

Image Denoising Technique Using Hybrid Fuzzy-Local Filter

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ABSTRACT: Visual information transmitted in the form of digital images is becoming a major method of communication in the modern age, but the image obtained after transmission is often corrupted with noise. Over the years a variety of methods have been introduced to remove noise from digital images. Image filtering is a technique of noise removal from images where the corrupted pixels are changed based on estimation of noises obtained from their neighbor pixels. called fuzzy filters first tries to classify a pixel as noisy or non noisy and if noisy modifies the pixel value. Over the years Fuzzy filters significant popularity because. The filtering comprises of two main steps: classification and filtering. In classification steps, pixels are classified as either noisy or non noisy and then noisy pixels are filtered. However, a fuzzy filter needs several iterations over large window size to approximate the noise. In this work we present a novel multi-pass Fuzzy based Colour image filtering using fuzzy ATMAV, ATMED and TMED filters and design a new filter called hybrid fuzzy filter. We show that the PSNR obtained through proposed method is better than all the conventional fuzzy filters.

KEYWORDS: Fuzzy Filter, Image Denoising, ATMED, ATMAV, TMED

I. INTRODUCTION

Image filtering is one of the most important areas of research in image processing and computer vision. The application extends to improving image visual quality in photographed image, removing blurring effect from images, eliminating noise effect generated from improper scanning and so on.

As such photographs are prone to be noise affected due to environmental, and light conditions. Also printed images are prone to get noise affected due to prolonged exposure to humidity and air. Image properties are generally represented by structural and texture information. Images like document images are sensitive near edges, where as natural images are insensitive near edges. Medical images are sensitive towards inner boundaries. Hence different images contains different information and therefore it is difficult to present generalized techniques that can offer satisfactory filtering performance for all the type of images. Conventional image filtering techniques fails to remove such noises due to particular properties of these images. Many images are scale sensitive. For instance a QR code generated for 300X300 dimensions will not be decoded when resized to 256x256.

Most of the existing image denoising technique including wavelets depends upon basis function. A basis function is a mathematical function that can be used to generate the image. Filtering techniques understands noise figure by comparing the basis function of the image and corresponding noise image. Wavelet is an extremely popular means of analyzing noise figure as it represents a multi scale basis function for the images. The parameters are selected in such a way that the aspect ratio remains same for all the scales. But the problem with curvelet transform is that images loses inter-structure and inter-texture zone information. Hence all the images need different approach for filtering.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

Fuzzy filters are new family of filters that promises to retain the characteristics of any type of images. Unlike other filters, these performs the filtering in two stages: firstly pixels are classified as noisy or non noisy and then filtering is applied on the noisy pixels. This is further performed in multiple iterations. In each iteration certain percentage of noise is eliminated. Therefore the method is more adoptive in nature and promises to deliver better quality filtering for broad variety of images.

II. PROPOSED WORK

The proposed technique is designed based on point operations in images. The approach first translates image to a fuzzy domain where pixel values are represented by HIGH, LOW, MEDIUM probability of noise. This process is also called fuzzification and the values forms a fuzzy set which is a finite set of values like Medium, HIGH, LOW. These values are quantified by a unique numbers. When the information in an image is transformed to one of these representation depending on the likelihood of a pixel to be noisy. The resultant image can be thresholded in fuzzy domain which results in a binary mask with noisy pixels being represented by white. Filter is applied only on the pixels that are “white” or high probable noisy in mask image.

This transform is an example of classical affine transform. The efficiency of this technique depends upon statistically consistent sub sampling of the images, i.e. defining a matrix on the image and allow independent operation over these sub images.

Main problem with the sub image based technique is that significant processing trail is left behind due to windowing. When an image is sampled with windows of same size, then algorithm fails at borders of every window. This is due to redundancy in information in two neighboring windows. A sliding window technique is used to overcome this obvious drawback of fuzzy based filters. Here, first an window is placed at a center pixel in a block and is then slided by a fixed sample in either direction.

Though sliding window based technique overcome classical fixed window filtering technique, it results in significant performance constraint in terms of reduces processing speed due to increase in number of operations to be performed as a whole. Both space and time complexity is further increased when window length is increased.

Therefore, we propose a hybrid technique with small window size and combining results of multiple filters, thereby utilizing the parallelism to maximum effect. This is overlapping sliding window method.

In each windows we find statistical minimum, maximum and mean value of the pixels..

In each of them an affine transform is applied using the fuzzy mean and variance which is calculated for every pixels in the window being analyzed. When the min and max values differs from the statistical mean of the set , the window is classified as having noisy pixels.

But such a deviation can be a result from edge effect too. Hence instead of classifying pixels as noisy, they are marked with fuzzy set depending upon the extend of variations.

This entire process is also known as Fuzzification process. Once entire image is fuzzified, we apply a membership function on Fuzzy image based on a statistical approach of fuzzy mean and variance. Final fuzzy image is obtained by using a weighted sum of the fuzzified values.

The weighted sum is calculated as either median fuzzy value or average fuzzy values. They are called Fuzzy Median and Fuzzy Average filters. Further if the weight is adaptive, i.e. if the weight changes based on the fuzzy values in a window, we call them adaptive filters. The weights used are membership degrees, which define the fuzzy partition. Detailed methodology is presented in next section.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

III. METHODOLOGY

We consider each image to be combination of three independent gray images separated out of three color channels. A gray level image is described by:

$$f : D \rightarrow E \tag{1}$$

where $D \subset R^2$ where R is radius over which pixels are same .We define D as a rectangle rather than circular area as

$$D = [x_0, x_1] \times [y_0, y_1] \tag{2}$$

Hence D is a window where pixels are referred as (x, y) .

Let there be

$$P = \{W_{ij} \mid (i, j) \in [0, m] \times [0, n]\} \tag{3}$$

a fuzzy partition of the window D .

Polynomial set given below is used as membership values,

$$qx_i : [x_0, x_1] \rightarrow [0,1],$$

$$qx_i(x) = C_m^i \frac{(x-x_0)^i (x_1-x)^{m-i}}{(x_1-x_0)^m} \tag{4}$$

$$qy_j : [y_0, y_1] \rightarrow [0,1],$$

$$qy_j(y) = C_n^j \frac{(y-y_0)^j (y_1-y)^{n-j}}{(y_1-y_0)^n} \tag{5}$$

$$p_{ij} : D \rightarrow [0,1],$$

$$p_{ij}(x, y) = qx_i(x) \cdot qy_j(y) \tag{6}$$

where $C_m^i = \frac{m!}{i!(m-i)!}$, $C_n^j = \frac{n!}{j!(n-j)!}$ and $(i, j) \in [0, m] \times [0, n]$.

The membership degrees of a point $(x, y) \in D$ in the fuzzy window W_{ij} is given by:

$$w_{ij} : D \rightarrow [0,1],$$

$$w_{ij}(x, y) = \frac{(p_{ij}(x, y))^\gamma}{\sum_{j=0}^n \sum_{i=0}^m (p_{ij}(x, y))^\gamma} \tag{7}$$

fuzzy membership function $w_{ij}(x, y)$ describe the position of the point (x, y) inside the window D .

The parameter $\gamma \in (0, \infty)$ controls the transform of fuzzification to defuzzification and vice versa with partition degree P .

For every window W_{ij} the fuzzy rule set also called cardinality $card(W_{ij})$ is the fuzzy mean $\mu_\phi(f, W_{ij})$ and the fuzzy variance $\sigma_\phi^2(f, W_{ij})$ of gray scale image f and is defined as below:

$$card(W_{ij}) = \sum_{(x,y) \in D} w_{ij}(x, y) \tag{8}$$

$$\mu_{\varphi}(f, W_{ij}) = \left\langle + \right\rangle_{(x,y) \in D} \left(\frac{w_{ij}(x,y)}{\text{card}(W_{ij})} \langle \times \rangle f(x,y) \right) \tag{9}$$

$$\sigma_{\varphi}^2(f, W_{ij}) = \sum_{(x,y) \in D} \frac{w_{ij}(x,y) \| f(x,y) \langle - \rangle \mu_{\varphi}(f, W_{ij}) \|_E^2}{\text{card}(W_{ij})} \tag{10}$$

We present classical fuzzy filter in figure 1 and show the above equations as a block diagram in following figure 2.

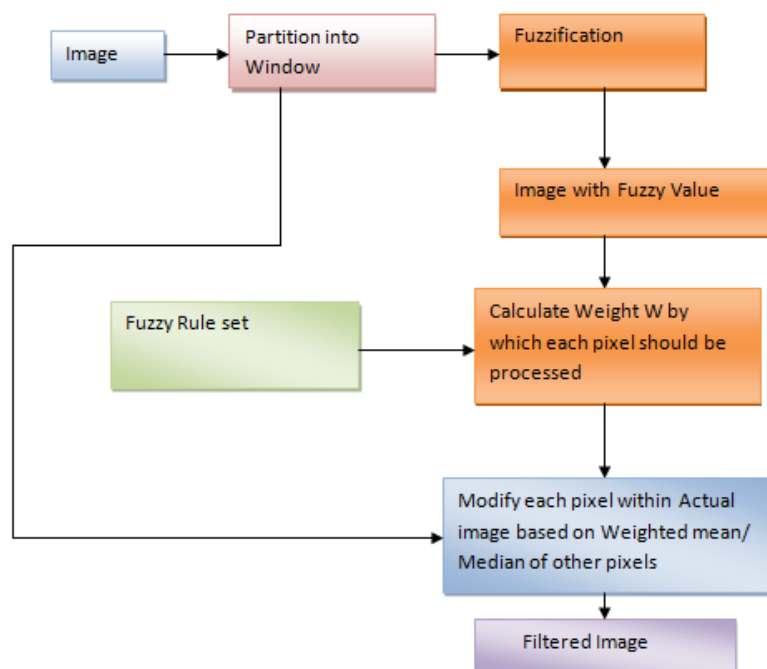


Figure 1: Classical Fuzzy Filter

The above diagram is classical fuzzy filtering. We update the approach with a multipass filtering where the output of one filter stage is filtered with another filter stage.

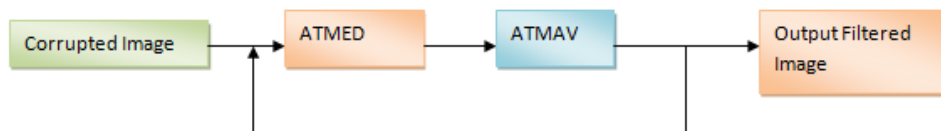


Figure 2: Design of proposed technique

Proposed technique therefore is not only more efficient in terms of computation but also better in handling noise as it takes into consideration of the result of different stages.

IV. RESULTS

We perform the analysis on two different type of images in order to understand the effect of filtering better. We applied the filters on digital photographs, Logos. Results are presented below.

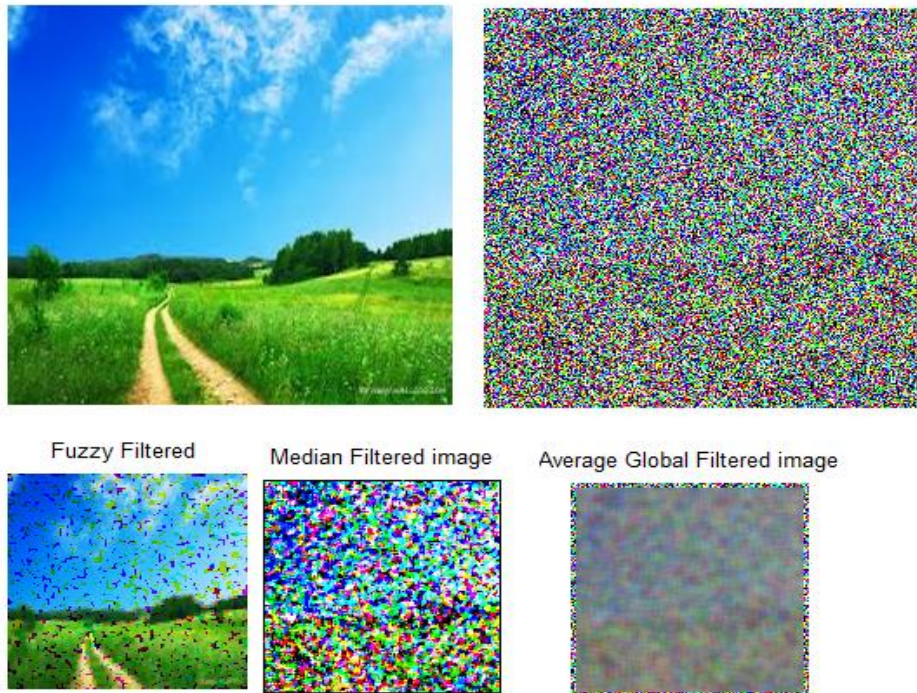


Figure 3: Result of performance on a natural photograph with 90% Salt and Pepper noise.

It can be clearly seen that the proposed technique is able to recover the image better under high noise. We can see the result when less amount of noise is applied in figure 4.

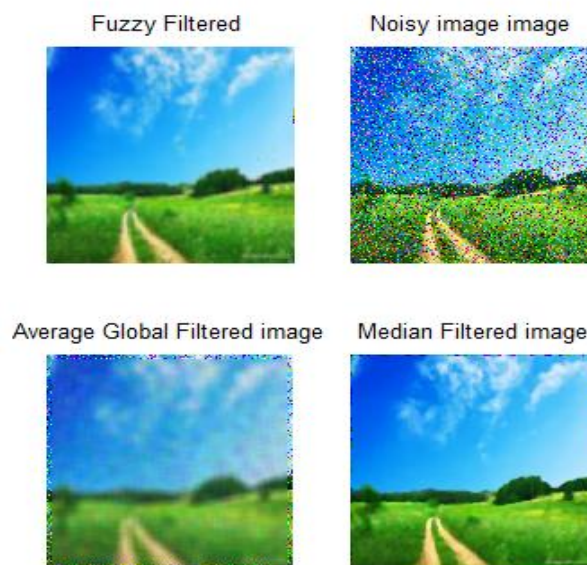


Figure 4: Effect of filtering for salt and pepper noise of 10%.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

Here also we can see that the proposed technique performs better than all other filters. We now apply the filters on a logo image. Logo images are strong representation of structured images and therefore is a good candidate for testing filter performance.



Figure 5: Performance comparison of filters on structural image

It can be seen that median filters perform better for this class of images. This is because structural information are more homogeneous and therefore needs filters that can retain the structure better. From our analysis it is evident that the proposed method is not suitable for structured image as large amount of redundant data in a window is wrongly classified as noise. However when the same experiment is conducted for large noise, fuzzy filter's performance was found to be more satisfactory.

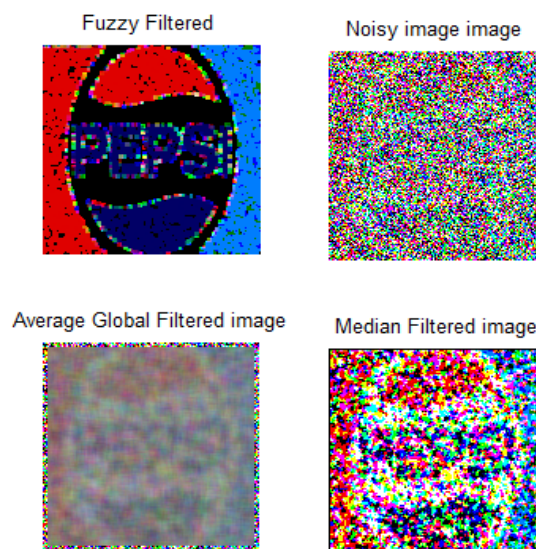


Figure 6: Performance of the filtering techniques for 90% Salt and Pepper Noise

We also analysed the performance on a face image. Filtering is one of the major pre-processing steps in many computer vision applications. Face recognition is one of the most popular areas of research. Hence we applied the filters on face images.

Further we compare the results for various level of noise and present the cumulative result in table 1.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

% Noise SPN	ATMED	Proposed Hybrid	Median
10	MSE=262.3978 PSNR=23.9412 db Ed=48.9717%	MSE=206.3843 PSNR=24.984 db Ed=44.8586%	PSNR 31.292 ED=32%
20	MSE=227.6676 PSNR=24.5578 db Ed=48.072%	MSE=206.882 PSNR=24.9736 db Ed=45.2442%	PSNR 27.266 ED=31%
30	MSE=215.0234 PSNR=24.8059 db Ed=44.6015%	MSE=205.2403 PSNR=25.0082 db Ed=39.7172%	PSNR 22.760 ED=23%
40	MSE=221.057 PSNR=24.6858 db Ed=41.9023%	MSE=209.2072 PSNR=24.925 db Ed=40.7455%	PSNR 18.435 ED=11%
50	MSE=270.297 PSNR=23.8124 db Ed=37.7892%	MSE=216.8069 PSNR=24.7701 db Ed=34.5758%	PSNR 14.952 ED=9%
60	MSE=471.837 PSNR=21.3929 db Ed=34.8329%	MSE=230.959 PSNR=24.4955 db Ed=35.2185%	PSNR 12.130 ED=8%
70	MSE=1189.4289 PSNR=17.3774 db Ed=22.6221%	MSE=350.9195 PSNR=22.6787 db Ed=26.3496%	PSNR 9.857
80	MSE=3111.7898 PSNR=13.2007 db Ed=10.4113%	MSE=1025.0146 PSNR=18.0235 db Ed=12.2108%	PSNR 7.982 ED=2.7%
90	MSE=7796.8423 PSNR=9.2116 db Ed=6.0411%	MSE=5162.0475 PSNR=11.0026 db Ed=4.7558%	PSNR 6.502 ED=1.1%

It can be clearly seen from table 1 that median filter fails to retain edge information and it smoothens the images on the edges. Fuzzy filters retain edge information better. However even among fuzzy filters proposed hybrid filter performs better. Visual analysis on lena image is shown in figure 8.

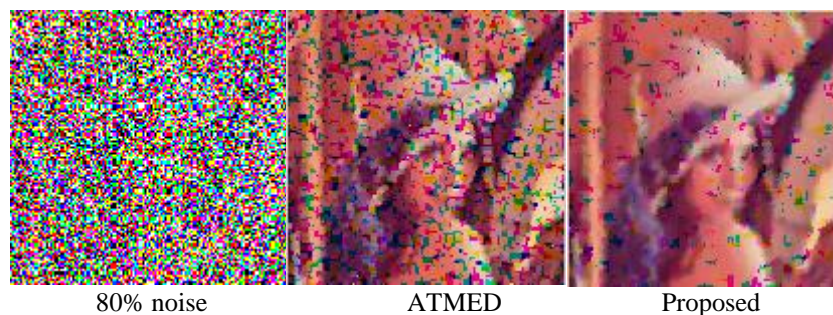


Figure 8: Performance of filters for Lena image.

V. CONCLUSION

I have implemented an image denoising technique using hybrid fuzzy local filter. In my work I have shown that the PSNR obtained through the proposed method is better than all the conventional fuzzy filters and I have found that this is more satisfactory.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

Here I have also shown that the proposed technique performed better than all other filter therefore it is evident that proposed technique can also be used as a pre-processing step in applications like image segmentation and pattern recognition.

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