INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Removal of Noises from Images by Improved Median Filter & Analysis of FCM Algorithm

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Abstract:
In different types of images there are different types noises are present such as impulse noise, speckle noise, position noise. Out of which impulse noise is a basic noise, which present in medical image as well as in binary and gray images and it brings blurring in the image, edges being distorted, and poor quality. The impulse noise is very hazardous to medical images so that reduction of such noise from images is major issue. For elimination of impulse noise many linear and non linear filters are used. But linear filters blur the image. Therefore noise reduction method by means of improved median filter is proposed. Clustering performance of FCM algorithm on different median filters is analysed. The performance and results obtained by proposed method are compared with standard median filter, Adaptive median filter, hybrid median filter & relaxed median filter.

Key words: *Improved median filter, Standard median filter, Adaptive median filter (AMF), Impulse noise, Relaxed median filter, Clustering, Hybrid median filters*

1. Introduction

Digital images are normally corrupted by many types of noises, including impulse noise. Impulse noise with a low noise percentage can change the appearance of the image significantly. The impulse noise which is a set of random pixels normally has a very high contrast to its surrounding. Impulse noise is also called as Salt and Pepper noise which take only the maximum and minimum values in the dynamic range (0,255) and occurs impulsively at pixel positions. The intensity of impulse noise has the tendency of being either relatively high or relatively low. Thus it severely degrades the image quality and cause great loss of information details. So it is important to eliminate noise in the images before some subsequent processing, such as edge detection, image segmentation and object recognition. . Like gray and binary images Medical images are more vulnerable to noises particularly impulse noise which is introduced during image acquisition, transmission and storage. Removing noises is highly complex because we have to keep balance between the improvement and the introduced degradation by a particular filter .When we consider the medical images then image segmentation plays an important role in analysis and application of medical images.

Median filter provides better performance only at lower noise densities but for high noise density they cannot perform well. For that purpose different modifications are done in median filters. Relaxed median filter (RMF) provides better noise removal and detail preservation but results in blurring at high noise densities. Hybrid median filter (HMF) uses diagonal neighborhood evaluation for de-noising, but does not perform well at low noise densities.

Image segmentation plays an important role in the analysis and applications of medical image processing. The main purpose of medical image segmentation is to extract interesting regions which contain important diagnostic information for clinical diagnosis and pathology research. Many image segmentation techniques are used such as thresholding, region growing, edge detection and clustering. Among the statistical clustering algorithms, Fuzzy C-Means (FCM) clustering is most popular for medical image segmentation because of its robustness. A conventional FCM does not use spatial information in the image. Its advantages include a straightforward implementation, fairly robust behaviour, applicability to multichannel data, and the ability to model uncertainty within the data. A major disadvantage of its use in imaging applications, however, is that FCM does not incorporate information about spatial context, causing it to be sensitive to noise.

2. Filtering Methods

2.1. Standard Median Filter

The main idea of the median filter is to run through the signal entry by entry, replacing each entry with the median of neighbouring entries. This provides very good noise removal but results in loss of fine details. The small filtering window leads to poor elimination of noise and big one leads to loss of fine details [3]. The standard median filter is given by

- $f(x,y) = \underset{(s,t)\,\varepsilon s_{xy}}{\text{median}} \{ g(s,t) \}$

Where (*x, y*) are the coordinates of the pixel located at the center of the contextual region *Sxy,* and (*s,t*) are the coordinates of the pixels belong to that region.

2.2. Adaptive Median Filter

The noise elimination performance is greatly affected by the size of the filtering window when the standard median filter algorithm is used. That is when the filtering window is small, the image detail can be preserved relatively well while noise filtering capability is poor; on the Contrary when the window is large noise restraint can be enhanced but image will blur. Therefore in order to combine the advantages of filtering performance in both cases the adaptive median filter is developed which adaptively changes its window size. This filter uses adaptively altered window size to detect noise pixels so the fine details are highly preserved and at the same time noise pixels also contribute in sorting the pixels in the window.

- $Y(n) = MED(x_{1,\dots\dots} x_{c-1}, x_{c<>} w_c, x_{c+1,\dots\dots} x_N)$

Where $x_{c<>}w_{c,}$ denotes the replication operator. $X_{c<>}\, w_{c=}.\ x_{c,}\ .\ x_{c\dots\dots}\ x_c(w_c$ times).and $N=(N+1)/2 = N_1+1$ is index of center sample. w_c is odd positive integer.

2.3. Hybrid Median Filter

In this filter, three median values are calculated in the N x N window: MR is the median of horizontal and vertical R pixels, and MD is the median of diagonal D pixels. The hybrid median value is the median of the two median values and the central pixel DCR [3]. For N=5;

$$\begin{bmatrix} D & * & R & * & D \\ * & D & R & D & * \\ R & R & DCR & R & R \\ * & D & R & D & * \\ D & * & R & * & D \end{bmatrix}$$

- MD = median{D pixels & DCR};
- MR = median{ R pixels & DCR };
- Let Xij and Yij be the input and the output at location (i,j) respectively, then the hybrid median filter is given by
- Yij = medianij {MR, MD, DCR} ;

2.4. Relaxed Median Filter

Let $\{x_i\}$ be m dimensional sequence where the index I ε Z_m .A sliding window is defined as subset W ε Zm of odd size 2N+1.W is sliding window $W_i=\{X_{i+r}\}$,rεW to be located at position i. Lower (l)
and Upper (u) bounds, define a sublist inside the [Wi](.), which contains the gray levels which are good enough not to be impulse noise. If the input belongs to the sub list, then it remains unfiltered, otherwise the standard median filter is output. Let m = N + 1 and l, u such that $1 \le l \le m \le u \le 2N + 1$. The relaxed median filter with bounds l and u is defined as
Yi = Relaxed median {Wi }

$$\begin{cases} X_i & \text{if } X_i\ \varepsilon\ [[W_i]_l, [W_i]_u]; \\ [W_i]_m & \text{otherwise} \end{cases}$$

Where [Wi] (m) is the median value of the samples inside the window Wi.

3. Proposed Method

3.1. Iterative Relaxed Median Filter (IRMF)

Relaxed median filter results in better noise removal with respect to other median filtering methods. Performance of this filter can be improved further by doing iterative filtering of the input image [9].
Iterative relaxed median filter algorithm is given as follows:

- Peak signal to noise ratio is calculated between filtered image and the original image.
- Filtered image is subjected to filtering again.
- PSNR is calculated for the new filtered image.
- Check the following condition

[PSNR (i) - PSNR (i - 1)) < Min (diff)

If the condition is satisfied, stop otherwise repeat steps 3-4. Where PSNR (i) is peak signal to noise ratio between newly filtered image and the original image.

3.2. Simulation Steps

- For MR brain image corrupted by impulse noise of different probability densities, apply median filtering methods by considering a window of size (mxn).
- Replace each pixel value by its spatially modified and filtered value and apply FCM algorithm.
- Calculate PSNR and MAE.

3.3. FCM Algorithm Steps

- **Step 1 :** Initialize membership $U^{(0)} = [\, u_{ij} \,]$ for data point g_i of cluster cl_j by random
- **Step 2 :** At the *k*-th step, compute the fuzzy centroid $C^{(k)} = [\, c_j \,]$ for $j = 1, .., nc$, where *nc* is the number of clusters, using

$$c_j = \frac{\sum_{i=1}^{n} (u_{ij})^m x_i}{\sum_{i=1}^{n} (u_{ij})^m}$$

Where *m* is the fuzzy parameter and *n* is the number of data points & x_i be a vector of values for data point g_i.

- **Step 3 :** Update the fuzzy membership $U^{(k)} = [\, u_{ij} \,]$, using

$$u_{ij} = \frac{\left(\frac{1}{\left\| x_i - c_j \right\|}\right)^{\frac{1}{(m-1)}}}{\sum_{j=1}^{n_c} \left(\frac{1}{\left\| x_i - c_j \right\|}\right)^{\frac{1}{(m-1)}}}$$

- **Step 4:** If $\| U^{(k)} - U^{(k-1)} \| < \varepsilon$, then STOP, else return to step 2.
- **Step 5 :** Determine membership cutoff

For each data point g_i, assign g_i to cluster cl_j if u_{ij} of $U^{(k)} > \alpha$

4. Validity Functions

4.1. Validity Functions for Noise Removal

Peak signal to noise ratio mean absolute error are used for analysis

$$PSNR = 20 \log_{10}\left(\frac{255}{RMSE}\right)$$

4.2. Validity Function for Clustering

Quality of a partition provided by clustering algorithms is evaluated by a function called cluster validity index.

4.3. Partition Coefficient (PC)

It measures the amount of "overlapping" between clusters. The disadvantage of PC is lack of direct connection to some property of the data themselves. The optimal number of cluster is at the maximum value.

$$PC = \frac{1}{N}\sum_{i=1}^{c}\sum_{j=1}^{N} {u_{ij}}^{2}$$

Where uij is the membership of data point *j* in cluster *i*

4.4. Partition Entropy (Vpe)

It is the mean ratio between the sum of central members (sum of membership degrees for the data close to the centroids) of each cluster and the volume of the cluster

$$PE = -\frac{1}{N}\sum_{i-1}^{c}\sum_{j-1}^{N} u_{ij}\log u_{ij}$$

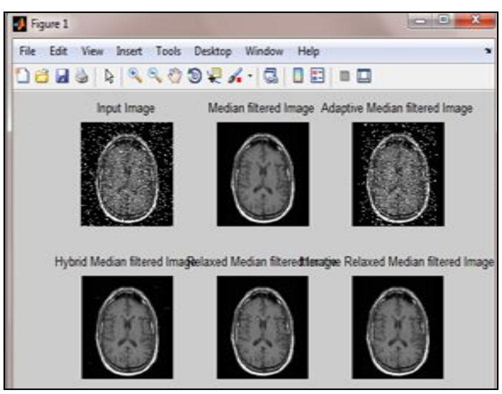
Partition with less fuzziness means better performance. The best clustering is achieved when the value Vpe is minimal.

5. Simulation & Results

For simulation of noise removal & clustering a 10% to 60% noise is added to MR image. A noisy MR image is filtered by various filters mentioned above & PSNR values are calculated for different noise densities.

Noise Density (%)	10	40	60
SMF	28.4324	16.9377	10.9983
HMF	15.3381	9.180561	7.50922
RMF	28.6078	13.9508	9.1412
IRMF	28.2425	17.6327	11.0157

Table 1: PSNR for different noise densities



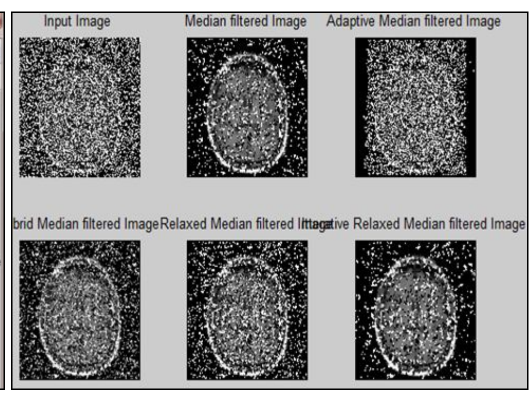
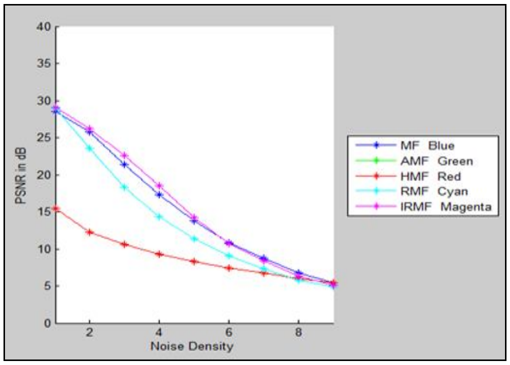


Figure 1: Output of different filters when 10% impulse noise added
Figure 2: Output of different filters when 60% impulse noise added



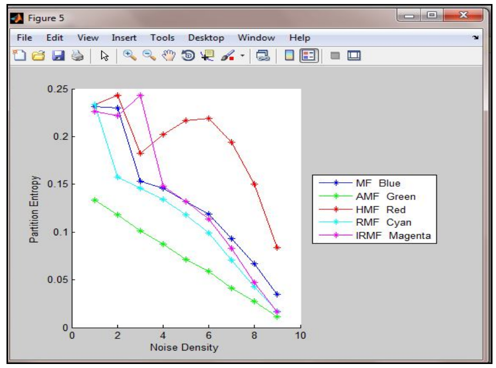


Figure 3: graph of PSNR vs noise density

Figure 4: graph of Partition Entropy vs noise density

6. Conclusion

From tabular results & images we conclude that Iterative Relaxed median filter gives better noise removal for medical images.From tabular results it shows that PSNR values are good for IRMF. Clustering performance is also good for Iterative relaxed median filtered image.

7. References

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