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Image Denoising Using Improved Neuro-Fuzzy Based Algorithm: A Review

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Abstract ***Processing the digital image is a subset of the electronic field, wherein the image is converted into an array of small integers, called pixels, representing a physical quantity such as the scene radiation, stored in a digital memory and processed computer or other digital equipment. Fuzzy logic can encode expert knowledge directly using rules with linguistic labels, it usually takes a lot of time to design and tune the membership functions which quantitatively define these linguistic labels. Neural network learning techniques can automate this process and substantially reduce development time and cost while improving performance. This review paper combines the features of neural network and fuzzy logic. It deals with Neuro-Fuzzy system which helps to take the decision about the pixels of the image under consideration. The main focus is on the removal of the various type of noise with the preservation of edge sharpness and image details along with improving the contrast of the images which is considered as one of the most difficult tasks in image processing.***

Keywords: ***Digital Image Processing, Image Denoising, Neural Network, Fuzzy Logic, Impulse noise.***

I.Introduction

An image is an artifact that is recorded by visual perceptions which is further digitized to convert it to a form which can be stored in a computer memory or on some form of storage media such as hard disk. This digitization procedure can be done by scanner, or by video camera connected to frame grabber board in computer. Once the image has been digitized, it can be operated upon by various image processing operations.

Noise in images is the random variation of sharpness or brightness either color information in images produced by scanners or various digital cameras. It can also originate in film grain and in the unavoidable shot noise of an ideal photon detector and is generally regarded as an undesirable by-product of image capture.

Effectively reduction of noise from digital color images by keeping its features intact (e.g., edges, color component distances, etc.) is the fundamental problem of digital image processing. Various types of noise which may exist in images: impulse noise, additive noise, and multiplicative noise. Impulse noise is usually characterized by some portion of image pixels that are corrupted, leaving the remaining pixels unchanged. Examples of impulse noise are fixed-valued impulse noise and randomly valued impulse noise. We talk about additive noise when a value from a certain distribution is added to each image pixel, for example, a Gaussian distribution. Multiplicative noise is generally more difficult to remove from images than additive noise because the intensity of the noise varies with the signal intensity (e.g., speckle noise).

Various filters are introduced in the literature for the removal of noise like linear filters. Linear filters were primary tools which were initially used for many signal and image processing applications due to the availability of systematic theory of design and analysis. These filters show good performance for the images corrupted with Additive White Gaussian Noise (AWGN) [8]. But the great disadvantage of linear filter is that they cannot cope with non-linearities of image formation model.

Image edges and corners contain high frequency content and details. Thus image edges should be preserved. For preservation of image details various filters are introduced. The filters which can preserve image details and edges are highly suitable for image denoising. By Low pass filtering including the loss of image details the lines are destroyed and the blurred edges are obtained. Thus for preserving image details non-linear filtering techniques are preferred.

An important non linear filter that will preserve the edges and remove impulse noise is standard median filter [20]. Median filter replaces every pixel by its median value from its neighborhood and often removes desirable details in the image. Specialized median filters such as weighted median filter , center weighted median filter and Recursive Weighted Median Filter (RWMF) [3] were proposed to improve the performance of the median filter by giving more weight to some selected pixel in the filtering window. But they are still implemented uniformly across the image without considering whether the current pixel is noise free or not. Therefore, a noise-detection process to discriminate between uncorrupted pixels and the corrupted pixels prior to applying nonlinear filtering is highly desirable. Some of the decision based algorithms, such as Adaptive Median Filter, Signal Dependent Rank Ordered Mean Filter, Tri-State Median Filter (TSMF), Progressive Switching Median filter, Multi-State Median Filter (MSMF) [5], Noise Adaptive Soft Switching

Median Filter (NASSMF) [24], a Difference Type Noise Detector [23], Detail Preserving Filter [16], and High Probability Noise Removal Filter [25] have been reported in the literature. These algorithms first detect the noisy pixels and remove it by applying either standard median filter or its variants. These filters are effective in removing low to medium density impulse noise.

Decision Based Algorithm (DBA) [21] was proposed to remove high density salt and pepper noise, in which, the corrupted pixels are replaced by either the median value of the window or neighborhood pixel, in contrast to other existing algorithms that use only median value for replacement of corrupted pixels. At higher noise densities, the median value may also be a noisy pixel, in which case, neighborhood pixel is used for replacement from the previously processed window. The main drawback of this method is that the quality of the restored image degrades as the noise level increases above 60%. Since neighborhood pixel value is used for replacement, when median value remains to be corrupted one, streaking in the image becomes persistent. This drawback was overcome by robust estimation based filter which was presented to remove salt and pepper noise effectively up to a noise density of 70%. It removed low to medium density impulse noise and also preserved edges very satisfactorily compared to other methods.

In the last few years, there has been a growing interest in the applications of soft computing techniques, such as neural networks and fuzzy systems, to the problems in digital signal processing. Neural networks are low-level computational structures that perform well when dealing with raw data although neural networks can learn; they are opaque to the user. In Fuzzy Systems, fuzzy logic deals with reasoning on a higher level, using linguistic information acquired from domain experts. Fuzzy systems lack the ability to learn and cannot adjust themselves to a new environment. Integrated neuro-fuzzy systems can combine the parallel computation and learning abilities of neural networks with the human like knowledge representation and explanation abilities of fuzzy systems. A Neuro-Fuzzy System is a flexible system trained by heuristic learning techniques derived from neural networks can be viewed as a 3-layer neural network with fuzzy weights and special activation functions is always interpretable as a fuzzy system uses constraint learning procedures is a function approximation (classifier, controller). Neuro-Fuzzy filtering techniques had been proposed for eliminating impulse noise and preserving edges and fine details of images [12].

The neuro-fuzzy network used in the structure of the proposed hybrid filter acts like a mixture operator and attempts to construct an enhanced output image by combining the information. The rules of mixture are represented by the rules in the rule base of the neuro-fuzzy network and the mixture process is implemented by the fuzzy inference mechanism of the neuro-fuzzy network. In neuro-fuzzy network various disadvantages of neural networks and fuzzy systems are removed.

II. **Related Work**

In paper 2001 Wu H.R. and Chen T. [22] "Adaptive Impulse Detection Using Center-Weighted Median Filters" Proposed the adaptive impulse detector with center-weighted median (ACWN) filter to remove effectively salt & pepper noise. This paper devises a novel adaptive operator, which forms estimates based on the differences between the current pixel and the outputs of center-weighted median (CWM) filters with varied center weights. These methods only perform well when an image is corrupted with 50% salt & pepper noise or lower.

In paper 2002 Zhang S. and Karim A. [24] "A New Impulse Detector for switching Median Filters" proposed a new technique for impulse detection in which switching median filters are presented which is based on minimum absolute value for four convolutions. The proposed filter is directed towards improved line preservation and provides improved impulse detection ability. Proposed filter is better than many of the existing SM filters such as median-based, WM-based, ROM-based and tri-state SM filters. Normalization is required in proposed filter.

In paper 2006 Luo W. [16] "An Efficient Detail-Preserving Approach for Removing Impulse Noise in Images" Presents an algorithm which preserves image details and removes impulse noise from the corrupted images. This algorithm is based on the alpha-trimmed mean, which is a special case of the order-statistics filter. Alpha-trimmed mean is used in impulse noise detection only instead of pixel value estimation. After identification of noise pixel, its value is replaced by a linear combination of its original value and the median of its local window. In proposed algorithm the filtering process is applied only to noisy pixels instead of all pixels in an image.

In paper 2007 Srinivasan K. and Ebenezer D. [19] "A New Fast and Efficient Decision-Based Algorithm for Removal of High-Density Impulse Noises" proposed decision-based algorithm for restoration of highly corrupted images by impulse noise. The new algorithm significantly shows better image quality than adaptive median filters (AMF), standard median filter (SMF), threshold decomposition filter (TDF) and recursive non-linear filters. The proposed method removes only corrupted pixel by the median value or by its neighboring pixel value. The proposed algorithm can perform effective noise removal up to 90% noise density level, while edges are preserved up to 80% and require simple physical realization structures. The main drawback of this method is that the quality of the restored image degrades as the noise level increases above 60%. This drawback was overcome by robust estimation based filter which was presented to remove salt and pepper noise effectively up to a noise density of 70%.

In paper 2009 Kumar V. et al. [13] "Robust Statistics Based Algorithm to Remove Salt and Pepper Noise in Images" A new robust estimation based filter is presented to remove salt and pepper noise effectively up to a noise density of 70% compared to standard median filter, weighted median filter, recursive weighted median filter, progressive switching median filter, signal dependent rank ordered mean filter, adaptive median filter and recently proposed decision based algorithm. The function of algorithm is to detect the corrupted pixel first as certain pixels are corrupted by impulse noise while remaining pixels remain uncorrupted. It removes low to medium density impulse noise and preserves edges compare to other methods very satisfactorily

In paper 2012 Aldinucci M. and Spampinato C. [2] "A Parallel Edge Preserving Algorithm for Salt and Pepper Image Denoising" proposed a two-phase filter for removing "salt and pepper" noise. In the first phase, an adaptive median filter is used to identify the set of the noisy pixels. In the second phase, these pixels are restored according to a regularization method, which contains a data-fidelity term reflecting the impulse noise characteristics. The first step identifies noisy pixels by means of a modified Adaptive Median Filter (AMF) classifier; whereas second step restores them using a variational approach which is solved by using regularization.

In paper 2013 Gargouri A. and Masmoudi D.S [7] "Neural Network Based image denoising with Pulse Mode Operations and Hybrid on-chip learning algorithm" proposed a pulse mode neural network (PMNN) based image denoising operation. In this paper a hybrid learning algorithm, in which, they applied the K-means algorithm to adjust the centers positions of the basic activation functions, as well as the back-propagation algorithm to update the connection weights. However, early pulse mode implementation suffers from some constraints due to the complexity of the on-chip learning ability, since the back-propagation algorithm is probably the most used, which costs much of hardware resources.

In paper 2013 Ahmed F. and Das S. [1] "Removal of High Density Salt and Pepper Noise in Images with an Iterative Adaptive Fuzzy Filter using alpha-trimmed Mean" Proposed a novel adaptive, iterative, fuzzy filter for denoising images corrupted by impulse noise. It operates in two stages - detection of noisy pixels with an adaptive fuzzy detector followed by denoising using a weighted mean filter on the "good" pixels in the filter window. Fuzzy filters when used in adaptive setting are simple and quite efficient. The filter uses α-trimmed mean which is effective for measure of central tendency than the classical mean thus, filter is shown to be robust to very high levels of noise, retrieving meaningful detail at noise levels as high as 97%

III. Need and Significance

After review of various papers it is concluded that there are still some drawbacks which are to overcome. These drawbacks are:

A. There is a lot of scope for reducing the time of denoising without affecting the accuracy.
B. Although all the spatial filters perform well on the digital images but still suffered from some constraints such as resolution degradation.
C. Gaussian filtering performed poorly on all the test cases. The resulting images show little detail and still contain noise.
D. The Wiener filter performed marginally better than the Gaussian filter. More noise was removed by this method, but the images were still blurry.
E. Previous methods attempt to separate the image into the smooth part (true image).However, not all images are smooth.
F. As previous methods cannot tell the difference between the noise and true image thus when the high frequencies are removed, the high frequency content of the true image will be removed along with the high frequency noise. This will result in a loss of fine detail in the denoised image.
G. By previous denoising filers low frequency noise will remain in the image even after denoising.

IV. Proposed Methodology

Although number of techniques has been proposed in literature but still after reviewing the literature these techniques have few drawbacks. For removing these all drawbacks new technique is required to overcome these problems in such a way:

A. Detection of noisy pixel in an input acquired image: An image is acquired by input source such as camera. A range is estimated in which the uncorrupted pixels may lie. The pixels which not lie in an estimated range are detected as noisy or corrupted pixels.
B. Removal of noise using Neuro-Fuzzy technique: When noisy or corrupted pixels are detected than some fuzzy rules are applied on these particular pixels along with some training. Thus, noise is removed and image is restored.
C. Comparison of results with existing techniques: When final restored image is achieved the result obtained by Neuro-Fuzzy technique is compared with various existing techniques such as Median Filter, Average Filter and Gaussian Filter.

V. Conclusion

This paper gives a review of various filtering techniques used in previous papers for removal of noise in images. In this paper a new technique is proposed which uses features of Neural Network and Fuzzy Logic. By using Neuro-Fuzzy hybrid technique noise is removed from images and edges are preserved by removal of blurriness from images.

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