Image Enhancement using Hybrid Fuzzy Inference System (IEHFS)

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ABSTRACT

Image enhancement is a primary need for the recognition of different biometrics in biometric-based identification systems. The recognition-rate of a biometric system depends heavily upon the quality of the input biometric given to the system. In this paper, a novel hybrid Fuzzy model (IEHFS) is proposed to improve the visual quality of iris images. The experimental results based on calculating PSNR values show that this hybrid model enhances the noisy biometric images better than the conventional filters like median filter and Wiener filter.

General Terms
Image Enhancement, Iris enhancement, Fuzzy Inference System.

Keywords
IEHFS, Wiener filter, Median filter, Top hat and bottom hat, PSNR, SSIM

1. INTRODUCTION
Biometric identification has taken the highest priority in identification techniques as it is secure, easily accessible and no need to remember it. Iris is one of the best ways among other biometric identification as it has less chances of getting changed, damaged, less effect of age, and no theft. But the image can acquire different types of noises due to incorrect image acquisition and storing [1]. There can be many types of noises encountered due to several reasons like the impulse noise (or salt and pepper noise) caused by some sudden changes or sharp disturbances in the image signal; due to which white or black or both pixels scatter or appear over the image. Such types of noise can be removed by using spatial filtering techniques like adaptive or median filtering.

Adaptive filtering produces good results by preserving edges and other high-frequency parts of an image. Hence wiener filter is applied to enhance the noisy image.

Median filter achieves higher performance when the image contains large domain matrices and do not contain any zero-valued elements. Median filters have been applied heavily to image processing problems [2].

Both the filters are applied on biometric images containing salt & pepper noise. Section II and III show the implementation of Wiener and median filters on Iris images.

Much work has been done to enhance the images. Soft-computing has recently been applied to image denoising process. Among all, Fuzzy technique is a promising technique for image enhancement [5]. It gives better results as compared to median and wiener filter[6]. These fuzzy filters, including FIR-filter [7], the weighted fuzzy mean filter [8], and the iterative fuzzy control based filter [9], do not produce very clear results for Gaussian noise. In this paper iris image is enhanced using hybrid fuzzy model based on the Mamdani model. Section IV discusses the working of the system. In section V, the experimental results and comparison among the three techniques are shown and conclusions are drawn in the last section.

Digital images can acquire variety of noise. It is the result of errors in the image acquisition process and it changes the real intensity of the pixel. An image can have noise due to various reasons; MATLAB toolbox provides a function by which these noises can be added into the image. The '**imnoise**' function will be used here for finding the best denoising method.

2. WIENER FILTER
Wiener filtering [1] is an effective linear image restoration approach. It is based on estimating the statistics from a local neighbourhood of a pixel. The task is to find the estimate of the "best" image from the degraded image. Image processing toolbox of Matlab offers functions like **wiener2** which uses a pixel-wise adaptive Wiener method using neighborhoods of size `m x n` to estimate the local image mean and standard deviation. Where the variance is large, it performs little smoothing. Where the variance is small, **wiener2** performs more smoothing. Wiener works on gray scale so the image is first converted to grayscale. Then wiener is applied. The Figure 1 shows the process.

The algorithm applied through MATLAB on Iris image to see the results

1. Read the image
```
RGB = imread('002_1_1.bmp');
imshow('001_1_1.bmp')
```
2. Change the image to grayscale
```
I = rgb2gray(RGB);
imshow(I)
```
3. Add noise to the image
```
J = imnoise(I,'salt & pepper',0.02);
imshow(J)
```
4. Remove noise by applying wiener
```
K = wiener2(J,[3 3]);
figure, imshow(K)
```

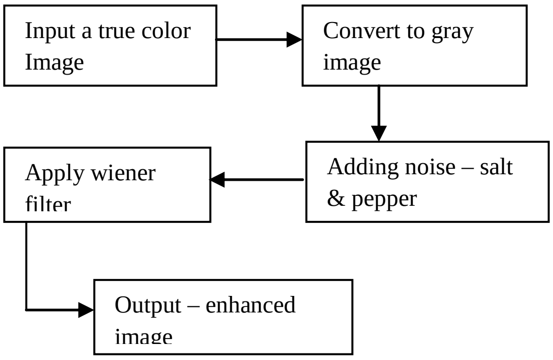

Fig 1: Applying wiener filter

3. MEDIAN FILTER

Averaging filter, in which each output pixel is set to an average of the pixel values in the neighborhood of the corresponding input pixel. Median filtering similar to it, the value of output pixel is determined by the median of the neighborhood. Median filtering is a nonlinear operation often used in image processing to reduce "salt and pepper" noise and preserve edges[10]. Here median filter is applied on Iris Image to remove this type of noise. Figure 2 shows the applied process.

The algorithm applied through MATLAB on the Iris image

1. Read the image
   `I = imread('002_1_1.bmp');`
   `imshow(I)`

2. Add noise to the image
   `J = imnoise(I,'salt & pepper',0.02);`
   `imshow(J)`

3. Remove noise by applying median
   `K = medfilt2(J,[3  3]);`
   `figure, imshow(K)`

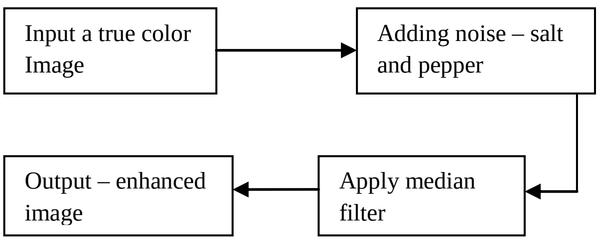

Fig 2: Applying median filter

However, when the noise level is over 50%, some details and edges of the original image are smeared by the filter [11]. Different approches of the median filter have been proposed, e.g. the adaptive median filter [12], the multi-state median filter [13], or the median filter based on homogeneity information [14] and [15].

4. IMAGE ENHANCEMENT USING HYBRID FUZZY INFERENCE SYSTEM (IEHFS)

Fuzzy inference maps the given input to the desired output using fuzzy logic by using membership functions, logical operations and IF-THEN rules. Fuzzy system can be classified in two types, Mamdani-type and Sugeno-type. The first one includes linguistic models based on collections of IF–THEN rules, whose antecedents and consequents utilize fuzzy sets. The Mamdani model [16] follows it. The second category, based on Takagi-Sugeno (TS) model systems [17], uses a rule structure that has fuzzy antecedent and functional consequent parts.

In this paper, hybrid Fuzzy inference system is applied by taking a movable window over the image of 5 x 5 size, where the pixels around the center pixel are named according to the direction to identify them. Their gray intensity is measured and a comparison is made in one direction to the other adjacent pixels to find their intensity level and then a new value is assigned according to the fuzzy rules and function. The output image is then passed through top and bottom hat filters to get a much enhanced image. The Iris image enhancement using the proposed IEHFS process is shown in figure 3. The proposed algorithm to enhance the Iris image has the following steps:

1. Read the image.
2. If image is true colour, convert it to gray image
3. The gray image I is considered to be of size m x n where I = {I(i,j) ϵ {1,2,…..255}} and i =1,2…….m and j=1,2,…….n.
4. A movable window W of size 5x5 is taken as shown in figure 4.
5. The fuzzification of the image is done, as shown by the matrix in figure 5.
6. Fuzzy rules are applied to enhance the image.
7. Top and bottom hat filters are applied on enhanced image.

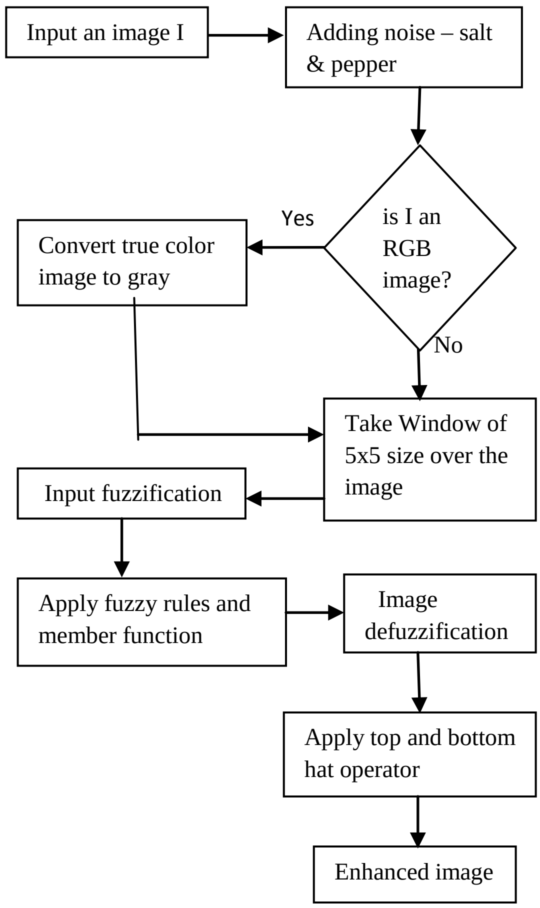

Fig 3: Applying IEHFS

NW1	**NNW**	**N1**	**NNE**	**NE1**
NWW	**NW**	**N**	**NE**	**NEE**
W1	**W**	**P(i,j)**	**E**	**E1**
SWW	**SW**	**S**	**SE**	**SEE**
SW1	**SSW**	**S1**	**SSE**	**SE1**

Center Pixel

Fig 4 :Dimensions of movable window W

$$\begin{pmatrix} i-2,j-2 & i-2,j-1 & i-2,j & i-2,j+1 & i-2,j+2 \\ i-1,j-2 & i-1,j-1 & i-1,j & i-1,j+1 & i-1,j+2 \\ i,j-2 & i,j-1 & i,j & i,j+1 & i,j+2 \\ i+1,j-2 & i+1,j-1 & i+1,j & i+1,j+1 & i+1,j+2 \\ i+2,j-2 & i+2,j-1 & i+2,j & i+2,j+1 & i+2,j+2 \end{pmatrix}$$

Fig 5 : Matrix of image input fuzzification

In the filtering Window W each pixel corresponds to the adjacent pixel by the given direction. The basic assumption in this technique is that the new pixel must be taken from the Window W. After fuzzification, the fuzzy rules applied are

```
NW=P(i-1,j-1)     NW1=P(i-2,j-2)

If (NW < 0.5)
     If ( NW1  < 0.5)
         P(NW) = 0  and P(NW1) = 0
    Else
        Temp = (NW + NW1) /2
        If (Temp > 0.5)
           P(NW) = P(i,j)
           P(NW1) = P(i,j
        Else
            P(NW) =0
            P(NW1) = 0
Else
    P(NW) = P(i.j)
    P(NW1) = P(i,j)
```

In this way, each pixel under 5 x 5 window is being checked with the center pixel intensity. If the intensity is less than 50%, then it is assigned the value 0 else it is equal to the P(i,j). The process is repeated for pixels in all the neighborhood pixels of the center pixel P(i,j) by sliding the 5x5 window. This way the whole image is enhanced. Finally, after applying these IF-THEN rules, the top and bottom hat filters are applied to the fuzzy-enhanced image in order to further enhance the image.

5. EXPERIMENTAL RESULTS

Multiple Iris images from CASIA database were taken for the experiment. For removing noise (salt-pepper) from the Iris images, all the three techniques were applied, and outputs obtained from all the techniques were compared. The PSNR and SSIM values are shown in the table 1, and the quality of the images are measured through it. The comparisons are shown graphically in figure 6. The images obtained from different techniques are shown in figure 7. The resulting enhanced images obtained from all the three techniques clearly show that the proposed method of image enhancement gives better performance in most of the cases than the rest two techniques.

6. CONCLUSION

The proposed algorithm uses the hybrid fuzzy system to enhance the iris image. The proposed system was applied on 40 different types of Iris images to check the level of enhancement. The enhanced images were compared with existing methods and showed the improved quality of the images. Still some more operations like wavelet filtering can be applied to make images appear more robust, further study is being done on fuzzification for better results. To make images appear clearer, some other methods like complex Gabor wavelets of different sizes can also be applied in order to fill the cuts and removing the unnecessary lines that are found in bad-quality iris images.

7. REFERENCES

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Table 1. Comparison of wiener, median and proposed enhancement methods based on PSNR and SSIM

Image	Wiener Filter		Median Filter		Proposed method(IEHFS)	
Iris Image	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
001_1_1	56.4991	0.98283	56.5485	0.98186	56.5932	0.98277
001_1_2	56.3661	0.98269	56.4001	0.98118	56.461	0.98185
001_2_1	56.6289	0.98294	56.7868	0.98324	56.8557	0.98347
001_2_2	56.5216	0.9823	56.6941	0.98327	56.7344	0.98321
002_1_1	56.5037	0.98192	57.9033	0.98751	57.9282	0.98744
002_1_2	56.5009	0.98253	57.4439	0.98605	57.5148	0.98605
002_2_1	56.7142	0.98206	57.7897	0.98708	57.8148	0.98698
002_2_2	56.4521	0.98279	57.3151	0.98557	57.387	0.9858
003_1_1	56.651	0.98489	56.8028	0.98354	56.8201	0.98359
003_1_2	56.7778	0. 98498	56.7357	0.98322	56.7625	0.98331
003_2_1	56.7367	0.9842	57.1149	0.9846	57.1156	0.98447
003_2_2	56.749	0.98472	56.8904	0.9843	56.9993	0.98453
004_1_1	57.5354	0.98577	58.0547	0.98671	58.0744	0.98671
004_1_2	57.5195	0.98567	57.7743	0.98615	57.8091	0.98612
004_2_1	57.5127	0.98567	57.9376	0.98653	57.9704	0.98655
004_2_2	57.4979	0.98588	57.7563	0.98609	57.8238	0.98622
008_1_1	56.577	0.98191	57.7671	0.98648	57.800	0.98675
008_1_2	56.4692	0.98122	57.8725	0.98666	57.9042	0.98701
008_2_1	56.7276	0.98337	57.0463	0.98392	57.0727	0.98411
008_2_2	56.8442	0.98322	57.8588	0.98658	57.9008	0.98689
009_1_1	56.6764	0.98214	57.2764	0.98456	57.3267	0.98482
009_1_2	56.9251	0.98298	57.904	0.98325	56.9967	0.98396
009_2_1	56.8162	0.98307	56.7731	0.9823	56.8891	0.98343
009_2_2	56.9126	0.98232	56.3946	0.9849	57.4498	0.98531
010_1_1	57.0617	0.98469	57.599	0.98643	57.6149	0.98626
010_1_2	56.7501	0.98357	57.7882	0.98683	57.7583	0.98649
010_2_1	56.7589	0.98379	57.1073	0.98471	57.1464	0.98472
010_2_2	56.4447	0.98302	57.453	0.98641	57.4581	0.98615

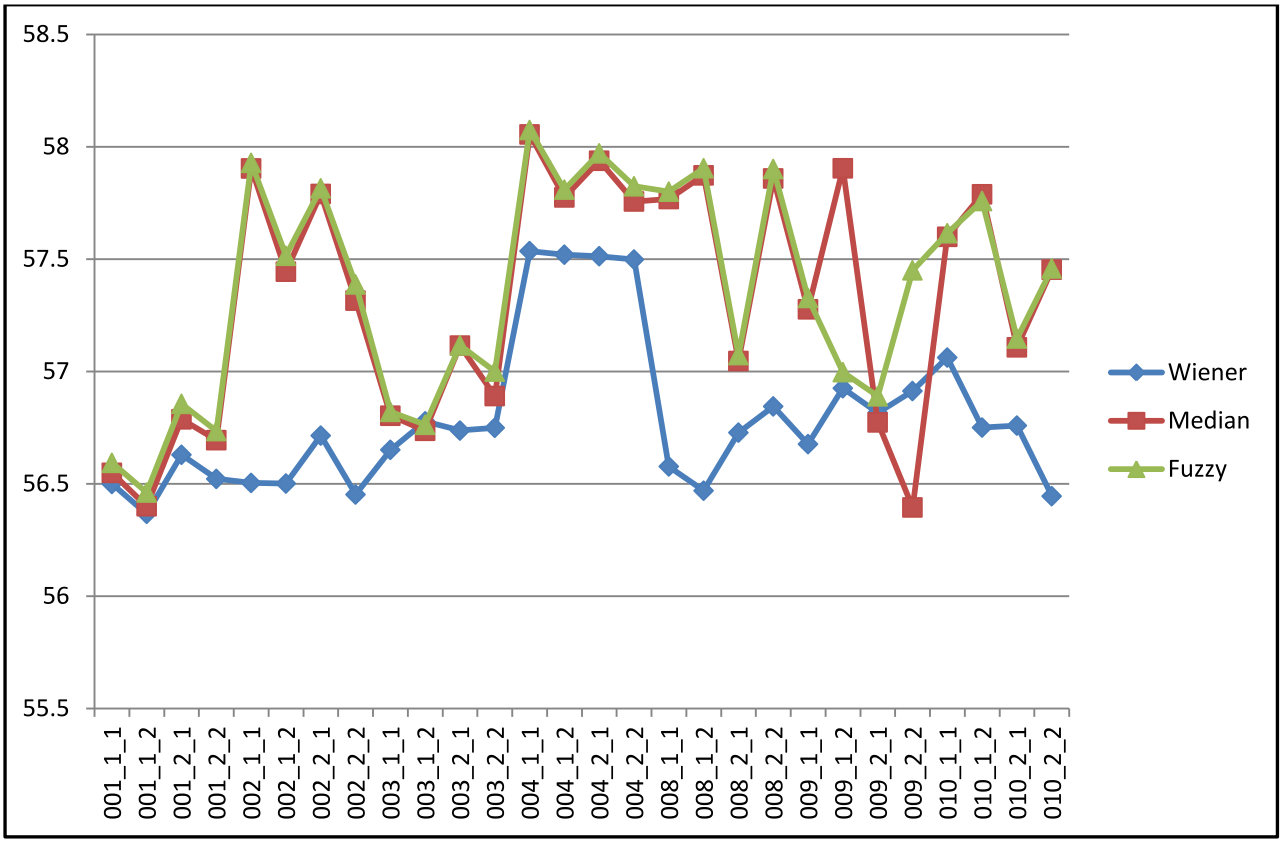

Fig 6: Graphical representation of PSNR and SSIM of Wiener, median and Proposed enhancement methods)

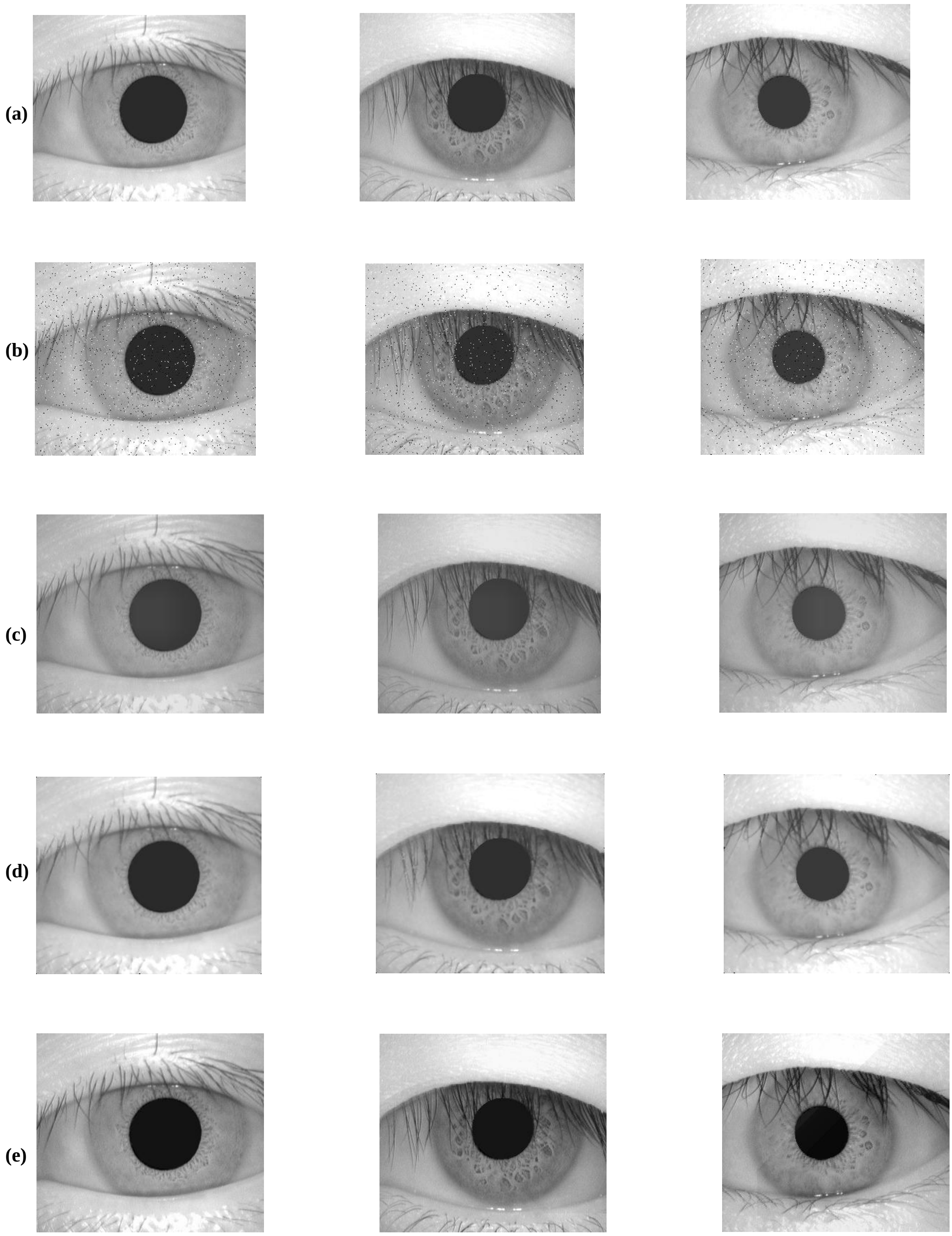

Fig 7: Enhancement of iris image a) Original image b) Noisy image c) Wiener-filtered image d) Median-filtered image e) Enhancement using proposed method (IEHFS)