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Image De-noising Technique based on Fuzzy Histogram Adaptive Filter

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ABSTRACT

Noisy images require de-noising techniques to filter out noise and produce noise free clear image. Noise in the image compromises the details of image. Many image processing techniques require removal of noise as a pre-processing step. Huge amount of literature is present that deals with techniques to remove the noise from digital images. There are some traditional filters, some filters derived from traditional filters and some filters are new innovations. The work proposed here is related to the development of a novel fuzzy histogram adaptive filter to reduce noise from digital images. Experimental results show that the proposed technique is superior to other well-known classical techniques available for the same purpose.

Keywords

Image de-noising, spatial filters, fuzzy filters, mean filter, median filter, HAF

1. Introduction

Noise reduction from digital images is a very important and a well-researched concept. Most of the image processing tasks require a clear or non-noisy image to produce good results. Thus, noise reduction also acts as a pre-processing step for other image processing techniques.

Digital image processing deals with retrieving and manipulating discrete image data as per the specific application needs. This field is becoming more and more popular these days due to its vast applications ranging from medical image processing to satellite imagery and many others. The highlight of digital image processing is its versatility. Most of the applications of image processing seek an image which is free of noise due to various factors. Providing an error free image to these systems is a challenge. Many techniques have been proposed to free an image of different types of noise. Plenty of literature is available which deals with this problem.

Noise comes up during the process of acquiring the image from the source like sensor; digital camera etc. Disturbances may occur due to ambient weather conditions or some other interference while capturing the image. The net effect is a corrupted image that needs to be pre-processed to reduce or eliminate the noise. Although noise gives an image a generally undesirable appearance, the most significant factor is that noise can cover and reduce the visibility of certain features within the image. The loss of visibility is especially significant for low-contrast objects. In addition, sometimes images are not of good quality, due to both hardware and software inadequacies, thus, they have to be enhanced and improved before other analysis can be performed on them. Figure 1 shows a sample noisy lena image along with its denoised version.

Figure 1. Sample Lena image with 5% random noise and denoised picture.

Before processing the image we have to remove the unwanted data from it, it means we have to remove the noise from the image. There are different types of noises each have different statistical properties [1].Various techniques are used to remove noise from image to enhance them. Some of the techniques are directly apply on the image data and some uses the transformations like wavelet or frequency. This paper presents fuzzy logic based technique to remove noise from digital images.

2. Literature Survey

Traditional filters include filters which are traditionally used to remove noise from images. We further divide

traditional filters into two classes: - spatial domain and transform domain.

In spatial domain various filters like mean filter[1], median filter, all work directly on the input image. It means it directly work on the pixels of original image. Out of various spatial based filters, wiener filter[2] gives better performance in case of Gaussian, Poisson and speckle noise. For impulse noise, median filter[4] outperforms all other filters. Various enhanced median filters like weighted median filter[5] are also used for this purpose.

It is needed when it is necessary to analyse the signal. Here, we transform the given signal to another domain and do the denoising procedure there and afterwards inverse of transformation is done in order to get final output. There are several transforms available like the Fourier transform, Hilbert transform, wavelet transform, etc. The Fourier transform is probably the most popular transform. Among different Fourier transforms[1] FFT is considered as best. However the Fourier transform is not give high performance in case of image denoising. Wavelet transform is better for this purpose[3]. Wavelet transform further provide different methods for removing noise from image which includes thresholding, non-orthogonal wavelet transform and coefficient model.

Fuzzy based filters are those filters which includes concept of fuzzy logic in their filtering procedure. Fuzzy based filters can also be further classified into two categories: fuzzy classical and fully fuzzy.

Fuzzy classical filters include the filters which extend the traditional filters using fuzzy logic. There are plenty of fuzzy traditional filters on which many researchers have worked. We here mention only some of them. Popular fuzzy classical filters are Fuzzy median filter (FMF)[8], Fuzzy Impulse noise Detection and Reduction Method (FIDRM)[6], Fuzzy random impulse noise reduction method (FRINR)[7], Fuzzy weighted mean (FWM)[9], Adaptive weighted fuzzy mean (AWFM)[10]. In fuzzy median filter[8] and fuzzy weighted mean filter[9], fuzzy logic is added to enhance the traditional median and mean filters. Fuzzy impulse noise detection and reduction method[6] and Fuzzy random impulse noise reduction method[7] is two step methods. In first step noisy pixels are detected from the input image and after detection procedure, noise is removed from the detected pixels, this forms second step. The fuzzy logic is used in detection step by forming the fuzzy rules to decide whether the pixel is corrupted with noise or not. In filtering procedure, traditional filters like mean filter, median filter, weighted mean filter etc. are extended using fuzzy logic.

Fully fuzzy filters are those Denoising filters which are purely based on fuzzy logic and have no connection with traditional methods. Various methods that come under this category are Fuzzy inference ruled by else-action filter (FIRE)[11], dual step fuzzy inference ruled by else-action filter (DSFIRE)[12], Piecewise Linear Fuzzy Inference Ruled by Else-action Filter (PWLFIRE)[13], Gaussian noise reduction filter (GOA)[14], histogram adaptive filter (HAF)[15]. These are not all developed filters. We only mention some of the popular filters only. FIRE[11] filters are a family of nonlinear filters which adopt fuzzy rules toprocess image data.Dual Step FIRE filter[12], adopts fuzzy reasoning at two different levels in order to cancel noise pulses without damaging fine image structures. DS-FIRE filter is able to largely outperform other methods in the literature. All fuzzy based filters use fuzzy rules based systems to add fuzzy logic in it.

3. Fuzzy Based Histogram Adaptive filter

The proposed histogram adaptive fuzzy (HAF) filter is particularly effective for removing highly impulsive noise while preserving edge sharpness. This is accomplished through a fuzzy smoothing filter constructed from a set of fuzzy IF-THEN rules, which alternate adaptively to minimize the output mean squared error as input histogram statistics change. An algorithm is developed to utilize (corrupted) input histogram to determine parameters for the near-optimal fuzzy membership functions. Construction of the HAF filter involves three steps: (1) define fuzzy sets in the input space, (2) construct a set of IF-THEN rules by incorporating input histogram statistics to form the fuzzy membership functions, and (3) construct the filter based on the set of rules. Unlike many neuro-fuzzy or fuzzy-neuro filters, where a random strategy is employed to choose initial membership functions for subsequent lengthy training, HAF can achieve near-optimal performance without any training.

4. Proposed Technique

For the problem of interest here, we assume an input gray image sized 512×512 with a pixel intensity from 0 to 255. With adaptive histogram approach i.e. Histogram Adaptive Filter (HAF), a fuzzy logic based technique was proposed to remove noise from digital images. In this technique we decide whether a pixel is noisy or not based on the intensity of the pixels surrounding the given pixel. For the said task we design a fuzzy inference system (FIS) that takes two inputs and produces one output as shown in Figure 2. The first input taken by the FIS is difference of the centre pixel and the pixel vertically/ horizontally preceding it. Second input the centre pixel and the pixel vertically/ horizontally succeeding it. We used Matlab for designing the proposed tool. Figure 3 shows membership function editor for the FIS.

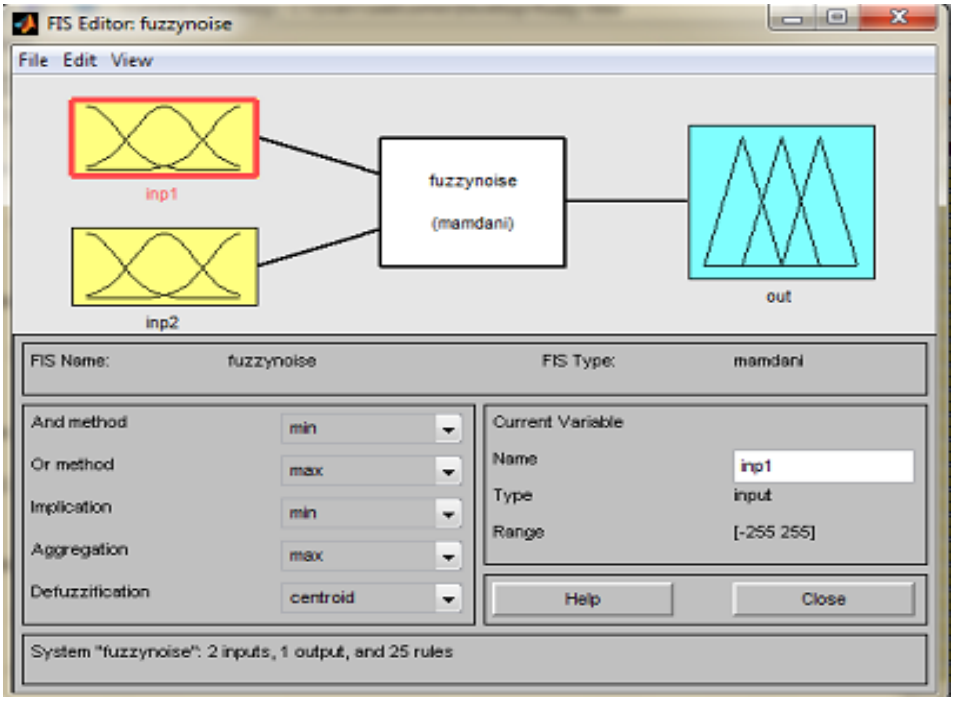

Figure 2. FIS with input and output

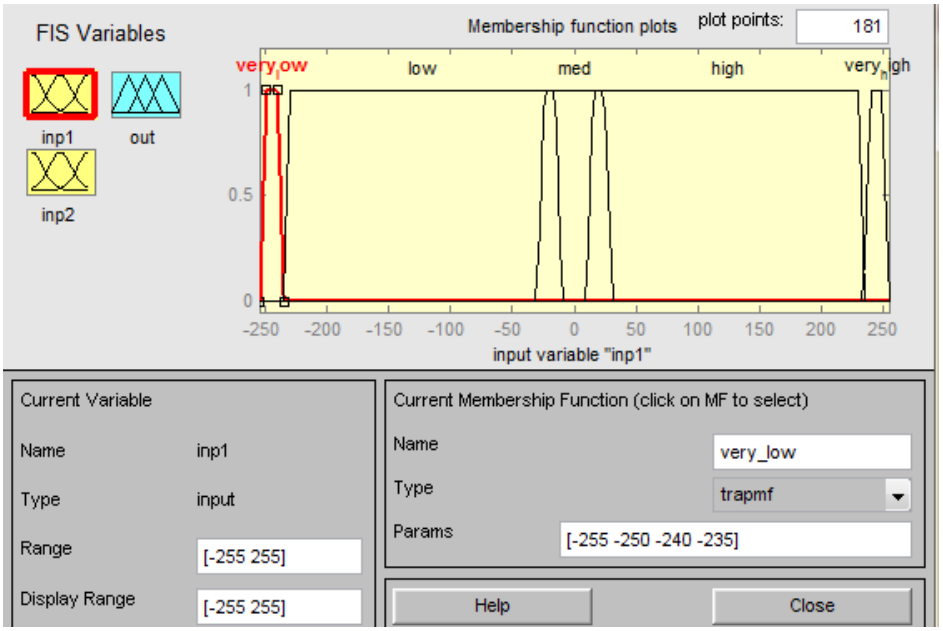

Figure 3. Membership function editor

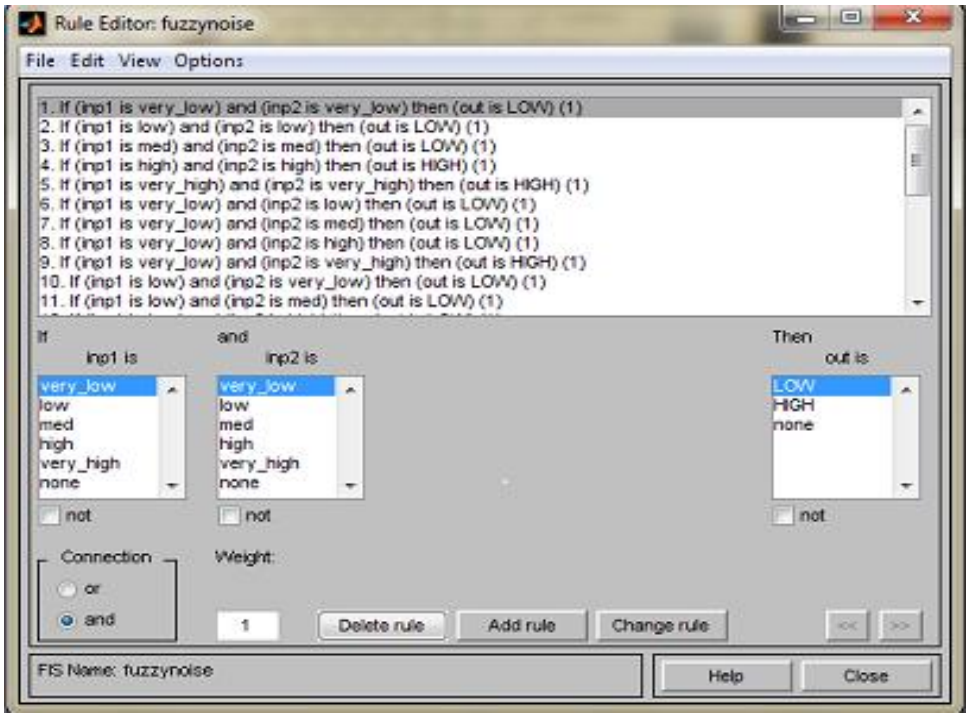

Figure 4. Rule editor

Figure 4 shows the rule editor for Matlab tool. The pixel is considered a noisy pixel if input 1 and input 2 i.e.; the differences of centre pixel with its neighbouring pixels is higher. Following are the rules considered for FIS:

If **inp1** is ***very low*** and **inp2** is ***very low*** then **output** is ***low***
If **inp1** is ***low*** and **inp2** is ***low*** then **output** is ***low***
If **inp1** is ***med*** and **inp2** is ***med*** then **output** is ***low***
If **inp1** is ***high*** and **inp2** is ***high*** then **output** is ***high***
If **inp1** is ***very high*** and **inp2** is ***very high*** then **output** is ***high***
If **inp1** is ***very low*** and **inp2** is ***low*** then **output** is ***low***
If **inp1** is ***very low*** and **inp2** is ***med*** then **output** is ***low***
If **inp1** is ***very low*** and **inp2** is ***high*** then **out** is ***low***
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If **inp1** is ***very high*** and **inp2** is ***med*** then **out** is ***high***
If **inp1** is ***very high*** and **inp2** is ***high*** then **out** is ***high***

In case of the centre pixel which belongs to a one line thick line, the FIS may signal a noisy pixel. To avoid such situations, a three layered technique is used in which the output of first layer is fed to second layer and so on.

5. Results

We conducted extensive experiments on synthetic as well as natural images and computed PSNR value for each. The PSNR is then compared with mean filter results as well as median filter results. Following are the results of the same.

TABLE 1: COMPARATIVE RESULTS IN PSNR (DB) OF DIFFERENT FILTERS FOR LENNA IMAGE CORRUPTED WITH SALT AND PEPPER NOISE

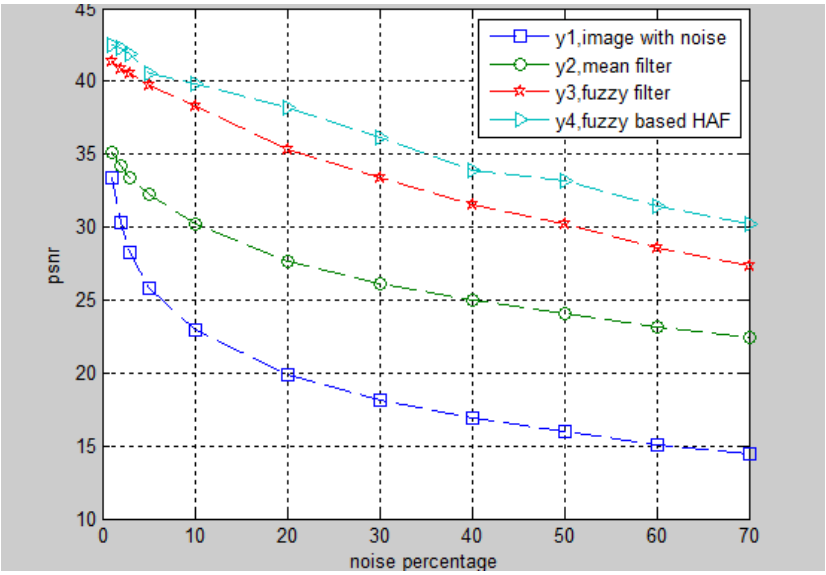
NP %	Filtering Techniques		
	Mean Filter	Fuzzy Filter	Fuzzy based HAF
1	35.1340	41.3238	42.4772
2	34.1683	40.8069	42.2556
3	33.4115	40.5509	41.9061
4	32.3040	39.7077	40.5690
10	30.2081	38.3102	39.8069
20	27.6814	35.3673	38.2126
30	26.1552	33.4299	36.1271
40	24.9798	31.5343	33.9347
50	24.0438	30.1847	33.1339
60	23.1996	28.5489	31.4157
70	22.4764	27.3113	30.2154

Figure 5. Restored results of enlarged *Lena* image corrupted with 40% of salt and pepper noise (a) True image, (b) Noisy image, (c) Mean Filtering, (d) Fuzzy filter (e) Fuzzy based histogram adaptive filter (HAF)

(a) (b) (C)

(d) (e)

Figure 6. Performance comparison of different filtering methods on image degraded by salt and pepper noise



5. Conclusion

It is clear from the results section that the proposed technique outperforms the well-known denoising filters called Mean filter and fuzzy filter. The proposed technique, as it is based on fuzzy logic, is well versed in handling the vagueness of information contained in noisy digital images.

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