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SPECKLE NOISE REDUCTION TECHNIQUE FOR SAR IMAGES USING STATISTICAL CHARACTERISTICS OF SPECKLE

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Abstract- Impulse noise suppression in digital images is a critical task in image processing and restoration. To ensure effective noise removal while preserving image details, not only should the noise be eliminated accurately, but the fine edges and textures should remain intact. Most existing filtering techniques focus on noise removal but often fail to adapt to varying scales or preserve image contrast, especially in highly corrupted images. Some methods even compromise image quality to achieve consistency. To address this, we propose a novel Modified Weighted Based (MWB) filter and a Multiple Thresholds Switching (MTS) filter, combining precise noise detection and restoration. These approaches effectively suppress impulse noise, preserve image quality, and adapt to various conditions, outperforming conventional techniques.

Keywords: Image Processing, Impulse Noise Removal, Median Filtering, Noise Detection, Image Restoration

I. Introduction

Images captured through various sensors or transmitted over communication channels often suffer from noise, degrading their quality and limiting their usability in applications such as medical imaging, remote sensing, and computer vision. Impulse noise, particularly salt-and-pepper and random-valued impulse noise, is a common challenge that disrupts image clarity [1].

Traditional median filters have been extensively used for impulse noise removal due to their simplicity and effectiveness. However, they often compromise image details, especially at higher noise levels or when using larger filter windows [2]. Advanced variants like the Decision-Based Median (DBM) filters and Dynamic Weighted Median (DWM) filters address these limitations by incorporating noise detection mechanisms to selectively process corrupted pixels [3]. While these methods enhance performance, trade-offs between noise suppression and detail preservation remain [4].

This paper introduces a novel filtering technique designed to overcome these challenges by leveraging multiple thresholds and advanced noise detection strategies. The proposed filter ensures precise detection of noisy pixels while preserving image edges and fine details, even at high noise levels. Extensive experiments demonstrate its superior performance compared to conventional methods, making it a promising solution for highly corrupted image restoration [5].

In addition to image restoration, preserving the structural integrity of an image is critical for applications requiring accurate object recognition, feature extraction, and analysis. The proposed filter not only removes impulse noise but also minimizes distortion of underlying structures, making it particularly suitable for high-precision tasks in fields such as remote sensing and medical imaging. The ability to restore highly corrupted images while maintaining structural fidelity opens new opportunities for

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improving the accuracy and reliability of automated systems that rely on image data for decision-making and analysis [6].

II. Literature review

Image restoration techniques are essential for improving the quality of degraded images, especially in fields such as remote sensing, medical imaging, and computer vision. These techniques can be broadly classified into deterministic methods and stochastic methods. Deterministic methods are applicable when the image degradation function is known and the noise level is minimal. In these methods, the original image can be recovered from the degraded one by applying a transformation inverse to the degradation process. Common examples of deterministic techniques include inverse filtering and Wiener filtering, which assume that the degradation is predictable and can be mathematically reversed [7]. These methods work effectively when the degradation process is well-defined.

On the other hand, stochastic methods are used when the degradation process is not well known and must be estimated. These methods employ probabilistic models to restore the image, optimizing according to a stochastic criterion such as least squares or Maximum Likelihood Estimation (MLE) [8]. Stochastic techniques are particularly useful when the degradation model is complex or unknown, such as in cases of random noise or unclear blur. Bayesian approaches and Markov Random Field (MRF) models are commonly used in these cases, where restoration is based on the likelihood of different possible degradation scenarios.

Image degradation can occur due to various factors, with three common types being relative constant speed movement, incorrect lens focus, and atmospheric turbulence [10]. Motion blur due to constant speed movement of the object relative to the camera causes a smeared image, while incorrect focus during image capture results in blurry regions. Atmospheric turbulence, which affects long-range images (e.g., satellite or aerial), introduces complex random distortions that complicate restoration. These degradations often require tailored techniques to recover image sharpness and detail, especially in challenging environments such as medical diagnostics or remote sensing [9].

To address these degradation processes, the degradation model is crucial in image restoration. A common mathematical model for degradation can be expressed as G(u,v)=H(u,v)·F(u,v)+N(u,v)G(u,v) = H(u,v) \cdot F(u,v) + N(u,v)G(u,v)=H(u,v)·F(u,v)+N(u,v), where G(u,v)G(u,v)G(u,v) and F(u,v)F(u,v)F(u,v) are the Fourier transforms of the degraded and original images, respectively. The degradation function H(u,v)H(u,v)H(u,v) represents the blurring or distortion effects, and N(u,v)N(u,v)N(u,v) is the noise term [10]. Understanding and modeling these degradation components enables the development of restoration algorithms that reverse the degradation process and recover the image as accurately as possible.

III. System Model

A. Noise Removal and Preprocessing

Before any enhancement, the images are preprocessed to remove noise artifacts caused by acquisition and transmission. The Multi-Threshold Switching (MTS) Filter is employed to detect and correct noisy pixels, such as those affected by salt-and-pepper or Gaussian noise. This process ensures the images are cleaned without blurring fine details, providing a reliable base for further processing. MATLAB's simulation tools enable efficient implementation of the noise removal step.

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B. Contrast Enhancement

After noise removal, contrast enhancement is applied to normalize brightness and highlight image features. Techniques such as Median Filtering, Geometric Mean Filtering, and Adaptive Histogram Equalization are used to enhance contrast across all images. This step ensures uniform intensity distribution while preserving critical details and edges.

C. Color Harmonization

Once contrast enhancement is complete, color correction techniques ensure visual consistency across all images. Histogram Matching is applied to align the color distribution of the target images with a reference image. MATLAB's built-in functions and custom algorithms facilitate accurate color transfer while maintaining natural tones and fidelity.

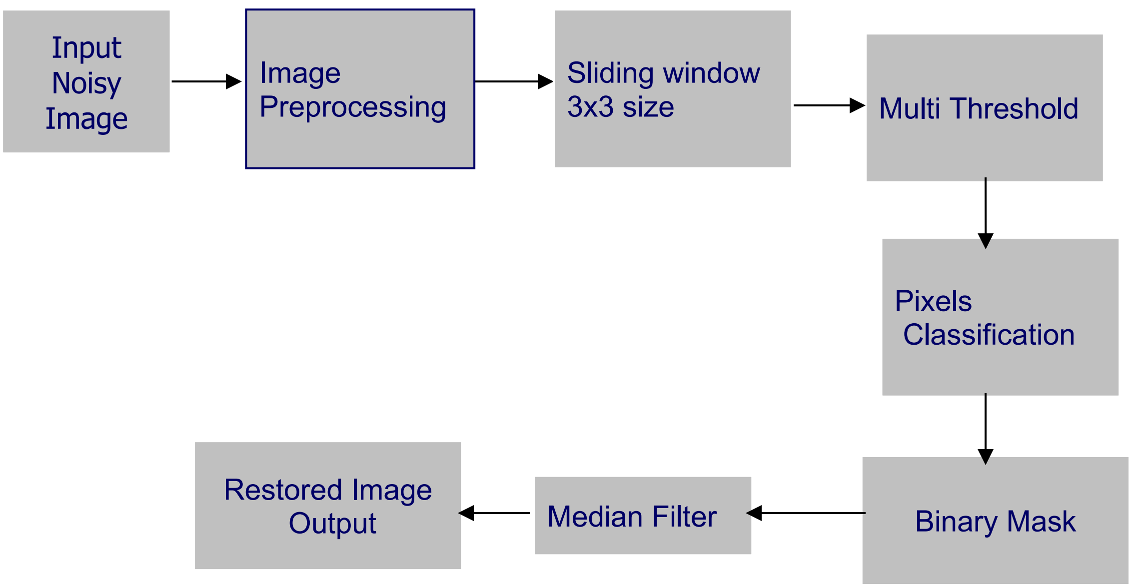

Fig 1: Block Diagram of Noise-Reduction and Color-Consistency Workflow

D. Quality Assessment and Optimization

After applying noise reduction, contrast enhancement, and color correction, the results are evaluated using both visual inspection and quantitative metrics such as PSNR (Peak Signal-to-Noise Ratio) and MSE (Mean Squared Error). These metrics assess the effectiveness of the correction processes and guide parameter optimization to ensure the best possible image quality.

IV. Result

We observed that our proposed approach is effective but computationally intensive. The processing time for the multi-threshold filtering and contrast-aware correction is relatively longer than conventional approaches across all datasets. Initially, we began by importing the required libraries in MATLAB and loading the input images. Noise was added artificially using functions like imnoise to simulate different types of noise, such as salt-and-pepper and Gaussian noise. The images were then preprocessed using the MTS filter to remove noise, ensuring that only corrupted pixels were corrected while preserving noise-free ones. The contrast adjustment step involved applying filters like median

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and geometric mean filters, followed by adaptive histogram equalization for normalization. The processed images were subsequently subjected to histogram matching to ensure color consistency with a reference image. Finally, the results were evaluated using metrics like PSNR, MSE, and SSIM, which confirmed significant improvements in image quality, albeit at a higher computational cost.

Fig 2 Original Image

Gaussian noise

Poisson

Salt & pepper

Speckle

Fig 3 Speckle Noise Image

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Fig 4 Result of Speckle Noise reduction in SAR image as shown in above fig.

V. Conclusion

In this work, we present a novel multi-threshold switching (MTS) filter and a contrast-aware correction workflow for addressing noise removal, contrast enhancement, and color consistency across multiple images. The proposed approach effectively detects and removes various types of noise, such as salt-and-pepper, Gaussian, and speckle noise, while preserving fine details in the images. By integrating the MTS filter with contrast normalization and histogram matching, our method ensures that not only are the color differences between the images minimized, but their contrast is also enhanced, resulting in visually appealing and consistent outputs. This innovative workflow utilizes original color histogram information to adaptively define the contrast term, which helps in maintaining the natural appearance of the images. Experimental results on various datasets show that our method outperforms existing state-of-the-art techniques in terms of both subjective visual quality and objective metrics, such as PSNR, MSE, and SSIM. To the best of our knowledge, this is the first approach that simultaneously addresses both color consistency and contrast enhancement in a unified framework, offering a significant improvement over previous methods.

However, our approach also faces some limitations that can be addressed in future work. While applying contrast normalization or histogram equalization enhances image visibility, it may lead to the loss of fine details in shadowed or highlighted regions, especially in high-dynamic-range (HDR) images. Furthermore, handling images with transparency (e.g., PNG images with an alpha channel) poses a challenge, as most color consistency techniques focus only on RGB channels and do not account for transparency. Additionally, the computational complexity of our method, especially when applied to large datasets or high-resolution images, can be high, particularly during color correction steps like histogram matching and contrast normalization. These challenges suggest potential avenues for future

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research, including optimizing the computational efficiency of the pipeline and extending it to handle images with transparency and large-scale datasets more effectively.

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