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Suppression Of Impulse Noise In Magnetic Resonance Imaging Using New Non Linear Filtering With Fuzzy Logic (NNL+FUZZY)

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Abstract*-In this paper, new nonlinear filtering with simple fuzzy logic is used for the denoisingof MRI images that highly contaminated by impulse noise. Noise contamination in magnetic resonance(MR) image could occur during acquisition, storage, and transmission in which effective filtering is required to avoid repeating the MR procedure. The proposed filtering algorithm is used to reduce different levels of salt and pepper noise in MR image. Besides visual inspection on filtered images, the mean squared error (MSE) is used as an objective measurement. When compared with the median filter, simulation studies show that the proposed filter can eliminate impulse noise of densities up to 70% while preserving the edges and fine details satisfactorily.***Key words*-**Impulse noise, Magnetic resonance imaging, Median Filtering, Nonlinear Filter, Fuzzy logic.

I. INTRODUCTION

The principal sources of noise in digital image arise during imageacquisition and noise in a channel during transmission, also due to faulty sensor in camera, a faulty memory. Noise in medical image affects the clinical visualization for making diagnostic interpretations. So for the diagnostic purpose it is very important to reduce noise present in an image, to do this there are two ways. The first way is to acquire a second image which results in increased cost and longer acquisition time, the second way is to apply some image processing technique to reduce the noise in an acquired image which usually requires less time and can reduce cost. A typical form of impulse noise in medical image is salt and pepper noise which represents itself as randomly occurring white (salt) and black (pepper) pixels. As a result, the values of some pixels are changed and image gets corrupted. The noise density is a term used to quantify the amount of salt and pepper noise in an image. To reduce noise in an image, several filtering techniques are used.Nonlinear filtering techniques are preferred for denoising images which are degraded by impulse noise. These nonlinear filtering techniques take into account for nonlinear nature of the human visual system.Thus, the filters having good edge and image detail preservation properties are highly desirable for visual perception. One of the simplest ways to remove salt-and-pepper noise is by windowing the noisy image with a conventional median filter. In practice, besides reducing noise, it is important to preserve the edges of an image as edges provide critical information on the visual appearance of an image. Median filtering is a smoothing technique which is effective in reducing noise in the smooth regions of an image, but can adversely affect the sharpness in edges.Since, the conventional median filter, which restores each pixel with the median pixel in the filtering window regardless whether it is a noise or noise-free pixel, exhibits blurring of filtered images. To overcome these limitations, some modified forms of median filter have been proposed. For small to moderate levels of salt and pepper noise, the median filter has been shown [1] to be useful in reducing noise whilst preserving edges, with deteriorating performances at a high level of noise. A New Nonlinear Filtering Technique (NNFT) for removing impulse noise from the images was introduced in [2], in which proposed NNFT detects whether a pixel is noisy or noise free and it exhibits good response at signal edges besides filtering out noise sufficiently.The conventional filtering techniques using mean, median and spatial median filters were analyzed to attain the improvement. The approach adaptively decides the masking center for a given MRI image.A rule based fuzzy filter for reducing high impulse noise called Rule Based Fuzzy Adaptive Median (RBFAM) Filter was introduced in [3]. The RBFAM filter is an improved version of the Adaptive Median Filter (AMF) which can preserve image details better than the AMF while suppressing additive salt and pepper or impulse type noise. In [4], a Fuzzy Adaptive Median Filter with Adaptive Membership Parameters (FAMFAMP) was proposed for the noise reduction of magnetic resonance images corrupted with heavy impulse (salt and pepper) noise, while preserving image edges and details. In [5], a simple filtering is introduced based on fuzzy filter which offers effective way to reduce different levels of salt and pepper noise while preserving details in MR images.

In this paper, we describe a New Nonlinear filtering combined with fuzzy filter for removing the impulse noise from MR images. The proposed New Non Linear filtering with Fuzzy logic used for noise reduction of magnetic resonance images corrupted with heavy impulse. The Section II discusses the scheme proposed for impulse noise detection and elimination. The simulation results obtained by applying the filter on different images are presented in section III to illustrate its efficacy. The conclusions are summarized in section IV.

II. PROPOSED FILTERING ALGORITHM

In this paper proposed filtering technique detects the impulse noise in the image using a decision mechanism. The corrupted and uncorrupted pixels in the image are detected by comparing the pixel value with the maximum and minimum values in the selected window. If the pixel intensity lies between these minimum and maximum values, then it is an uncorrupted pixel and it is left undisturbed. If the value does not lie within the range, then it is a corrupted pixel and is replaced by the median pixel value or already processed immediate neighbouring pixel in the current filtering window.
Then the window is moved to form a new set of values,with the next pixel to be processed at the centre of thewindow. This process is repeated until the last image pixelis processed. This Impulse noise detection and filtering isbased on the following condition:

if$X_{min}<X_{i,j}<X_{max}$
{$X_{i,j}$ is a noiseless pixel;
no filtering is performed on $X_{i,j}$ }
else
{$X_{i,j}$ is a noisy pixel;
determine the median value}
if median ≠ 0 and median ≠ 255
{Median filter is performed on $X_{i,j}$ }
$X_{i,j} = X_{med}$
else
{Median itself is noisy}
$X_{i,j} = X_{i-1,j}$
end;
end;

where, $X_{i,j}$ is the intensity of central pixel inside thefiltering window, X_{min}, X_{max} and $X_{med}$are the minimum,maximum and median pixel value in filtering window ofnoisy image. $X_{i-1,j}$ is the intensity of the already processedimmediate top neighbouring pixel.
In order to process the border pixels, the first and lastcolumns, respectively are replicated at the front and rearends of the image matrix; similarly, the first and last rows,respectively, are replicated at top and bottom of the image.The first row pixels of the image are processed using thesame algorithm described above except that in step 5, if themedian value is also detected to be an impulse it is replacedby one of the uncorrupted nearest neighbourhood pixelvalues in the processing window.

III. FUZZY FILTER

The fuzzy image processing has three main stages: imagefuzzification, modification of membership values, and, if necessary, image defuzzification. The main power of fuzzy imageprocessing is in the middle step (modification of membershipvalues). After the image data are transformed from gray-levelplane to the membership plane (fuzzification), appropriatefuzzy techniques modify the membership values. why we should use fuzzytechniques in image processing. There are many reasons to dothis. The most important of them are as follows:

- Fuzzy techniques are powerful tools for knowledgerepresentation and processing.
- Fuzzy techniques can manage the vagueness andambiguity efficiently.

Fuzzy set theory and fuzzy logicoffer us powerful tools to represent and process humanknowledge in form of fuzzy IF-THEN rules.

In this paper the fuzzy filtering is applied on the processed values which are obtained after New Non Linear filtering (NNFT). The proposed fuzzy filtering can be described as follows:

Let $x(i, j)$ be the input of a 2-dimensional fuzzy filter, theoutput of the fuzzy filter is defined as

If $\sum_{(r,s)} F[x(i+r, j+s)] \le 3$……for 3×3 window

$$y(i,j) = \frac{\sum_{(r,s)\in A} F[x(i+r,j+s)] \times x(i+r,j+s)}{\sum_{(r,s)\in A} F[x(i+r,j+s)]}$$

$F[x(i, j)]$ is the general window function and A is the area ofthe window. For a square window of dimensions $L×L$, therange of r and s are: $-R \le r \le R$ and $-S \le s \le S$, where $L = 2R+1 = 2S+1$.
Otherwise;

$$y(i,j) = y(i-1,j)$$

In the case of a standard median filter (MED filter), thewindow function is defined as

$$F[x(i+r,j+s)] = \begin{cases} 1 \; for \; x(i+r,j+s) = x_{med}(i,j) \\ 0 \qquad otherwise \end{cases}$$

such that the output value $y(i, j)$ at the center of a window $A$is
replaced by the median value $x_{med}(i,j)$ among all the inputvalues $x(i+r,j+s)$ for $r,s \in A$at discrete indexes (i, j). Theiterative version of the MED filter (denoted by MEDi filter) inwhich the filtering is applied iteratively until noise is reducedto a satisfactory level.

The proposed NNFT algorithm with fuzzy filtering exhibits the superior performance in terms of eliminating impulse noise up to 70% and preserving edged and fine details.

I. SIMULATIONS AND RESULT

In the simulations, the MR image of “spine.tif” having dimensions M×N (367×490) is chosen. The pixels $x(i, j)$ for $1 \le i \le M$and $1 \le j \le N$, of the image is corrupted by salt and peppernoise, $n(i, j)$. Low, medium, and high levels of salt and peppernoise, each with a noise density value of 0.15, 0.30, and 0.45,respectively, is added to the original image (Fig. 1) to formthree noisy images (Fig. 2 for noise density = 0.30, Fig. 5 fornoise density = 0.45). Each of these three noisy images is to befiltered by proposed filter using three different squarewindows of dimensions$L$xLpixels and with values of L = 3, 5, 7.

For objectivemeasurement, the mean squared error (MSE) is used tocompare the relative filtering performances of various filters.The MSE between the filtered output image $y(i, j)$ and theoriginal image $x(i, j)$ of dimensions MxNpixels is defined as

$$MSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[y(i,j) - x(i,j)]^2}{M \times N}$$

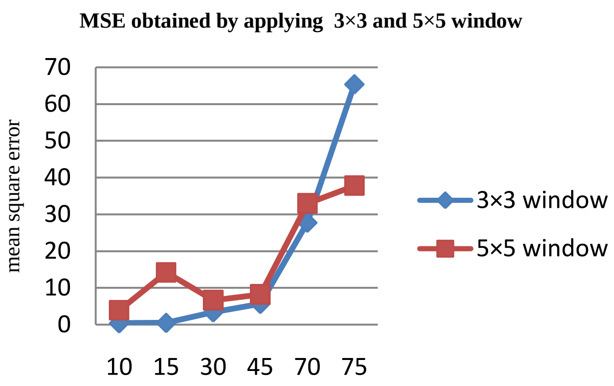
The MSE values obtained for NNFL+FUZZY filtering using 3×3 and 5×5 window are summarized in Table I and II.

TABLEI:MSE VALUES OBTAINED USING PROPOSED NNL+FUZZYUSING 3×3 WINDOW ON DIFFERENT TEST IMAGE CONTAMINATED WITH VARIOUS DENSITIES OF IMPULSE NOISE.

Noise density	MSE of noisy image	MSE of filtered image(NNL)	MSE of filtered image (NNL+FUZZY)
10	53.4218	34.7230	0.4013
15	65.7997	42.7170	0.4964
30	92.6256	61.8080	3.3799
45	114.3371	77.4754	5.6546
70	142.4305	111.5045	27.7462
75	147.7677	121.4726	65.3646

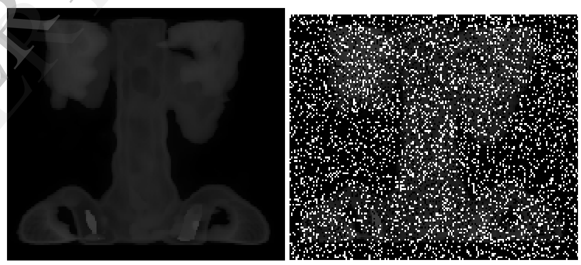
TABLE II: MSE VALUES OBTAINED USING PROPOSED NNL+FUZZY USING 5×5 WINDOW ON DIFFERENT TEST IMAGE CONTAMINATED WITH VARIOUS DENSITIES OF IMPULSE NOISE.

Noise density	MSE of noisy image	MSE of filtered image(NNL)	MSE of filtered image (NNL+FUZZY)
10	53.8288	35.0907	3.9536
15	66.1348	46.2346	14.2096
30	93.4479	60.7805	6.6754
45	113.9386	77.1486	8.2596
70	142.4998	112.3225	32.9836
75	147.7677	121.4726	37.7795

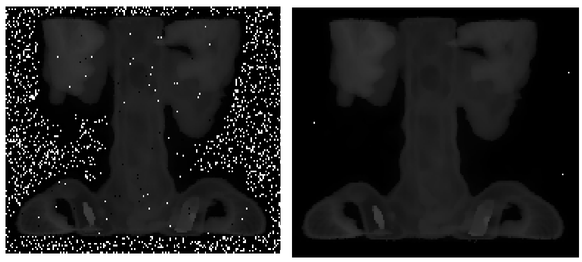


Fig, 1 MSE obtained by applying NNL+FUZZY using 3×3 and 5×5 window for image corrupted with various densities of mixed impulse noise .

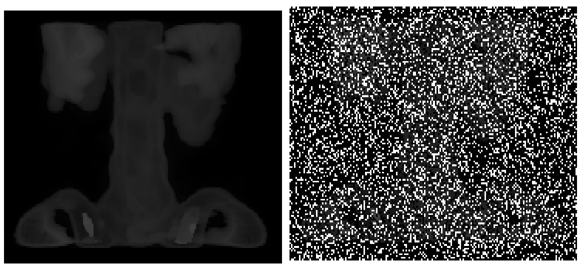
Fig.1 illustrates the performance of New NonlinearFilter with fuzzy logic and compares the result using 3×3 and 5×5 window in terms of MSE when applied on “spine.tif” image contaminated with different noise densities. The results obtained using 3×3 window shows that it is effective for less noise desensitise up to 70% whereas 5×5 window is effective for higher noise densities.



(a1) (b1)



(c1) (c3)



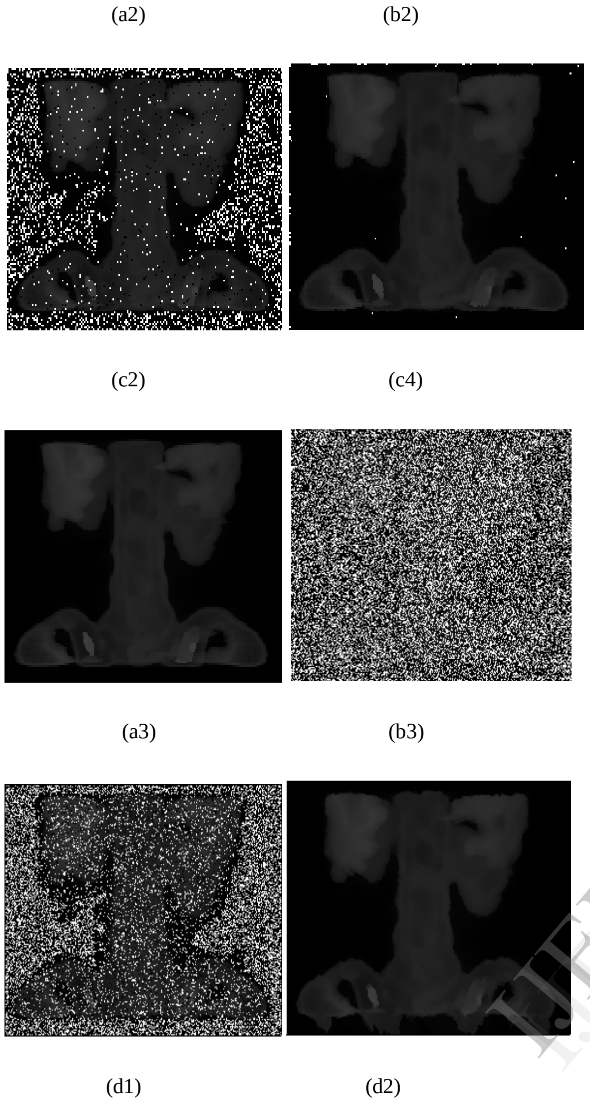


Fig.2 Subjective performance of New Nonlinear filtering with fuzzy (NNL+FUZZY) Technique for spine image: ($a_{1,2\&3}$) original image of "spine.tif", ($b_{1,2\&3}$)Noisy image (Salt and pepper noise, noise density=0.3, 0.45 and 0.70 respectively), ($c_{1\&2}$) filtered image by NNL technique, ($c_{3\&4}$) filtered image by NNL+FUZZY technique using 3×3 window and (d_1)filtered image by NNL technique, (d_2) filtered image by NNL+FUZZY technique using 5×5 window.

II. CONCLUSION

A New Nonlinear Filtering Technique with fuzzy logic (NNL+FUZZY) has been developed in this paper. The filter has been shown to be more effective in eliminating the impulse noise. Further, since the filtering is performed only on corrupted pixels, the essential features of the images, namely, edges and fine details are preserved satisfactorily. This filter offers a simple and effective way to reduce different levels of salt and pepper noise while preserving details in MR images.

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