

Fuzzy Center Weighted Hybrid Filtering Techniques for Denoising of Medical Images

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Abstract

Noise removal is one of the pre-processing tasks in several medical image processing techniques. Many researchers work on different types of filters used to remove different types of noises from medical images. This paper proposes some fuzzy center weighted hybrid filtering techniques, FCWH₃F, GFCWHF, TFCWHF and ATFCWHF, for the simultaneous removal of Gaussian and speckle noise from medical images, by topological approach. The quality of the enhanced images is measured by the statistical quantity measures: Root Mean Square Error (RMSE) and Peak Signal-to-Noise Ratio (PSNR).

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INTRODUCTION

Now-a-days an image is nothing but a digital image and is very much imperative for daily life applications. One such application is medical imaging which may be magnetic resonance imaging or ultrasound imaging or X-ray imaging or computer tomography. The images collected by different types of sensors are generally tainted by different types of noises. Noise may be generated due to imperfect instruments used in image processing, problems with the data acquisition process and interference, all of which can degrade the data of interest. Denoising is an essential step that makes diagnosis more efficient for doctors. The importance of image filtering is constantly

growing because of ever increasing use of television and video systems in consumer, commercial, medical and communication applications. Image filtering is not only used to improve image quality but is also used as a preprocessing technique before most image processing operations such as encoding, recognition, compression, tracking, etc. In other words, without filtering as a preprocessing, the other processing would have inappropriate results.

In early 1970s median filter has been introduced by Tukey[1]. It is a special case of non-linear filters used for smoothing signals. Median filter now is broadly used in reducing noise and smoothing the images. In 2005, Quan et al [2] described a filtering method for images that strayed from the partial differential equation filtering methods. A gradient weighted filter is applied to the image, but it does not remove impulse noise, so the method also uses a 3x3 window median filter to improve the fringes. This combination of weighted and median filters is applied to the image several times to get a resulting fringe pattern with good contrast and low noise. In 2005, Manikandan and Ebenezer[3] proposed an algorithm employing adaptive-length recursive weighted median filters for improving impulse noise filtering capability. An improved adaptive median filtering method for denoising impulse noise reduction was carried out by Mamta Juneja et al. [4] in 2009. Sun-Jea KO[5] proposed and analyzed the properties of CWM and ACWM filters, which preserves image details. Rosalina Abdul Salam et al.[6] proposed a centre weighted median filter for live-cell video enhancement and they compared it with three different types of filters and showed that the most effective filter is the centre weighted median filter. In the literature several fuzzy and non fuzzy filters have been studied for removal of random noise from medical images. In 1993, Kwan and Cai [7,8] developed median filters using fuzzy concepts and also analyzed the performance of various fuzzy filters for noise reduction in images. Nachtegael et al.,[9,10] reviewed fuzzy filters for noise reduction in images and also reported a comparative study of classical and fuzzy filters for noise reduction in 2001. Gnanambal Ilango and Marudhachalam [11,12,13] described different types of new hybrid filtering techniques for removal of Gaussian noise from ultrasound medical images, center weighted hybrid filtering techniques and also fuzzy hybrid filtering techniques for simultaneous removal of Gaussian and speckle noises.

This work is organized as follows: In Section 2 basic definitions are given. Section 3 deals with proposed fuzzy center weighted hybrid filtering techniques for de-noising the ultrasound medical images. In Section 4, both quantitative (RMSE & PSNR) and qualitative comparisons have been provided. Section 5 puts forward the conclusion drawn by this paper.

BASIC DEFINITIONS

This section presents some general definitions of digital neighbourhoods, which will be used along the development of this paper.

Digital image

A digital image [14] is a function $f : Z \times Z \rightarrow [0, 1, \dots, N-1]$ in which $N-1$ is a positive whole number belonging to the natural interval [1, 256]. The functional value

of 'f' at any point p(x,y) is called the intensity or grey level of the image at that point and it is denoted by f(p).

4-neighbours of a point

The 4-neighbours [15] of a point p(x,y) are its four horizontal and vertical neighbours (x + 1, y) and (x - 1, y) and (x, y + 1) and (x, y - 1). A point 'p' and its 4-neighbours is denoted by N₄(p).

8-neighbours of a point

The 8-neighbours [15] of a point p(x,y) consist of its 4-neighbours together with its cross neighbours. A point 'p' and its 8-neighbours is denoted by N₈(p).

2.4 Cross neighbours of a point

The cross neighbours [11] of a point p(x,y) consists of the neighbours (x + 1, y) and (x - 1, y) and (x, y + 1) and (x, y - 1). A point 'p' and its cross neighbours is denoted by C₄(p).

$$\text{i.e., } C_4(p) = N_8(p) - N_4(p).$$

2.5 LT neighbours of a point

The LT neighbours [11] of a point p(x,y) consists of the neighbours (x - 1, y - 1) and (x + 1, y + 1). A point 'p' and its LT neighbours is denoted by L₃(p).

2.6 RT neighbours of a point

The RT neighbours [11] of a point p(x,y) consists of the neighbours (x - 1, y + 1) and (x + 1, y - 1). A point 'p' and its RT neighbours is denoted by R₃(p).

DEFINITIONS OF SOME FUZZY CENTER WEIGHTED HYBRID FILTERING TECHNIQUES

The image processing function in a spatial domain can be expressed as

$$g(p) = Y(f(p)) \tag{1}$$

where Y is the transformation function, f(p) is the pixel value (intensity value or grey level value) of the point p(x,y) of input image and g(p) is the pixel value of the corresponding point of the processed image.

Definition of Fuzzy filters:

Let f(p) be the input image of a two dimensional fuzzy filter, the output the fuzzy filter is defined as [16]:

$$g(p) = \frac{\sum_{p \in N_8(p)} F(p) \cdot f(p)}{\sum_{p \in N_8(p)} F(p)} \tag{2}$$

where F(p) is the general 8-neighbour function. With the definition of fuzzy filters various fuzzy hybrid filtering techniques are defined, which we shall describe as fuzzy center weighted hybrid max filter(FCWH₃F), the Gaussian fuzzy center weighted hybrid filter with center weighted hybrid max center(GFCWHF), the symmetrical triangular fuzzy center weighted hybrid filter with center weighted

hybrid cross median center (TFCWHF) and the asymmetrical triangular fuzzy center weighted hybrid filter with center weighted hybrid max center(ATFCWHF).

Fuzzy Center Weighted Hybrid Max Filter(FCWH₃F)

In fuzzy center weighted hybrid max filter, the general 8-neighbour function is defined as:

$$F(p) = \begin{cases} 1 & \text{for } f(p) = cwhmv(p), p \in N_8(p) \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

where $cwhmv(p)$ is the center weighted hybrid max value, which is maximum of median pixel value of 2 times $f(p_c)$ and LT neighbours of a point 'p', median pixel value of 2 times $f(p_c)$ and RT neighbours of a point 'p' and pixel value of 'p'. The grey level value of center pixel is denoted by $f(p_c)$.

Gaussian Fuzzy Center Weighted Hybrid Filter (GFCWHF)

The Gaussian fuzzy center weighted hybrid filter with the center weighted hybrid max value within 8-neighbour of a point chosen as the center value is defined as:

$$F(p) = e^{-\frac{1}{2} \left(\frac{f(p) - cwhmv(p)}{\sigma(p)} \right)^2}, \text{ for } p \in N_8(p) \quad (4)$$

where $cwhmv(p)$ and $\sigma(p)$ represents respectively, the center weighted hybrid max value and standard deviations of all the input values of 'p' for $p \in N_8(p)$.

Triangular Fuzzy Center Weighted Hybrid Filter (TFCWHF)

The symmetrical triangular fuzzy center weighted hybrid filter with center weighted hybrid cross median value within 8-neighbour of a point chosen as the center value is defined as:

$$F(p) = \begin{cases} 1 - \frac{|f(p) - cwhcmv(p)|}{nm(p)}, & \text{for } |f(p) - cwhcmv(p)| \leq nm(p) \\ 1 & \text{for } nm(p) = 0 \end{cases} \quad (5)$$

$$\text{where } nm(p) = \max[mx(p) - cwhcmv(p), cwhcmv(p) - mn(p)], \quad (6)$$

$cwhcmv(p)$, the center weighted hybrid cross median value, which is the median of median pixel value of LT neighbours of a point 'p', median pixel value of RT neighbours of a point 'p' and pixel value of 'p'. $mx(p)$ and $mn(p)$ are, respectively, maximum and minimum value of all the input values of 'p' for $p \in N_8(p)$.

Asymmetrical Triangular Fuzzy Center Weighted Hybrid Filter (ATFCWHF)

The asymmetrical triangular fuzzy center weighted hybrid filter with center weighted hybrid max value within 8-neighbour of a point chosen as the center value is defined as:

$$F(p) = \left\{ \begin{array}{l} 1 - \frac{cwhmv(p)-f(p)}{cwhmv(p)-mn(p)}, \text{ for } mn(p) \leq f(p) \leq cwhmv(p) \\ 1 - \frac{f(p)-cwhmv(p)}{mx(p)-cwhmv(p)}, \text{ for } cwhmv(p) \leq f(p) \leq mx(p) \\ 1, \text{ for } cwhmv(p) - mn(p) = 0 \text{ or } mx(p) - cwhmv(p) = 0 \end{array} \right\} \quad (7)$$

where $cwhmv(p)$ is the center weighted hybrid max value, which is maximum of median pixel value of 2 times $f(p_c)$ and LT neighbours of a point ‘p’, median pixel value of 2 times $f(p_c)$ and RT neighbours of a point ‘p’ and pixel value of ‘p’. And $f(p_c)$ is grey level value of center pixel. $mx(p)$, $mn(p)$ are maximum and minimum value of all the input values of ‘p’ for $p \in N_8(p)$ respectively.

EXPERIMENTAL RESULT ANALYSIS AND DISCUSSION

The proposed fuzzy center weighted hybrid filtering techniques have been implemented using MATLAB 7.0. The performance of the various fuzzy center weighted hybrid filtering techniques is analyzed and discussed. The measurement of noise reduction is difficult and there is no unique algorithm available to measure noise reduction of ultrasound images. So we use statistical tool to measure the noise reduction of ultrasound images. The Root Mean Square Error (RMSE) and Peak Signal-to-Noise Ratio (PSNR) are used to evaluate the enhancement of ultrasound images.

$$RMSE = \sqrt{\frac{\sum(f(i,j)-g(i,j))^2}{mn}} \quad (8)$$

$$PSNR = 20 \log_{10} \frac{255}{RMSE}. \quad (9)$$

Here $f(i,j)$ is the pixel value of original ultrasound image , $g(i,j)$ is the pixel value of filtered ultrasound image and m, n are the total number of pixels in the horizontal and the vertical dimensions of the image. If the value of RMSE is low and value of PSNR is high then the noise reduction approach is better. Table 4.1 and Chart 4.1 show the proposed fuzzy center weighted hybrid filtering techniques, FCWH₃F, GFCWHF, TFCWHF and ATFCWHF, are compared with some existing filtering techniques namely, EHMF, MF, HMF, M3F, GMED, TMED, ATMED, GMAV, TMAV and ATMAV with regard to ultrasound medical image for a knee image.

Table 4.1

FILTERS	RMSE	PSNR
FCWH3F	2.7191	39.4428
GFCWHF	12.8418	25.9586
ATFCWHF	11.1956	27.1502
TFCWHF	12.5339	26.1694
EHMF	9.2866	28.774
MF	9.2561	28.8026
HMF	7.3038	30.8602
M3F	8.963	29.0821
ATMAV	11.6435	26.8095
ATMED	11.6912	26.774
GMAV	12.8559	25.9491
GMED	12.79	25.9937
TMAV	12.7055	26.0513
TMED	12.6571	26.0844

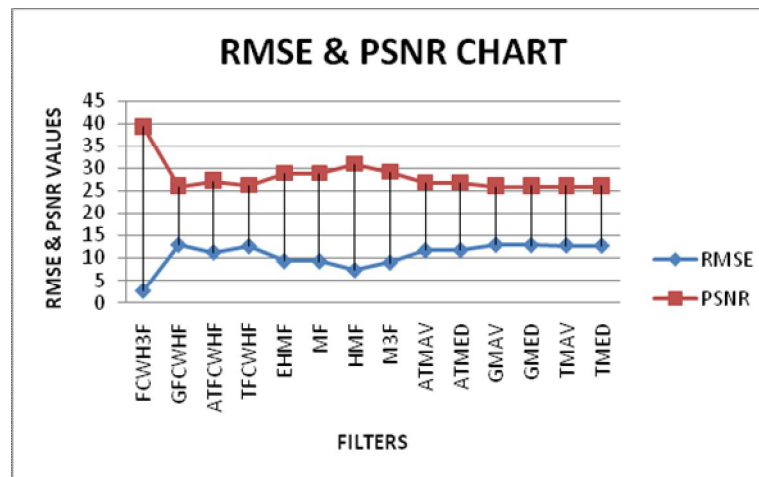


Chart 4.1

CONCLUSION

In this work, we have introduced some fuzzy center weighted hybrid filtering techniques for simultaneous removal of Gaussian and speckle noise of variance 10% from ultrasound medical images. To demonstrate the performance of the proposed techniques, the experiments have been conducted on ultrasound knee image and compared with other well known techniques. The performance of fuzzy center weighted hybrid filtering techniques for removal of speckle noise and Gaussian noise simultaneously is measured by using quantitative performance measures such as RMSE and PSNR. The output results indicate that one of the proposed center

weighted hybrid filter FCWH₃F Filter performs significantly better than other existing techniques, since FCWH₃F has low RMSE value and high PSNR value. The proposed method is simple and easy to implement.

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