An Optimized Neuro-Fuzzy Network based Image Denoising Techniques

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\textbf{Abstract.} Neuro-Fuzzy (NF) system is used in various field of research. Neuro-Fuzzy systems combining neural networks and fuzzy set theories can be employed as powerful tools for the removal of impulse noise from various images. Neuro-Fuzzy system is based on a fuzzy system which is trained by learning algorithm derived from neural network theory. The learning procedure operates on local information, and causes local modifications in underlying fuzzy system. Image noise is random (not present in the object image) variation or brightness or color information in images, and is generally an aspect of electronic noise. It can be produced by sensor and circuitry of scanner or a digital camera. Images are often corrupted by noise during the acquisition or transmission process. The goal of denoising is to remove the noise while retaining as much as possible the important signal features of an image. Neuro-Fuzzy network based impulse noise filtering for gray scale images is presented. The proposed method is constructed by hybrid technique of Mamdani and Sugeno based fuzzy interference system approach followed by Optimized intelligent water drop (IWD) technique, Tuning parameter approach, Optimized fuzzy intelligence noise filter approach. As demonstrated by experimental results, Peak signal-to-noise ratio (PSNR) and Root Mean Square Error (RMSE) possess better performance. The proposed filter has some advantages over its competitors. The hybrid rule is applied to reduce the error of the optimization. In hybrid based fuzzy interference system approach, the system develops a fuzzy logic based scheme to filter a noisy signal. This can be applied in various sources to reduce noise. A one input and output Mamdani fuzzy interference system is designed for the filter where the input is a noisy signal and output is a filtered output. Fuzzy rules have been used to obtain the filtered output.

\textbf{Keywords:} Neuro-Fuzzy, image processing, hybrid technique.

\textbf{INTRODUCTION}

Noise is any undesired information that contaminates an image. Noise appears in an image from a variety of sources. Removal of noises from the images is a critical issue in
the field of digital image processing. Image denoising is an important image processing task both as a process itself, and as a component in some other processes. The main property of a good image denoising model is that it will remove noise while preserving edges. Usually, linear models have been used. But the back draw of a linear model is that they are not able to preserve edges in a good way. Edges, which are recognized as discontinuities in the image, are smeared out. Thus noise cancellation or noise filtering is an important task in image processing, mainly when the final product is used for edge detection, image segmentation, and data compression.

The neuro fuzzy network based image denoising for gray scale images is presented in this paper. In this case, non linear techniques perform better than linear filters. This leads to blur the edges. The impulse noise filter consists of two modes of operation, namely, training and testing (filtering). During training process, each Neuro-Fuzzy (NF) filter is trained individually by using a simple artificial training image and the internal parameters of each NF filter are adaptively optimized. During testing process, the outputs of two NF filters are fed to the postprocessor, which in turn generates the final output of the proposed filter. The main filtering methods to remove the noise from images are based median filtering techniques

The paper is organized as follows. In section 2, the proposed method of neuro fuzzy filter and the hybrid technique is discussed. The experimental analyses are described in section 3 and the final section summarizes the paper.

THE PROPOSED METHOD

The proposed system deals with operating the pixel values. Two district pixels are obtained in the 3-by-3 pixel filtering window. Hence, the first pixel takes the horizontal direction and the corresponding second pixel obtains the vertical direction. In figure 1 the middle pixel P2 is the existing one under in operation, the rest pixels P1 and P3 are mentioned for operations centering the middle P2 pixel.

(a) ![Vertical direction](image1.png)
(b) ![Horizontal direction](image2.png)

**FIGURE 1.** Two neighbourhood pixels. (a) Vertical direction, (b) Horizontal direction.
Fuzzy rules have been used to obtain the filtered output. The de-fuzzier filter output has been obtained using centroid method. In Mamdani based fuzzy interference system (FIS) Approach $m_{11}, m_{12}, m_{13},...$ are the membership function. The membership values take place between 0 to 1. The membership function gives the best solution for remove the noisy from various images.

The four inputs of each NF filter, $x_1, x_2, x_3, \text{ and } x_4$, can be defined as follows:

\[
\begin{align*}
X_1 &= p_{1} - m \\
X_2 &= p_{2} - m \\
X_3 &= p_{3} - m \\
X_4 &= m.
\end{align*}
\]

**Neuro Fuzzy System**

A neuro-fuzzy system is a fuzzy system that uses a learning algorithm derived from or inspired by neural network theory to determine its parameters (fuzzy sets and fuzzy rules) by processing data samples. Modern neuro-Fuzzy systems are usually represented as special multilayer feedforward neural networks. However, fuzzificatios are also considered, for example self-organizing feature maps. A neuro-fuzzy system is based on a fuzzy system which is trained by learning algorithm derived from neural network theory. The learning procedure operates on local information, and causes only local modification in the underlying fuzzy system.

A neuro-fuzzy system can be viewed as a 3-layer feedforward neural network. The first layer represents input variables, the middle (hidden) layer represents fuzzy rules and the third layer represents output variables. Fuzzy sets are encoded as connection weights. Sometimes 5-layer architecture is used, where the fuzzy sets are represented in the units of the second and fourth layer.

The internal structures of the two NF filters are identical to each other. Each of them is a first order Sugeno type fuzzy inference system with 4 inputs and 1 output. Each input has three generalized bell type membership functions and the output has a linear membership function. While the NF filter has 4 inputs and each input has 3 membership functions, the rule base contains a total of $81(3^4)$ rules defined as follows:

\[
\begin{align*}
\text{Rule 1:} & \quad \text{if} \quad (x_1 \text{ is } M_{11}) \quad \text{and} \quad (x_2 \text{ is } M_{21}) \quad \text{and} \quad (x_3 \text{ is } M_{31}) \quad \text{and} \quad (x_4 \text{ is } M_{41}) \quad \text{then} \quad y_1 = d_{11}x_1 + d_{12}x_2 + d_{13}x_3 + d_{14}x_4 + d_{15} \\
\text{Rule 2:} & \quad \text{if} \quad (x_1 \text{ is } M_{11}) \quad \text{and} \quad (x_2 \text{ is } M_{22}) \quad \text{and} \quad (x_3 \text{ is } M_{31}) \quad \text{and} \quad (x_4 \text{ is } M_{42}) \quad \text{then} \quad y_2 = d_{21}x_1 + d_{22}x_2 + d_{23}x_3 + d_{24}x_4 + d_{25} \\
\text{Rule 3:} & \quad \text{if} \quad (x_1 \text{ is } M_{11}) \quad \text{and} \quad (x_2 \text{ is } M_{23}) \quad \text{and} \quad (x_3 \text{ is } M_{31}) \quad \text{and} \quad (x_4 \text{ is } M_{43}) \quad \text{then} \quad y_3 = d_{31}x_1 + d_{32}x_2 + d_{33}x_3 + d_{34}x_4 + d_{35} \\
\text{Rule 81:} & \quad \text{if} \quad (x_1 \text{ is } M_{13}) \quad \text{and} \quad (x_2 \text{ is } M_{22}) \quad \text{and} \quad (x_3 \text{ is } M_{33}) \quad \text{and} \quad (x_4 \text{ is } M_{43}) \quad \text{then} \quad y_{81} = d_{81}x_1 + d_{82}x_2 + d_{83}x_3 + d_{84}x_4 + d_{85}. 
\end{align*}
\]

where $M_{ij}$ denotes the $j$th membership function of the $i$th input, $y_k$ denotes the output of the $k$th rule, $d_{kl}$ is the consequent parameter, $i = 1; 2; 3; 4$, $j = 1; 2; 3$, $k = 1, \ldots, 81$, $l = 1, 2, 3, 4, 5$. 

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The hybrid technique

To deal with the problem of the image, the current work contributes the following methods for noise reduction. The proposed method is constructed by the following approaches,

1. Hybrid technique of Mamdani and Sugeno based fuzzy interference system approach,
2. Optimized intelligent water drop(IWD) technique,
3. Tuning parameter approach,

This system is constructed by combining two NF filters with a postprocessor. Each of the two NF filters is a first order Sugeno and Mamdani type fuzzy inference system with 4-inputs and 1-output. As for each pixel of the input image, the four inputs of each NF filter, x1, x2, x3, and x4, are obtained by selecting the data block, respectively. The system develops a fuzzy logic based scheme to filter a noisy signal. This can be applied in various sources to reduce noise. A one input and one output Mamdani fuzzy interference system is designed for the filter where the input is noisy signal and the output is a filtered output.

![Diagram](image)

**FIGURE 2.** The structure of hybrid technique method

Noise is a factor that degrades the quality of images, so we need to use an efficient technique to remove the noise from the image. Fig.2 shows the structure of hybrid technique, where the noisy signal is the input and the output is a filtered output.

**EXPERIMENTAL RESULTS**

Experimental results are presented in this section to demonstrate the performance of the proposed hybrid technique of Mamdani and Sugeno based fuzzy interference system approach. In our simulation, six original images shown in Fig. 3 are 8-bit gray scale images with the same size of 256-by-256 pixels. The system method has used the design of experiments in order to find an optimum combination of parameters, which could have an effect on the performance of the system.
The system considered peak signal-to-noise-ratio (PSNR) for finding the optimum combination of parameter and Root mean square error (RMSE). The peak signal-to-noise ratio, abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Since many signals have a very wide dynamic range, PSNR is generally expressed in terms of the logarithmic decibel scale. The mean squared error (MSE) of an estimator is one of many ways to quantify the difference between values implied by an estimator and the true values of the quantity being anticipated. MSE is a risk function, corresponding to the expected value of the squared error loss or quadratic loss. MSE measure the average of the squares of the "errors." The error is the amount by which the value implied by the estimator differs from the quantity to be anticipated. The difference occurs because of randomness or because the estimator doesn’t account for information that could produce a more accurate estimate.

**TABLE (1).** Comparison of PSNR values for different images.

<table>
<thead>
<tr>
<th>Name of the image</th>
<th>NF(Sugeno)</th>
<th>NF(Hybrid technique)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airplane</td>
<td>33.2734</td>
<td>42.7512</td>
</tr>
<tr>
<td>Barbara</td>
<td>39.5834</td>
<td>43.9042</td>
</tr>
<tr>
<td>Baboon</td>
<td>37.5293</td>
<td>42.2369</td>
</tr>
<tr>
<td>Boat</td>
<td>37.9497</td>
<td>44.0316</td>
</tr>
<tr>
<td>Leena</td>
<td>39.0300</td>
<td>44.6049</td>
</tr>
<tr>
<td>Peppers</td>
<td>42.2369</td>
<td>42.7693</td>
</tr>
</tbody>
</table>
TABLE (2). Comparison of RMSE values for different images.

<table>
<thead>
<tr>
<th>Name of the image</th>
<th>NF(Sugeno)</th>
<th>NF(Hybrid technique)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airplane</td>
<td>1.3699</td>
<td>0.5034</td>
</tr>
<tr>
<td>Barbara</td>
<td>0.6876</td>
<td>0.4179</td>
</tr>
<tr>
<td>Baboon</td>
<td>0.8710</td>
<td>0.3422</td>
</tr>
<tr>
<td>Boat</td>
<td>0.8298</td>
<td>0.4120</td>
</tr>
<tr>
<td>Leena</td>
<td>0.7328</td>
<td>0.3857</td>
</tr>
<tr>
<td>Peppers</td>
<td>0.5066</td>
<td>0.4764</td>
</tr>
</tbody>
</table>

The above table shows, the proposed hybrid method of Mamdani and Sugeno performed well than the existing one. The proposed method of PSNR results in higher value and the MSE gives the least effective among the methods compared. It is easy to implement over smooth the images.

CHART(1). COMPARISON OF PSNR VALUES FOR DIFFERENT IMAGES.

CHART(2). COMPARISON OF RMSE VALUES FOR DIFFERENT IMAGES
CONCLUSION

An optimized neuro-fuzzy network based image denoising technique for gray scale images was presented in this paper. The proposed method is constructed by hybrid technique of Mamdani and Sugeno based fuzzy interference system approach followed by Optimized intelligent water drop (IWD) technique, Tuning parameter approach, Optimized fuzzy intelligence noise filter approach. As supported by the simulation results, the proposed technique compares favorably with conventional techniques in the capabilities of noise reduction and detail preservation.

REFERENCES