Performance Analysis of Image Denosing Technique Using Wavelet and SOM Neural Network Model

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Abstract. *Image denoising is a critical initial step in the analysis of image data, essential for mitigating data corruption and enhancing image quality by producing a cleaner output compared to its noisy counterpart. This paper presents a hybrid method aimed at improving gray-scale images, which are particularly susceptible to high levels of environmental noise. To achieve effective noise reduction, the paper employs a wavelet transform domain method, recognized for its effectiveness in such applications. However, this method does not account for local noise components, leading to residual noise in the gray-scale image post-denoising. To address this issue, the approach incorporates the collection of low component values using multiple sequences and employs a self-organized map network to refine the denoising process further. Overall, this hybrid methodology aims to significantly enhance the quality of gray-scale images by systematically addressing the noise reduction challenge.*

Keywords: Image Processing, SOM, Neural network, PSNR.

Introduction

Image denoising is a crucial step in image preprocessing, vital for minimizing and eliminating noise from images, particularly in medical applications where computer vision techniques are employed. These techniques can generate gray-scale and RGB images; however, gray-scale images, often akin to black and white images, tend to retain higher levels of distortion and noise, compromising image quality and obscuring important content. Consequently, image denoising becomes necessary to ensure accurate prediction and analysis of medical images. Various researchers have explored different filtering methods to enhance medical image quality during the denoising process. Notably, transform-based functions, especially the wavelet transform, are well-established methods used in this context. The wavelet transform facilitates image denoising across multiple layers via low-pass and high-pass filters. Some studies have implemented a sequence of transform functions aimed at reducing noise levels effectively. In this dissertation, a modified technique using a Self-Organizing Map (SOM) neural network model is proposed to enhance multiple sequence methods. Although traditional wavelet transform denoising is effective due to its multi-scale properties in handling high-frequency noise, it typically employs a uniform threshold value that fails to account for the uneven noise distribution in medical images. This oversight can lead to loss of significant information and excessive smoothing. In contrast, median filters, recognized as nonlinear filters, exhibit strong edge-preserving capabilities and can address the blurring effects commonly associated with minimum mean square filtering and mean filtering methods.

Literature Review

The document presents a comprehensive overview of various image processing techniques specifically focused on denoising methods applicable to different imaging frameworks, including Synthetic Aperture Radar (SAR), depth imaging from Kinect devices, and Magnetic Resonance Imaging (MRI). [1] Highlight the impact of granular noise on effective image analysis, stressing the importance of selecting appropriate mother wavelets for denoising. They found that Daub4 and Daub20 wavelets yield satisfactory results for different scene types. [2] Propose a novel de-noising algorithm for Kinect depth images that employs edge-based segmentation to enhance depth map accuracy while mitigating noise across spatial-temporal boundaries. [3] Investigate salt-and-pepper noise in images using unique noise models, demonstrating that small square filtering techniques can preserve crucial image details while improving restoration quality. [4] Discuss a refined coarse-to-fine deblurring method that addresses motion blurring without necessitating precise movement segmentation, which simplifies the restoration of small structures in images. [5] Examine a new iterative noise removal approach for Kinect-derived images, achieving significant background and shadow removal while enhancing depth data accuracy for various applications. [6] Extend their research to SAR image denoising through local region segmentation based on spatial similarity, leveraging Principal Component Analysis (PCA) for more efficient noise reduction via a Linear Minimum Mean Square Error (LMMSE) filter tailored for multiplicative noise. [7] Tackle signal augmentation for first-generation wavelet applications and introduce a lifting scheme aimed at reducing computational demands while ensuring invertibility through finite precision mathematics. [8] Describe the NL-SAR technique, which constructs extended non-local neighborhoods for denoising various SAR image forms. They provide accompanying source code, emphasizing fully automated parameter tuning for efficiency. [9] Focus on a new design for wavelet shrinkage optimization that enhances computational efficiency while effectively reducing noise in the transform domain. Their findings suggest improved performance over traditional methods, especially regarding maintaining image resolution and minimizing artifacts. [10] Explore multiple denoising strategies, including filtering techniques, wavelet-based methods, and multi-fractal approaches, concluding that LMS adaptive filters outperform mean filters while maintaining complexity. Wavelet shrinkage is noted to be optimal for Gaussian noise types. Overall, this synthesis underscores advancements and varied methodologies in the field of image denoising, reflecting a trend toward hybrid approaches that leverage the strengths of different techniques for enhanced image quality.

Proposed Model

This section discusses an image denoising methodology utilizing a Self-Organizing Map (SOM) neural network model, primarily focusing on the extraction of image features through a wavelet transform (WT) function. The process begins with the extraction of N-dimensional features from the WT, which are then projected into an M-dimensional feature space by the SOM, acting as a clustering mechanism that categorizes these features into relearned noise classes. The methodology incorporates a Multiple Sequences (MS) mechanism, essential for processing collections of local intensity data from medical images, which combines noise values with high-intensity image values to generate vectors for processing.

The proposed algorithm is delineated into several steps:

1. The input image is initially decomposed into two layers via the WT function, yielding distinct higher and lower value layers.

2. The collection of lower intensity values is executed using the MS, which gathers local noise values and combines them with high intensity values.
3. The aggregated noise value undergoes conversion into feature vector image data, which is then processed through the SOM network.
4. During the feature mapping phase within the SOM network's feature space, a fixed cluster is created according to the image detail's threshold.
5. The processing steps of the SOM network include initializing each node's weights, selecting a random training vector, identifying the Best Matching Unit (BMU), calculating the neighborhood radius around the BMU that diminishes with iterations, and adjusting the weights of nodes in the BMU's neighborhood.
6. The convergence of the SOM is achieved by repeating the weight adjustment process based on the Euclidean distance measurement between node weights and input vector values, incorporating a learning rate that follows an exponential decay function.

Finally, the output of the SOM network provides the denoised image, which allows for the calculation of its Peak Signal-to-Noise Ratio (PSNR) value, concluding the image processing chain.

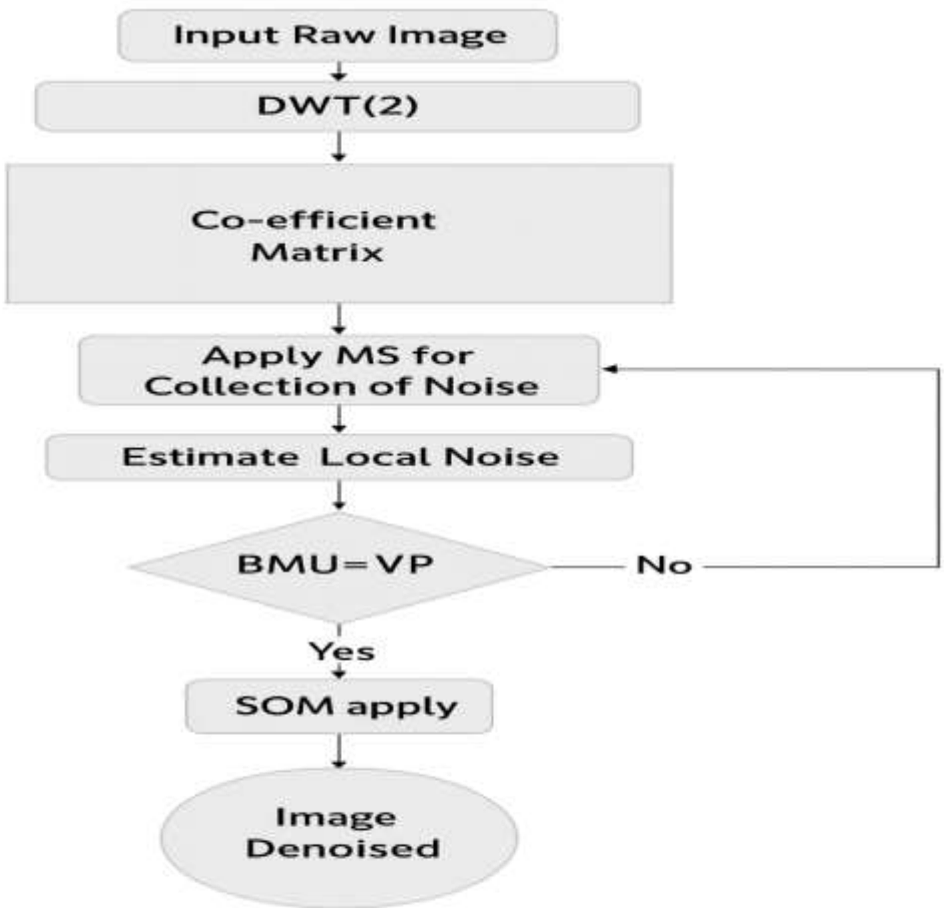

Figure 1: Proposed model for image denosing based on wavelet and SOM neural network model.

Experiment Result & Analysis

The document examines the effectiveness of a proposed method for image denoising and filtration, utilizing MATLAB. The experiments employ well-known image datasets, specifically the cameraman, baboon, and leena images, to assess performance through the Peak Signal-to-Noise Ratio (PSNR) values.

Table 1: Shows the Comparative output PSNR value using Winner filter, BLS-GSM and Wavelet method applied on barbara.jpg Image.

Method	PSNR (DB)	Used Image
WINNER FILTER	13.56	barbara.jpg
BLS-GSM	9.48	
WAVELET	18.53	

Table 2: Shows the Comparative output PSNR value using Winner filter, BLS-GSM and Wavelet method applied on lena.jpg Image.

Method	PSNR (DB)	Used Image
WINNER FILTER	11.256	lena.jpg
BLS-GSM	5.68	
WAVELET	10.278	

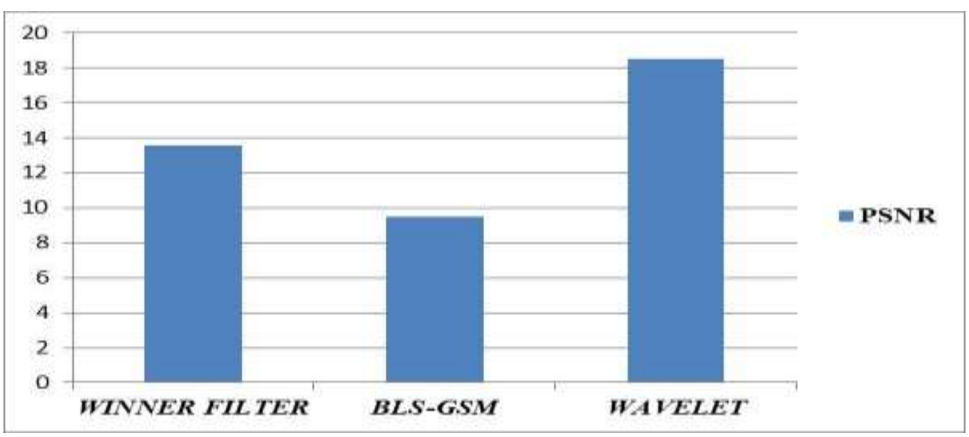

Figure 2: Displays the results for the 'barbara.jpg' image, is processed through the Wavelet method.

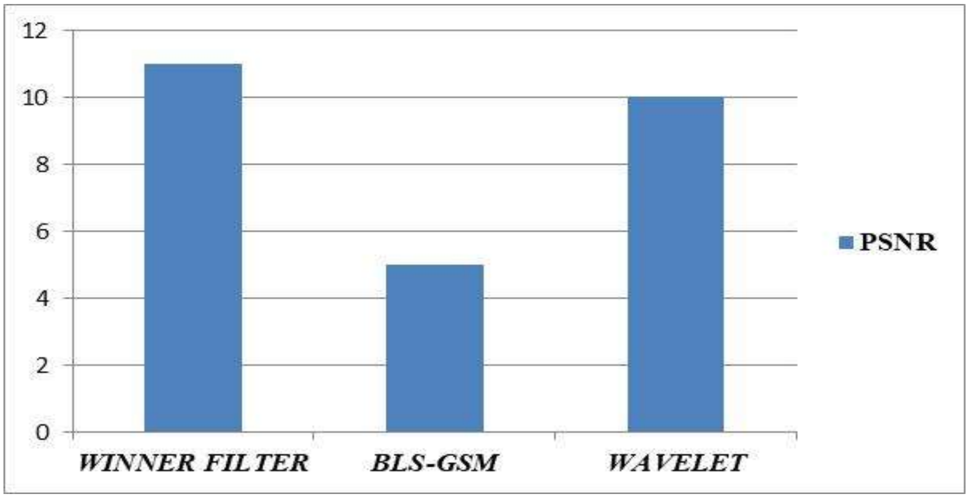

Figure 3: Displays the results for the 'lena.jpg' image, is processed through the Wavelet method.

Conclusion

In this research work, a hybrid method combining Self-Organizing Maps (SOM) with wavelet transforms and neural networks is introduced for denoising digital images. The SOM technique is utilized to establish correlations between the noisy and original Discrete Wavelet Transform (DWT) coefficients and their approximations. Experimental results demonstrate that the proposed method effectively removes noise, as indicated by improvements in Peak Signal-to-Noise Ratio (PSNR) and visual quality. Various architectures and activation functions were explored in this study. The findings suggest that the proposed threshold-based denoising algorithm shows substantial clarity compared to traditional denoising methods, particularly in scenarios with high noise levels and complex images, reflecting its robustness in performance. However, a significant drawback noted is the increased computation time required for better denoising effects, especially when employing larger hybrid models. The system's efficiency in processing color digital images remains an issue, underscoring the need for future research focused on enhancing color image denoising efficiency while addressing the computational time challenges posed by larger hybrid configurations.

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