noise.*

GJCST Classification : *I.4.3*

MULTI-SENSOR IMAGE FUSION FOR IMPULSE NOISE REDUCTION IN DIGITAL IMAGES

Strictly as per the compliance and regulations of:

Multi-Sensor Image Fusion for Impulse Noise Reduction in Digital Images

M.Premakumar [α], N.Sowjanya [Ω], Dr.P.RajeshKumar [β]

Abstract - This paper introduces the concept of Multi-sensor image fusion technique for impulse noise reduction in digital images. Image fusion is the process of combining two or more images into a single image while retaining the important features of each image. Multiple sensor image fusion is an important technique used in military, remote sensing and medical applications. The images captured by five different sensors undergo filtering using five different vector median filtering algorithms and the filtered images are fused into a single image, which combines the uncorrupted pixels from each one of the filtered image. The fusion algorithm is based on quality assessment of the spatial domain from the individual de-noised images. The performance evaluation of our algorithm is evaluated using PSNR between original image and individually filtered and the fused image. Experimental results show that this fusion algorithm produce a high quality image compared to individually de-noised images.

Keywords : *Image Fusion, Image Restoration, Image Processing, Impulse Noise.*

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[3][4]. In this paper, the images captured by multiple (five) sensors are differently noised depending on the proximity to the object, environmental disturbances and sensor features. These noise images are filtered using five different vector median filtering algorithms such as Vector Median Filter, Rank Conditioned Vector Median Filter, Rank Conditioning and Threshold Vector Median Filter, Center Weighted Vector Median Filter and Absolute Deviation Vector Median Filter. The filtered images are fused into a single image using the quality assessment of spatial domain

Author [α Ω] : Department of ECE, Sri Vishnu Engineering College for Women, Bhimavaram.
Author [β] : Associate professor, Department of ECE A.U. College of Engineering, Andhra University.

from the de-noised images, thus producing a high quality image. The performance evaluation of the image fusion is evaluated using PSNR between the original and fused image. This paper is organized as follows: Section II present the impulse noise in images, Section III present different filtering algorithms, Section IV present the image fusion algorithm, Section VI present experimental results and finally Section VII reports conclusion.

II. Impulse Noise in Images

Impulse noise [5] 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. Hence unlike Gaussian noise, 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 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. If p is the total noise density then salt noise and pepper noise will have a noise density of $p/2$. This can be mathematically represented by (1)

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

Where y_{ij} represents the noisy image pixel, p is the total noise density of impulse noise and xij is the uncorrupted image pixel.

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. We can mathematically represent random valued impulse noise as in (2).

$$y_{ij} = \begin{cases} n_{ij}\ with\ probability\ p \\ x_{ij}\ with\ probability\ 1\text{-}p \end{cases} \qquad (2)$$

Where n_{ij} is the gray level value of the noisy pixel.

III. Fltering Algorithms

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

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

If δ_i is the sum of the distances of the ith vector pixel with all the other vectors in the kernel, then

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

where $(1 \leq i \leq N)$ 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

$$\delta_1 \leq \delta_2 \leq \delta_3 \leq ..., \leq \delta \qquad (5)$$

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

$$X_{(1)} \leq X_{(2)} \leq ..., \leq X_{(9)} \qquad (6)$$

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.,

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

The *Rank Conditioned Vector Median Filter* [7] improves the performance of the vector median filter. The vector median of the kernel replaces the central pixel when the rank of the central pixel is greater than a predefined rank of a healthy vector pixel inside the window. The rank of the healthy vector pixel is obtained by simulating RCVMF codeon a noiseless image. Then, the mean value of the obtained ranks of the central vector pixel is calculated. This value is rounded off to a whole number, and it is considered to be rank of the healthy vector pixel of a kernel.The rank conditioned vector median filter can be expressed as:

$$
\begin{aligned}
X_{RCVMF} &= X_{VMF}, &&\text{if } r_c > r_k \\
&= X_C &&\text{otherwise}
\end{aligned}
\qquad (8)
$$

Where r_c is a rank of the central vector pixel and c=5.and r_k is the predefined healthy vector pixel rank inside the window.

The **Rank-Conditioned and Threshold Vector Median Filter** [8] aims to further enhance the RCVMF by incorporating an additional test – a distance threshold for the detection of impulses. In RCVMF, a central vector having greater than the predefined rank implies a corrupt vector. However, it may not be true always, because the vectors may be close as per the distance measure. Hence another criterion Θ, is taken into account. It is the distance between the central vector pixel and the vector pixel corresponding to the predefined rank. To find out the value of this pre-determined distance threshold Θ, the code simulating RCTVMF is executed on a noiseless image. Then the mean of the obtained θ values is calculated and used for the simulations at various noise percentages. The distance is calculated as follows :

$$D = \Delta(X_c, X_{(k)}) \qquad (9)$$

Where X_c is the central vector and $X_{(k)}$ ($1 < k < 9$) is a rank ordered and healthy vector pixel inside the window. On the basis of the above information, the filter has the following form :

$$
\begin{aligned}
X_{RCTVMF} &= X_{VMF}, &&\text{if } r_c > r_k \text{ and } D > \Theta \\
&= X_c &&\text{otherwise}
\end{aligned}
$$

In **Center Weighted Median Filter** [8] the kernel vector pixels are assigned some non negative values called weights. The central vector pixel is assigned a non negative weight while the weight of the neighboring pixels is kept unity. The weights denote the number of copies is obtained. The output Y (say), of a weighted median filter of span N (where N generally denotes the kernel size, $N=9$) associated with N integer weights,

$$W = [W_1.W_2.....W_N] \qquad (10)$$

is given by ,

$$Y = \textit{vectormedian } [W_1*X_1, W_2*X_2, ..., W_9*X_9]$$

Where the vectormedian [.] denotes the vector median operation.

In **Absolute Deviation Vector Median Filter** [9], the impulse noise detection mechanism does not require the distance calculation and subsequent ordering of the vectors of a kernel. The algorithm deals with the difference values of the red (R) and the green (G) intensities denoted by Ω_{RGi} (say), and the difference values of the green (G) and blue (B) intensities denoted by Ω_{GBi} (say), (where $1 \leq i \leq N$, $N=9$).

In a 3×3 kernel, it has been observed empirically that Ω_{RGi} and Ω_{GBi} values closely correspond to each other. Thus the mean absolute deviation $\mathbf{D'}_{RG}$ and $\mathbf{D'}_{GB}$ i.e. the mean of $\mathbf{D}_{RGj}$ and $\mathbf{D}_{GBj}$ (where $1 \leq j \leq N$, and $j \neq c$, $c = (N+1)/2$, $N = 9$) has small values. $\mathbf{D}_{RGj}$ and $\mathbf{D}_{GBj}$ are the absolute deviation values of Ω_{RGj} and Ω_{GBj} from Ω'_{RG} and Ω'_{GB} respectively. Ω'_{RG} and Ω'_{GB} denote the mean of Ω_{RGj} and Ω_{GBj} (where $1 \leq j \leq N$, and $j \neq c$, $c = (N+1)/2$, $N = 9$).

The absolute deviation of the central vector Ω_{RGc} and Ω_{GBc} values from Ω'_{RG} and Ω'_{GB} is obtained respectively as $\mathbf{D}_{RGc}$ and $\mathbf{D}_{GBc}$.

If the absolute deviation $\mathbf{D}_{RGc}$ and $\mathbf{D}_{GBc}$ of the central vector pixel exceeds the value of $\mathbf{D'}_{RG}$ or $\mathbf{D'}_{GB}$ respectively for a 3X3 kernal, the central vector pixel is to be replaced by the vector median of the kernel. The algorithm is represented as follows.

In a 3X3 kernel,

Step 1: Find the difference values of red(R) and green(G) intensities denoted by Δ_{RGi} and the difference values of the green(G) and blue(B) intensities denoted by Δ_{GBi} .

$$\Delta_{RGi} = X(i, R) - X(i,G)$$
$$\Delta_{GBi} = X(i,G) - X(i,B) \qquad \text{Where } i= 1\ldots9 \qquad (11)$$

Step 2: Calculate the mean of Δ_{RGi} and Δ_{GBi} denoted by Δ^1_{RGi} and Δ^1_{GBi}. Where i=1,2…9 and i≠5.
Step 3: Calculate the absolute deviation between Δ and Δ^1.

$$D_{RGi} = | \Delta_{RGi} - \Delta^1_{RGi} |$$
$$D_{GBi} = | \Delta_{GBi} - \Delta^1_{GBi} | \quad \text{where i= 1,2,…9} \qquad (12)$$

Step 4 : Calculate the mean of D_{RGi} and D_{GBi} denoted as D^1_{RGi} and D^1_{GBi}. where i=1,2….9 and i≠5.

Step 5 : Now

$$D_{RGc} = | \Delta_{RGc} - \Delta^1_{RGi} |$$
$$D_{GBc} = | \Delta_{GBc} - \Delta^1_{GBi} | \qquad \text{where i= 1,2,…9, i≠ 5}$$
and c is the central vector . $\qquad (13)$

Step 6 : If $D_{RGc} > D^1_{RGi}$ or $D_{GBc} > D^1_{GBi}$ where i=1,2…9 and i≠5. central vector is corrupted, hence central vector is replaced by Vector Median of kernel.

IV. Image Fusion Algorithm

The block diagram for multi-sensor image fusion is shown in figure 1. 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 five different filtering algorithms. These five 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 $I^1, I^2,\ldots, I^5$ be the noisy images of an object or scene captured by sensors $S^1, S^2 ,\ldots, S^5$ respectively. Let I^i be of size *NXN* where $i =1,2,\ldots,5$.
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 $i=1,2,..,5$ are divided into non-overlapping rectangular blocks (or regions) with size of *mxn* . The jth image blocks of $\mathbf{R}^i$ 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 λ^i_j.

Quality Assessment value λ is given by

$$\lambda = \lambda_1 - \lambda_2 \qquad (14)$$

where

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

$$\lambda_2 = \frac{1}{2}\left(trace(J) - \sqrt{trace(J) - 4\det(J)}\right) \qquad (15)$$

The covariance matrix of the gradient vectors for all b^2 sites in this block is given by

$$J = \frac{1}{b^2}\sum_{s\in B}g_s^T g_s = \begin{bmatrix} j_{11} & j_{12} \\ j_{21} & j_{22} \end{bmatrix} \qquad (16)$$

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

$$\lambda_{(1)} > \lambda_{(2)} > \ldots\ldots > \lambda_{(5)} \qquad (17)$$

and this implies the same ordering to the corresponding blocks

$$R_{(1)} > R_{(2)} > \ldots > R_{(5)}$$

Where 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;

$$\textit{Fused Block} = R_{(1)} \qquad (18)$$

V. Experimental Results

The proposed method of image fusion for impulse noise reduction in images was tested on the true color remote sensing image with 290x290 pixels. The images are captured by five different sensors with different noise densities. The noisy images are filtered using five different vector median filtering algorithms. The filtered images are fused into a single image using the Image fusion method based on the quality assessment in spatial domain.. The experimental results are shown in Figure 2. Table (1) shows the PSNR value of fused image with different noise densities of input images with respect to original image.

VI. Conclusion

This paper presents the multi-sensor image fusion method for impulse noise reduction in digital images. This technique can be used in military, remote sensing and medical applications. The experimental results show that our fusion algorithm works better in removal of impulse noise in digital images. The proposed method is simple and can be used for realtime imaging applications.

References References Referencias

1. Tao Chen, Kai-Kaung Ma and Li-Hui Chen, "Tri-state median filter for image Denoising", IEEE Transactions on Image Processing, Vol 8, no.12, pp.1834-1838, December 1999.
2. Reihard Berstein," Adaptive nonlinear filters for simultaneous removal of different kinds of noise in images," IEEE Trans on circuits and systems , Vol.cas-34, no 11,pp.127-1291, Nivember 1987.
3. O.Rockinger," Image sequence fusion using ashift invariant wavelet transform," IEEE transactions on image processing, 3:288- 291, 1997.
4. Chaveli Ramesh and T.ranjith, "Fusion performance measures and a lifting wavelet transform based algorithm for image fusion", In Proc. 5th International conference on image fusion, july 2002,pp 317-320.
5. S.Indu, Chaveli Ramesh, " A noise fading technique for images corrupted with impulse noise", Proceedings of ICCTA07, IEEE.
6. J.Astola, P.Haavisto and Y.Neuro," Vector Median Filters", Proc. of IEEE, vol. 78. No.4. pp. 687-689, April 1990.
7. LL. Alparone, S. Baronti and R. Carla, "Express Letters - Two- Dimensional Rank-Conditioned Median Filter," IEEE Trans. On Circuits and Systems-II: Analog and Digital Signal Processing, vol. 42, no. 2, pp. 130- 132 , February 1995.
8. K. M. Singh and P. K. Bora, "Adaptive Vector Median Filter for Removal Impulses from Color Images," Proc. of Int.Symposium on Circuits and Systems, vol. 2, pp. II-396 - II-399, May 2003.
9. R.H.Laskar, B.Bhoowmick, R.Biswas and S.Kar, " Removal of Impulse Noise from Color Image", TENCON IEEE 2009.

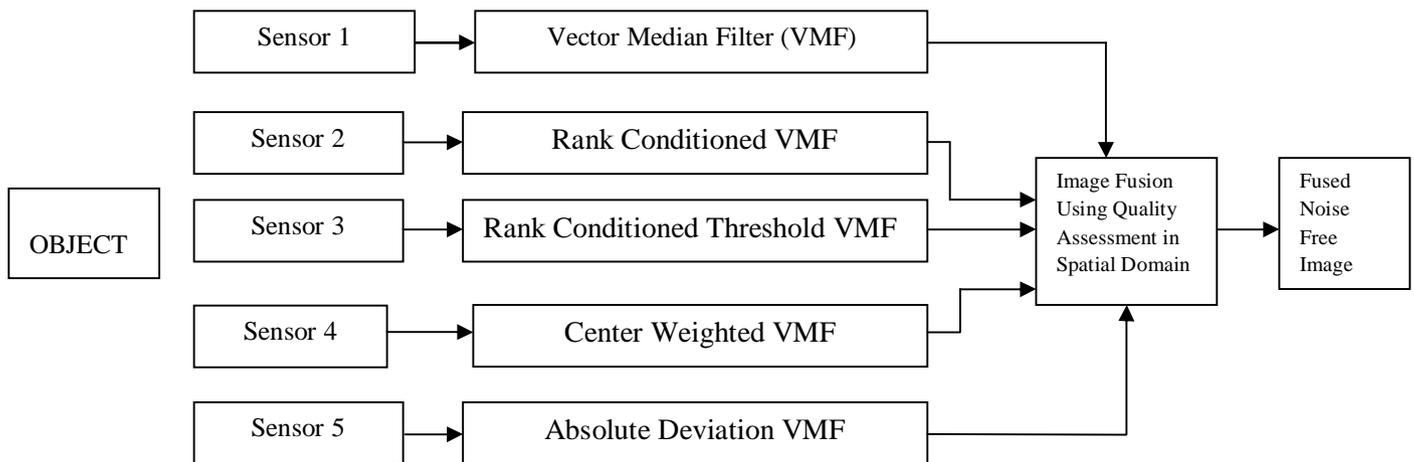Block Diagram of Multi Sensor Image Fusion :

Figure 1 : Block Diagram of multisensor Image fusion

Multi sensor Image Fusion:
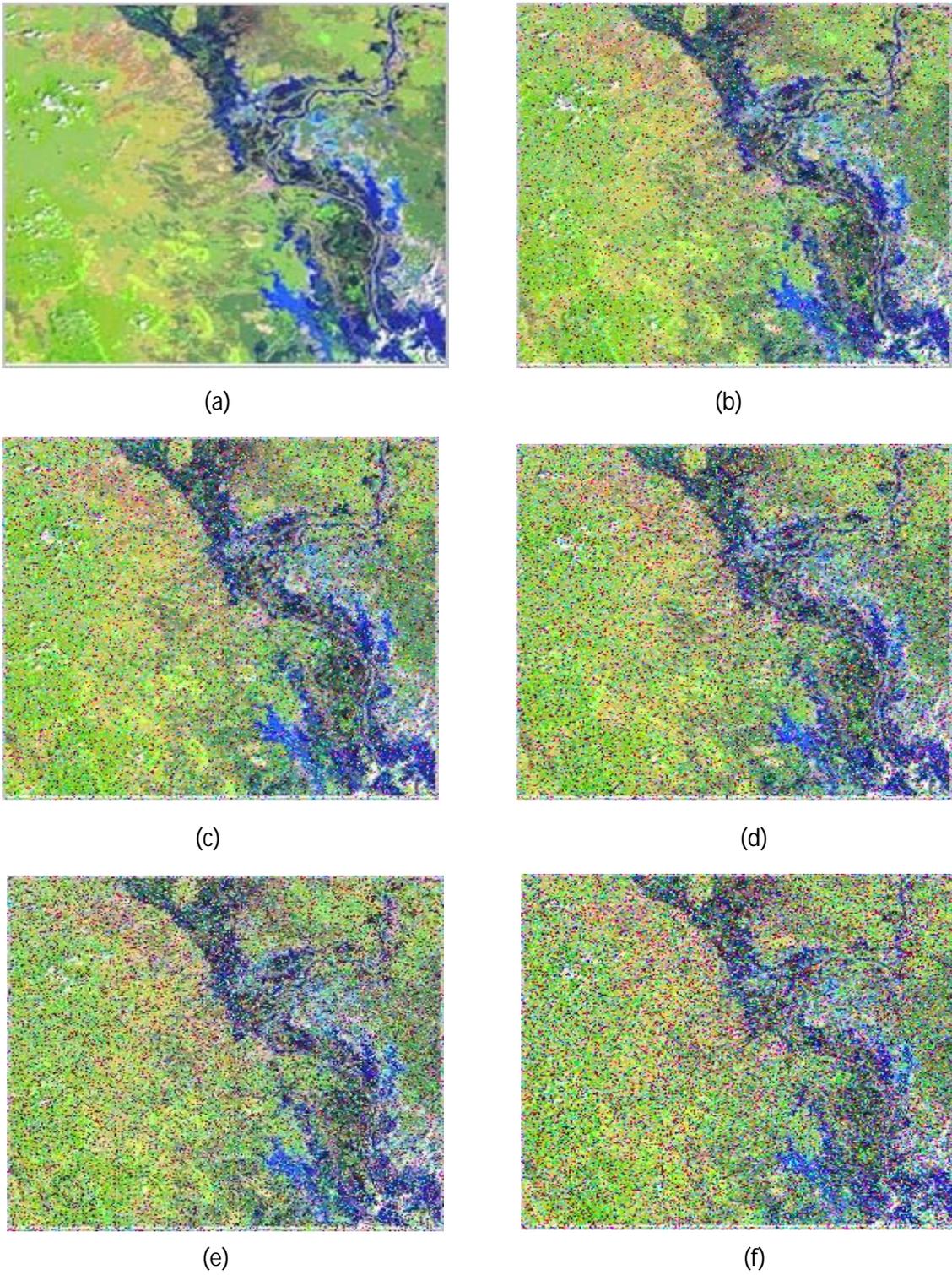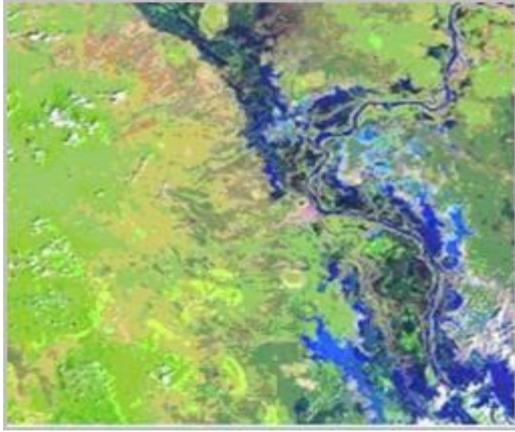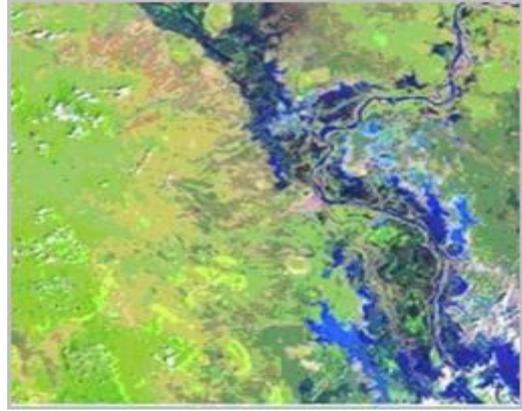

(a)

(b)

(c)

(d)

(e)

(f)

Figure 2(a) : River Image captured by five sensors with impulse noise. (a) Original Image (b) 10% Noise (c) 15% Noise (d) 20% Noise (e) 25% Noise (f)30% Noise
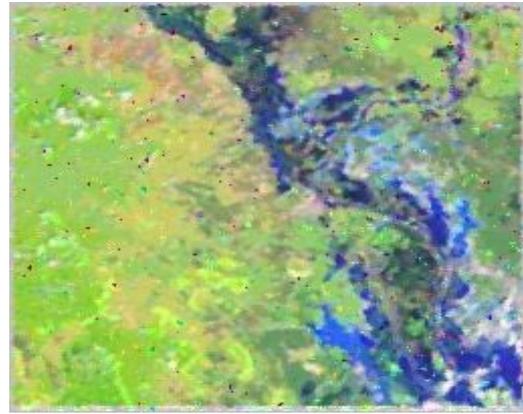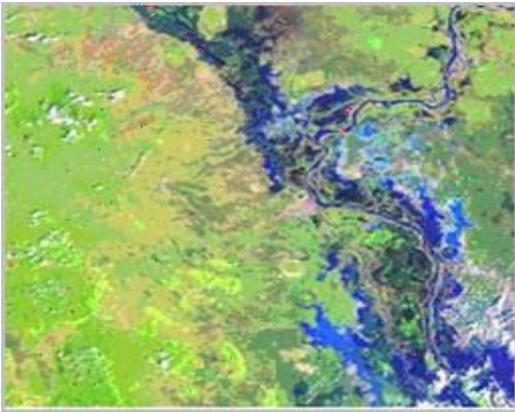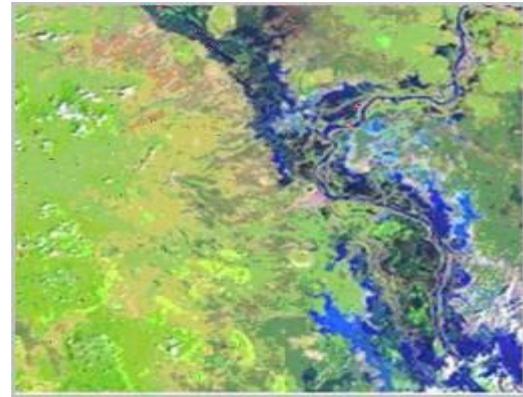
34

(a)

(b)

(c)

(d)

(e)

(f)

Figure 2(b) : Images filtered by different Filters. (a) Vector Median Filter (b) Rank conditioned Vector Median Filter (c) Rank conditioned & threshold Vector Median Filter (d) Center weighted Vector Median Filter (e) Absolute Deviation Vector Median Filter (f) Fused Image

Table 1: comparison of performance of the different filters and fused image with respect to original image.

Noise %	Filter	PSNR
10	Vector median filter(VMF)	31.25
15	Rank conditioned VMF	30.522
20	Rank conditioned & threshold VMF	27.961
25	Center weighted VMF	22.73
30	Absolute deviation VMF	29.46
	Fused Image	33.6