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An analysis of various noise removal techniques to enhance image quality

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Abstract

Objective: To analyze the state of the art techniques for noise removal and find an efficient technique that overcomes the major problems. The impulse noise in particular destroys the quality of the image.
Method: The research includes analysis of a number of noise removal or denoising techniques for the image quality enhancement. The different effective techniques are considered to find the suitable most efficient technique. In this paper, various efficient techniques for the noise removal in image are analyzed and evaluated.
Results: The techniques analyzed have better performance than their predecessors but still cannot provide complete satisfaction. If the features of every method presented are combined together it enables better results which are impossible, as this hybrid technique can completely destroy the image. The performance evaluation conducted shows that the neuro-fuzzy network based noise removal method removes the noise, especially the impulse noise and retrieves the original image with high quality by preserving the sharpness of edge and detail information.
Conclusion: The neuro fuzzy network based method has better and more efficient performance than the other techniques.

Keywords: Neuro fuzzy network, impulse noise, transmission errors

1. Introduction

Image denoising is an important task in the image processing as the final images are utilized for image segmentation and compression processes. The images are often affected by the noises in such a way it is difficult to view the original image with perfect sharpness. The images get blurred and the information of quality are corrupted due to the problems in transmission that causes error portions to be added to the images. This causes the image to degrade from its originality and appear as a poor image unable to provide clear vision. The images are also corrupted by the use of the noisy sensors. The sensors used in the data collection and processing can cause external noises to be included while processing. The high noises generated at the sensors or other instruments changes the size and quality of an image.

The impact of noises in the images is a major concern particularly in the monitoring applications of health care, weather, etc. The impulse noise is a form of noise that is incorporated into the images by the sensors and other random tools used in the processing. The impulse noise is the dominant noise forming bright or dark spots in the original image that are not authentic imagery. The impulse noise causes a state of blur known as salt and pepper due to its behavior of corruption with bright and dark spots. The cause of the noise is due to errors in the analog-to-digital or digital-to-analog conversions, transmission errors and noise from the electromagnetic equipment. The spots are random and hence the uniform noise removal techniques are inadequate to tackle this noise. The techniques like median filtering and dark frame subtraction can be utilized to remove impulse noise. But the randomness in the placement of the dark/bright spots causes the techniques to deep analyze the image that in turn destroys the overall quality of the image even without noises. Hence the noise removal techniques are needed to construct in such a way it reduces noise effect but does not alter the image quality.

The analysis of the techniques to remove noise elements in the image mainly focus on the identification of the suitable method. Various methods have been discussed in detail in order to evaluate their performances so that it would provide the most efficient technique. The techniques have been presented concentrating mainly on the efficient removal of impulse noise. The impulse noise removal in general is processed by the removal of the corrupted pixel irrespective of the location information and finer details in it. This results in the reduction of image quality.

Most of the image noise removal techniques do not focus on the retrieval of the quality information but only on the noise removal. This mechanism cannot enhance the image as it reduces the edge and finer details. Most of the techniques aim to achieve its goal of noise removal using comprehensive techniques that suits the images. Thus the techniques provide better performance but only at the cost of image quality degradation.

In this research, the main contribution is to deep analyze each method and conclude with the best technique in the literature in terms of noise removal and image quality enhancement. The organization of the research is given as follows:

In this section, a brief introduction is given about the noisy images and the cause and effect of noises in the processing system. In section II, various research methodologies are that are to be evaluated are discussed in a detailed manner. In section III, the techniques presented in section II are compared with their benefits and issues. In section IV the methods are evaluated and the numerical results obtained are discussed. Finally in section V, the overall conclusion of the research work is presented.

2. Analysis of research methodologies

[1] Presented a novel two stage noise removal algorithm to tackle the impulse noise. This approach, as the name suggests, is a two stage process. In the first stage, an adaptive two-level feed forward neural network (NN) is presented along with a back propagation training algorithm. This application helps in removing the noise cleanly and maintains the uncorrupted information. The method is a two level approach which includes removal of noisy pixels and then the removal of misclassified noise pixels. The NN uses the gray-level difference (GD), average background difference (ABD), and accumulation complexity difference (ACD) mechanisms. In the first level classifies the pixels and identifies the noisy pixels. Then it filters the pixel alone without removing the image details. The second level of NN detects and removes the misclassified pixels that are noisy but averted in the first level. In the second stage, the fuzzy decision rules are introduced to enhance the image quality. The model consists of a fuzzy decision module, an angle evaluation module and an adaptive compensation module. The fuzzy decision module is inspired by the human visual system (HVS) which classifies the image pixels into human perspective sensitive class and non-sensitive classes. This reduces the blur of the images. The angle of human perception is evaluated that improves the pixel classification and introduces human like monitoring. The adaptive median filter is implemented finally to selectively improve the edges and the finer details of the image.

The main advantage of this algorithm is that it detects and removes the noises along the edges with a short time. But still there is drawback in the approach that it cannot suit all types of images as the noise densities vary with the type of image.

[2] Presented a novel filter technique using fuzzy to remove the random impulse noise in the color image sequences. The fuzzy filtering technique consists of three successive filtering steps. In the first step, the detection process is carried out by calculating a degree each for which the pixel is noise-free and another degree for which the pixel is considered to be noisy. The degree is calculated using the fuzzy rules. If the noisy degree is greater than noise free degree, then the pixel is noisy and the filtering is employed. The filtering technique removes the noise in the red color band alone as the other color bands are analogous. The pixels having less noise components but with a high noise free degree are filtered using displacement vectors to remove noise portions. Some of the pixels may be left out of filtering as they are incorrectly assigned as the noise free pixels. These pixels can be filtered in the second step of filtering. In the next filtering step, the output of first filtering is taken as the input. The pixels are further evaluated using a different degree finite than the first step. The other two color bands are also considered to detect the difference of the noisy and noise free pixels. In the third filtering technique, temporal, spatial and color informations are also considered. This step enables the removal of isolated noise elements in the red color band with high accuracy. Thus the noise can be removed without removing the edge and finer details of the image.

The fuzzy filtering technique does not consider the green and blue color bands as they are analogous but the noise elements in some images may be duly present in these color bands. Hence a hybrid technique combining the features of the two above techniques is presented in the following approach.

[3] Presented the hybrid technique consisting of two stages- the fast adaptive neural fuzzy interference system (ANFIS) and fuzzy decision system. In the first stage, the noise removal is done using the ANFIS. The approach uses the widespread densities of the noisy pixels that differentiate the edge details to remove the noise accurately. It uses the Modified Levenberg-Marquardt training algorithm to train the neural networks inorder to reduce the execution time. The approach initially classifies the pixels into noisy and noise free. Then the ANFIS approach removes the impulse noise by background removal and grey scale detection. The misclassified pixels if present are then analyzed to retrieve the finer details of the images. After the impulse noise suppression, the corrupted pixels are needed to be enhanced. The fuzzy decision system based on the concept of human visual system is introduced to analyze the image details and a NN is implemented to retrieve the image details to enhance the quality. The method computes three degrees namely, structural degree, visibility degree and complexity degree to determine the features of the image that are required to improve the sharpness of the image. The method uses a hyper trapezoidal fuzzy membership function for the analysis of the image and NN for image compensation that preserves the image quality by suppressing only the noise content. The approach overall removes impulse noise to the maximum limit.

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Though the method is efficient for perceptual image quality, it does not consider the noise elements in the pixels with less noise degree. It considers only the pixels with higher noise degree.

[4] Suggested a hybrid method to remove the impulse noise along with the Gaussian noise and the mixed noise. The method uses a combination of appropriate noise filter, an edge detector and ANFIS to remove the noises and enhance the quality. The ANFIS initially constructs a neural network to remove the impulse noise. Then the random weights are feed in a series process to train the NN. The FIS is created to make efficient decision system. This approach readily removes the impulse noise effectively. The median filter is accompanied in the process to eradicate noise by differentiating the image components. The Gaussian noise filter is used to filter the pixels with the noise. The method efficiently analyzes the different type of edge detectors namely canny, sobel and prewitt. The analysis results indicate that the canny edge detector is more effective than the other detectors. The sobel and the prewitt detectors return the edges at the points where the gradient of the image is maximum. Hence the canny detectors are preferred as they remove the impulse, Gaussian and mixed noises effectively at all edges. The canny detector detects the edges by considering the local maxima of the gradient image. The detection method uses two thresholds, one for strong while the other for weak edges. Unlike other detectors, canny detector is not sensitive to noise and hence detects the weak edges accurately with less error rates. Thus the method is highly efficient in preserving the thin lines; texture and fine edge details while noise removal.

[5] Suggested a method based on partial differential equations (PDE) for the denoising of the images. The method has been prescribed for the noise removal in the remote sensing images. The PDE utilizes the auxiliary noise free images as priors to compare the images. The prior images are noise free and are utilized by the help of a smoothing term. The prior images are fed into the PDE denoising method to compute the variation of the corrupted images. The smoothing term is a specific smoothing direction with a specific smoothing index of the prior image. The images are compared with the reference image with consideration over the multi-component image of different bands. The variation in the direction of the edges of the noisy images when compared with the reference image helps in deletion of the noise elements [6] and preserves the details during the denoising process. The PDE denoising method enables the noise removal for the applications of geographical and climatic monitoring thus effective in accurate results. The remote sensing images are usually multispectral in nature requiring valiant features to evaluate the pixels and noise removal. The PDE provides the noise removal with less errors providing best edge construction.

The PDE denoising method reduces the complexity of the noise removal in remote sensed images but the process is highly suitable only for wider color band images. In order to overcome this problem, In [7] presented a VLSI based architecture but it has high implementation cost. The method focused on replacing the existing infrastructure with a fully in-built architecture. Hence the method is not considered for practical small scale applications.

[8] Introduced a quaternion vector filter to remove the random impulse noise in the color video images. The filtering technique consists of two successive steps, impulse detection and noise removal. The luminance distances and the chromaticity differences presented in quaternion form are computed to measure the color distances between the image pixels. The color distances are used to determine the noise level in a pixel. If a pixel has higher noise level it is filtered first in a deep filter mechanism. The spatio temporal features are also utilized to differentiate the noisy and noise free pixels and then the noise free pixels are preserved. In the final processing stage, the 3D weighted vector median filtering is employed to suppress the noise in the noisy pixels only. The noise free pixels are conserved while the noisy pixels after denoising are enhanced to preserve the edge details. The method overall provides better results than its predecessors.

The quaternion vector filter though has its own drawback. The weight based filtering needs weighted pixels that vary with the change in chromaticity.

[9] Presented a new hybrid neuro-fuzzy filtering technique that helps in restoring the corrupted digital images. The digital images are generally corrupted by impulse noise at the time of image acquisition. The hybrid technique comprises of a non-linear filter, a canny edge detector and the ANFIS. The neural network is initially formed to train the images. The neural fuzzy approach analyzes the images and suppresses the noises. The corrupted images are compared with a noise free image to detect the edges. This edge detection is possible only with the canny detector as other detectors are prone to noise. The canny detector traces the edges at the similar direction of the reference image. The non-linear filter generally filters the normal noises generated due to the transmission. The fuzzy system interprets the constraint learning in the classifier approximation. The images are processed in raster scanning fashion that helps in detail analysis of the image. The luminance values are interpreted to preserve the quality after image denoising. The approach is adaptive in nature and hence can be utilized in the real time applications.

The hybrid neuro-fuzzy filtering technique is efficient in impulse noise removal but it is similar to the previous methods in the fact that it provides noise removal only in the noisy pixels but not the noise free pixels which has

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minor noise elements. Due to such problems in these techniques, the following approach which seems far better in performance is presented.

[10] presented a filtering technique based on the neuro-fuzzy network to suppress the impulse noise in the grayscale images. The technique implements two neuro-fuzzy filters with a post processor to suppress and enhance the image. The neuro fuzzy filters are usually the first order sugeno type filter with four inputs and one output. The NF filters evaluates a different relation between the median values of all the pixels in a predefined selecting data window for the estimation of noisy pixels. The processing of noisy images is performed by two stages namely, training and testing phase. The training of the neuro fuzzy network is by using a reference image to adapt the internal optimization parameters of the network. The samples are extracted from the noise free images to train the network. In the testing phase the noisy images are processed in the two neuro-fuzzy networks by comparing the corrupted images with the reference image. Then they are post processed to obtain the noise removed images. The method has better optimization performance and better convergence speed.

Thus the above discussed method has been identified as the better technique as the approach provides deep analysis of the pixels and removes the noise elements in all pixels. The efficiency of this approach is better than the other techniques and also it provides pathway for further improvement.

[11] Proposed adaptive weighted median filter to remove the impulse noise in the images and preserve the edges considerably. The conventional methods apply the filter to all the pixels which alters the intensity of the images. Hence the proposed filter identifies the noise pixels alone and then removes the salt and pepper noise from them. [12] Proposed an efficient re-ranking method using the incremental learning and hashing approach in which the noise removal is carried out by removing background interferences. The approach includes extraction of visual features with effective noise filtering.

[13] Proposed a denoising approach called PURE-LET for denoising medical images corrupted with Poisson noise. PURE-LET uses bilateral filtering technique for the noise removal. Similarly, [14] proposed a method called Parallel Fuzzy Inference System (PFIS) for image denoising in the medical images. The PFIS approach processes a dissimilar neighbourhood association between the center pixels of the image and generates the fuzzy inference rules to remove noise in the medical images. Though the methods are efficient, the noise removal can be further enhanced to preserve the image quality using improved filtering techniques.

3. Comparison of Methodologies

This section provides an overview about the pros and cons that are occurred in the research methodologies whose functional scenarios are discussed in depth in the previous section. From the following table 1, it can be predicted a better approach that provides considerable improvement in the proposed scenarios. The table helps in detecting the efficient technique as well as in provisioning the future enhanced than can be performed to overcome its shortcomings.

4. Numerical results

The evaluation tests has been conducted using MATLAB to find the better simulation approach that can lead to efficient noise removal with improved image quality. This performance evaluation is conducted in terms of Mean square error (MSE) and Peak Signal to Noise Ratio (PSNR). The graphical illustration of these parameters in terms of various research methodologies is given and discussed detailed in the following.

4.1. Mean Square Error

Mean square error is estimation of the difference between the noise free image pixels and the noisy image pixels. It is used to access the quality of the image.

$$MSE = \frac{1}{M \times N} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i.j)]^2 \qquad (1)$$

Where, I is the noise free image and K is the noisy image, $M \times N$ is the size of image

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Table 1. Comparison of Research Methodologies

TITLE OF PAPER	AUTHOR NAME	METHOD USED	MERITS	DEMERITS
A novel two-stage impulse noise removal technique based on neural networks and fuzzy decision	Sheng-Fu Liang, Shih-Mao Lu, Jyh-Yeong Chang, and Chin-Teng Lin	Two-stage impulse noise removal technique	Efficient noise removal along the edges at a fast time	Spatial features are not considered
Fuzzy random impulse noise removal from color image sequences	Tom Mélange, Mike Nachtegael, and Etienne E. Kerre	Fuzzy filter technique	High Accuracy for impulse noise removal Reduced computation time	Analogous bands are not considered
An enhanced Two-stage impulse noise removal technique based on fast ANFIS and fuzzy decision	V.Saradhadevi, V. Sundaram	Fast ANFIS and fuzzy decision filtering	Improved perceptual image quality Improved performance level	Less noise degree images are not analyzed
A Hybrid Approach for Efficient Removal of Impulse, Gaussian and Mixed Noise from Highly Corrupted Images using Adaptive Neuro Fuzzy Inference System (ANFIS)	C. Hemalatha, Azha Periasamy and S. Muruganand	Adaptive Neuro Fuzzy Inference System (ANFIS)	Improved image conservation Adaptive technique for different noises	More computational cost
Remote-sensing image denoising using partial differential equations and auxiliary images as priors	Peng Liu, Fang Huang, Guoqing Li, and Zhiwen Liu	Partial differential equations (PDE) denoising	Reduces complexity in noise removal	Suitable only for wide band images
Quaternion-based impulse noise removal from color video sequences	Lianghai Jin, Hong Liu, Xiangyang Xu, and Enmin Song	Quaternion filtering (QF) technique	High performance for random impulse noise removal Image edges are preserved	Pixel weight varies with change in chromaticity
Image Denoising Using A New Hybrid Neuro-Fuzzy Filtering Technique	R. Pushpavalli, and G. Sivarajde	Hybrid Neuro-fuzzy (HNF) filtering	Less error rate Better performance in noise removal	Noise free pixels are not processed
A neuro-fuzzy network based impulse noise filtering for gray scale images	Yueyang Li, Jun Sun, and Haichi Luo	Neuro-fuzzy (NF) network impulse noise filtering	Efficient performance optimization Better computation time	Can be used significantly in gray scale type images only while for other images require further improvement

In figure 1, the comparison of literature methods in terms of mean square error is given. In x-axis the literature methodologies are taken whereas in the y-axis the mean square error is taken. From this graph it can be proved that the Neuro-fuzzy (NF) network impulse noise filtering has better MSE value than the other techniques.

4.2. Peak Signal to noise ratio

Peak signal-to-noise ratio (PSNR) is used to represent the index of image quality analysis and substitutes the average MSE of pixels in the PSNR computing equation to obtain the PSNR value of the image, expressed as,

$$\mathrm{PSNR} = 20 \times \log_{10}\left(\frac{255}{\sqrt{\mathrm{MSE}}}\right) \qquad (2)$$

Figure 1. Mean Square Error

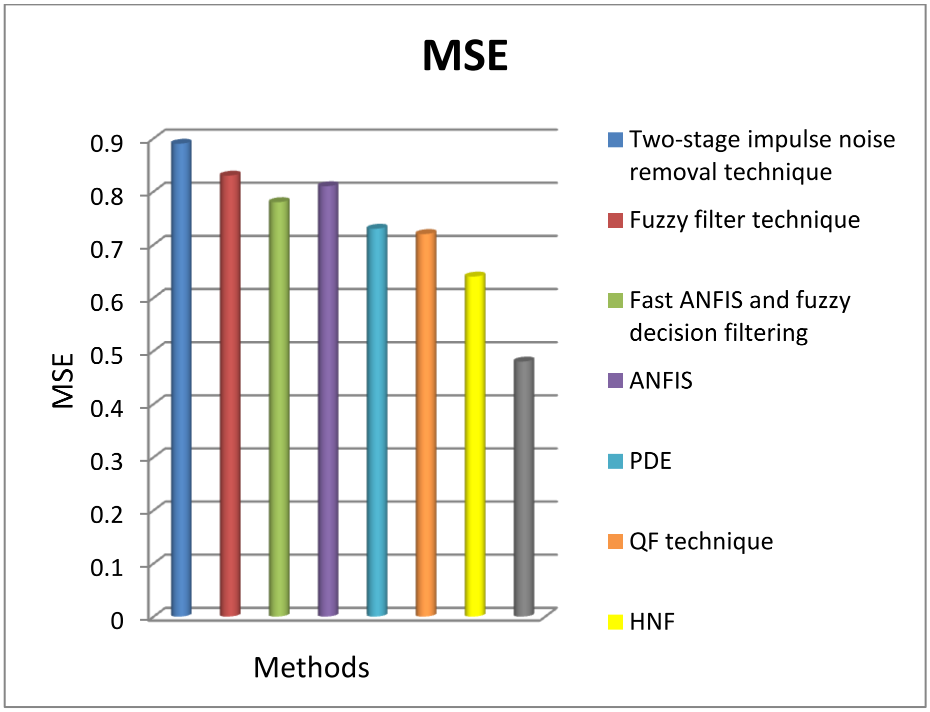
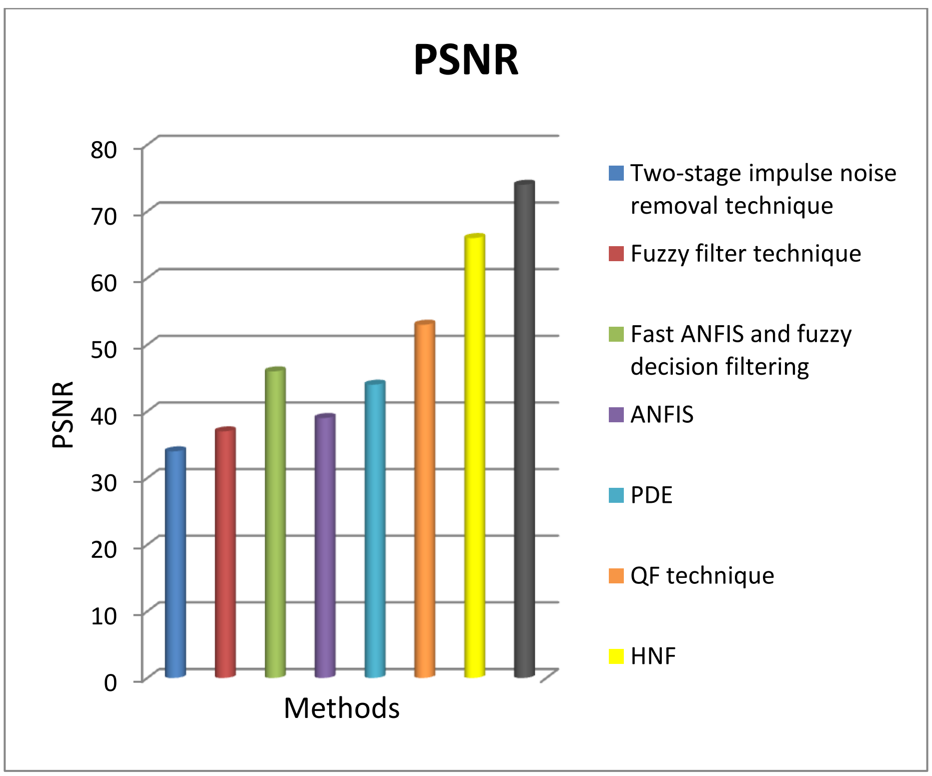


Figure 2. Peak Signal-to-Noise Ratio



In figure 2, the comparison of literature methods in terms of peak signal-to-noise ratio is given. In x-axis the literature methodologies are taken whereas in the y-axis the peak signal-to-noise ratio is taken. From this graph it can be proved that the Neuro-fuzzy (NF) network impulse noise filtering has better PSNR value than the other techniques.

Thus the performance evaluation is done and the numerical results also proves that the Neuro-fuzzy (NF) network impulse noise filtering is efficient than other techniques.

5. Conclusion

Noise often corrupts the images and makes them unusable for any applications. Hence it is important remove the noise elements, particularly the impulse noise, to enhance the image quality. The simulations results show that the Neuro-fuzzy network based impulse noise filtering technique is the better than the other techniques.

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